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The President of EUAS

Professor E.G. Ladopoulos

& The Board Governors of EUAS

Contents

Non-linear 4-D Real Time Expert Seismology. The Leading Technology for Petroleum & Gas Exploration ?

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Short Biography

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Included in the list of 2000 Outstanding Scientists of 20th Century by Cambridge Bio Centre.
Included in the list of 2000 Outstanding Scientists of 21st Century by Cambridge Bio Centre.
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Over 500 publications in high quality scientific journals and 5 books.
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The modern method *"Non-linear Real-Time Expert Seismology"* is investigated for the designation of the exact location of the on-shore and off-shore petroleum and gas reserves worldwide. So, the above "innovative" and "groundbreaking" technology is applied by using a non-linear 3-D elastic waves real-time expert system and hence, the oil and gas reserves can be successfully determined. Besides, exact 3-D images are produced of the underground topography of the area. So, the above high innovative petroleum method is working under Real Time Logic for searching the on-shore and off-shore oil and gas reserves developed on the continental crust and on deeper water ranging from 300 to 3000 m, or even deeper. The proposed method can be used for the exploration of petroleum reserves in very deep depths, like 20,000 to 30,000 m. Also, 4-D seismic imaging is proposed, which incorporates many 3-D seismic surveys over the same reservoir at specified intervals of time. ***China National Petroleum Corporation*** by applying the above tecchnology is following a new project for very deep drillings over 10,000 m. More specifically they will do a drilling of 10,420 m length in the basin Sichuan in the South-West China and another drilling of over 11,100 m length in the basin Tarim in Xianjiang. So, as we could notice ***China National Petroleum Co.*** are following my suggestions published over the last 15 years for very deep on-shore and off-shore drillings for the exploration of petroleum and gas. There is a lot of confidential information in my publications regarding the exact determination of an oil field. So, major petroleum companies should contact us directly for such information. Furthermore, an "innovative" method is investigated in the area of 4-D multiphase flows for the determination of the properties of reservoir materials, when petroleum reserves together with water are moving through porous media. Then the estimation of the future oil production from the reservoir

can be evaluated. Consequently, the above petroleum engineering problem is reduced to the solution of a non-linear singular integral equation, which is numerically solved by using the Non-linear Singular Integral Operators Method (N.S.I.O.M.). Besides a modern model is proposed for oil and gas well development, by using the "Non-linear ESP Artificial Lift Method". According to the proposed new sophisticated technology the ESP Artificial Lift Method will be extended to non-linear form, by adding multiple pumps. So, the well will be able to handle very big flow rates which could be 500,000 bpd, or even up to 1,000,000 bpd.

A.1 Four-dimensional Non-linear Real-time Expert Seismology

The energy demand for petroleum and gas will increase up to 2030 by 50-60%, as it is increasing worldwide yearly at a pace of 1.5 to 2.0%. In addition, the total estimated petroleum all over the world in place stands today approximately at 1.5 trillion barrels, and with current petroleum consumption at 90 million barrels per day, the hydrocarbons in place are predicted to last for the next 40 years. Consequently, there is an absolute need by major petroleum companies to increase their stock by finding new oil and gas reserves. For this reason international petroleum companies should be looking into other alternatives, like to drill to ever deeper horizons and in the relatively unexplored ocean depths. It is known that oceans cover about 70% of the earth's surface and most of the waters are at more than 2000 m deep. Hence, major oil companies and scientific petroleum organizations are prepared for tapping into the relatively unknown areas with potential for large discoveries.

Energy is one of the largest economic domains globally. Our proposed innovative and groundbreaking method in the area of oil exploration, hence in the overall energy domain, will help improve our competitive role in the international scene. There are many seas around with a big amount of unexplored quantities of oil and gas in deep waters waiting to be explored. In such case the role of many countries worldwide should be emphasized and will be reduced their dependency from external sources.

As the recent theoretical and experimental evidence demonstrates the possibility that petroleum may have formed in the depths of the earth, then major oil companies must be ready to face the new challenges of drilling even deeper, to the basement rock, where very huge oil and gas fields may await to be discovered. Modern technologies will have therefore a major impact in the future. Through the technological progress to be achieved in the future exploration, then major reductions in costs can be very much expected. It is believed that the expected progress of enhanced oil recovery methods will reduce their future technical cost substantially. Consequently, it is absolutely sure that drilling depths will be increasing in the future and the industry should be geared up and ready for meeting the many challenges. According to the current research the drillings in the near future could reach the 20,000 m, or even the 30,000 m in the subsurface of earth.

On the other hand, since 1920 and for over a century the basic and prevalent theory on oil and gas reserves exploration, was *"Reflection Seismology"* and *"Refraction Seismology"*. According to the above methods the basic idea is to collect reflections of elastic (seismic) waves and then through various mathematical operations, by using Snell's law and Zoeppritz equations or the Kirchhoff equations to convert them to maps of the earth's structure. [1] - [9]. Hence, the methods of *"Reflection Seismology"* and *"Refraction Seismology"* for almost a century, have been used with several improvements for petroleum resources exploration.

By the current research for the on-shore and off-shore oil and gas reserves exploration the modern technology of *"Non-linear Real-Time Expert Seismology"* is investigated, as was recently proposed by E.G.Ladopoulos [12]-[15], [17]-[22], [24]-[31], [34]-[39], [42], [45]. So, *"Non-linear Real-Time Expert Seismology"* is a very "*innovative*" and "*groundbreaking*" method on petroleum and gas reserves exploration. According to the above modern technology a non-linear 3-D elastic waves real - time expert system is proposed for the exploration of petroleum and gas resources all over the world, including the off-shore petroleum reserves, of the seas and oceans in the whole world. The above new generic technology will work under Real Time Logic [46]-[50] for searching off-shore fuel reserves developed on the continental crust and on deeper water ranging from 300 to 3000 m, or even much more. Furthermore, the new exploration method will be the best device for searching the on-shore and off-shore hydrocarbon resources in very deep depths,

even approaching 20,000 m or 30,000 m. By using therefore a new and very sophisticated model, then the exact location of the oil and gas reserves may be designated in the special areas where geological anticlines occur.

Consequently, the concept of the current research goes beyond other national and international RTD activities. For this reason, this research activity should be coordinated at a worldwide level and any improvements and applications of this technology should be channelled through the big petroleum producers. The potential areas and markets of application of our research results will be the global oil market. The research results are applicable to all oil companies and scientific organizations working on oil exploration in the whole world. For maximum impact in the medium-/long-run, our proposed high technology should be applied by the oil companies for land and marine oil and gas exploration.

Additionally, through the new method exact 3-D images are produced of the underground topography of the area. Furthermore, 4-D imaging can be taken on a given area multiple times over an extended period of time. So, through the current research 4-D seismic imaging is proposed, which incorporates many 3-D seismic surveys over the same reservoir at specified intervals of time. Studying multiple time-lapsed 3-D surveys, or three-dimensional subsurface images, portrays the changes in the reservoir over time.

Consequently, there are many basic benefits for the new theory of "*Non-linear Real-Time Expert Seismology*" in comparison to the existing theories of *"Reflection Seismology"* and *"Refraction Seismology"*. These are the following:

a) The new method *"Non-linear Real-Time Expert Seismology"* is based on the special form of the geological anticlines, normal faults, reverse faults or deformations caused by intrusion of the bottom of the sea, in order to decide which areas of the bottom have the most possibilities to include hydrocarbon reserves. This is effected by using the proposed modern technology. On the other hand, the existing theory is only based to the best chance and do not include any theoretical and sophisticated model. Thus, currently international oil companies by using the existing methods of *"Reflection Seismology"* and *"Refraction Seismology"* must do a lot of expensive test drillings in big areas of seas, if they want to have a chance to find oil and gas reserves. As every deep drilling is too expensive, then every dry drilling would cost a lot of money to the oil companies.

b) The new proposed technology of elastic (sound) waves is based on the difference of the speed of the sound waves which are travelling through solid, liquid, or gas. In a solid the elastic waves are moving faster than in a liquid and the air, and in a liquid faster than in the air. On the other hand, existing theories are based on the applications of Snell's law and Zoeppritz equations or the Kirchhoff equations, which are not giving good results, as these which we are expecting by the new method.

c) The new method *"Non-linear Real-Time Expert Seismology"* is based on a Real-time Expert System working under Real Time Logic, that gives results in real time, which means every second. Existing theories do not include real time logic.

Reflection in Four-dimensional Non-linear Real-time Expert Seismology

Wavelength of the wave is the distance between two successive maxima (or between any two successive points in the same phase) and is denoted by l. Since the waveform, traveling with constant velocity u, advances a distance of one wavelength in a time interval of one period, then follows that the velocity of sound waves u is given by the following relation:

$$u = l\, v \tag{A.1.1}$$

where v denotes the frequency.

So, it is clear, that the velocity u differs when the sound waves are traveling through solid, liquid, or gas. In a solid the elastic waves are moving faster than in a liquid and the air, and in a liquid faster than in the air. If searching for example for off-shore oil resources over the sea, by transmitting sound waves, then there will be a difference in the velocity of the waves in the sea, the solid bottom and in a potential reservoir.

In order the new technology to be better explained, consider the example of Figure 1. In the above example consider that in the bottom of the sea there is a potential oil reservoir. In this case, the speed of the elastic waves in the air (u_{air}), will be different from the speed in the water (u_{water}), and different from the speed in the solid bottom (u_{solid}) and different from

the speed in the potential reservoir (u_{oil}), while the frequency of the elastic waves remaining the same when transmitted through every different matter.

Thus, by the current research a real - time non-linear 3-D plane - polarized elastic waves expert system is proposed in order to explore the on-shore and off-shore petroleum and gas resources, according to the new theory of *"Non-linear Real-Time Expert Seismology"*, in contrast to the old theory of *"Reflection Seismology"*.

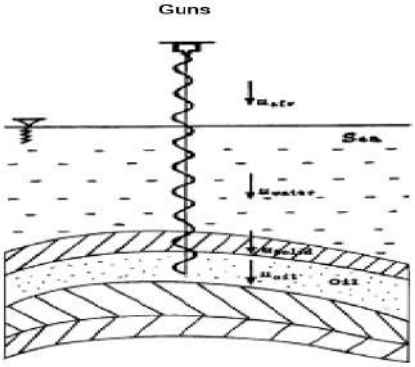

Fig. 1 Elastic Waves Method for the Exploration of Oil Reserves.

This modern and innovative Sound Waves Technology will work under Real Time Logic for searching off-shore petroleum reserves developed on the continental crust and on deeper waters ranging from 300 m to 3000 m, or even deeper and for very deep depths in the subsurface of earth up to 20,000 m or even to 30,000 m (Figure 2).

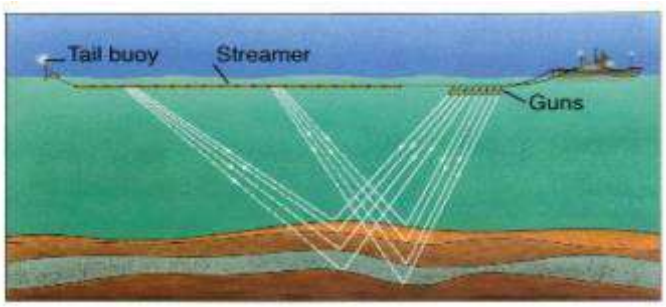

Fig. 2 Non-linear Real-time Expert Seismology.

The travel time T of the seismic waves is calculated as following:

$$T = \frac{2\left(d^2 + x^2/4\right)^{1/2}}{v} \tag{A.1.2}$$

in which d denotes the depth, x the distance between source of wave and the geophone or hydrophone detector and v is the average speed.

In addition, from (A.1.2) follows equation (A.1.3):

$$T^2 = \frac{4d^2 + x^2}{v^2} \tag{A.1.3}$$

Furthermore, the normal incident time T_o is given by the formula:

$$T_o = \frac{2d}{v} \tag{A.1.4}$$

From eqs (A.1.3) and (A.1.4) follows:

$$T^2 - T_o^2 = \frac{x^2}{v^2} \tag{A.1.5}$$

Consequently, from eqn (A.1.5) follows that the travel time curve for a constant velocity horizontal layer model is a hyperbola whose apex is at the zero-offset travel time T_o:

$$\frac{T^2}{T_o^2} - \frac{x^2}{(T_o v)^2} = 1 \tag{A.1.6}$$

Finally, from (A.1.5) the mean velocity is equal to:

$$v = \frac{x}{\sqrt{T^2 - T_o^2}} \tag{A.1.7}$$

A.2 Non-linear Singular Integral Operators Method for 4-D Petroleum Multiphase Flows

Petroleum well test analysis is a kind of a very important history matching process for the determination of the properties of reservoir solids. Thus, during the movement of petroleum reserves through porous media, then both single-phase and multiphase flow occurs. By the current research the multiphase flows are studied when the oil reserves are mixed with water. In addition, when a petroleum well test is conducted then the well is subjected to a change of its flow rate and the resulting pressure response is possible to be measured. Besides, this pressure is compared to analytical or numerical models in order to estimate reservoir parameters such as permeability. Then the estimation of the future oil production from the reservoir can be evaluated.

So, by using the Non-linear Singular Integral Operators Method (N.S.I.O.M.) [10], [11], [16], [23], [32], [33], [40], [41], [44] as proposed by E.G.Ladopoulos , then the pressure response in multiphase flows from the well test conducted in a heterogeneous reservoir will be computed. Besides, some properties of the porous medium equation, which is a Helmholtz differential equation, are proposed and investigated. Furthermore, basic properties of the fundamental solution will be analyzed and investigated.

In addition, 4-D multiphase flows can be taken on a given area multiple times over an extended period of time. Consequently, through the current research 4-D multiphase flows are proposed, which incorporates many 3-D flows over the same reservoir at specified intervals of time. Studying multiple time-lapsed 3-D surveys, or three-dimensional subsurface images, portrays the changes in the reservoir over time.

The benefits of the new method in comparison to existing methods are the following:

1. The new method is based on the N.S.I.O.M., by using non-linear singular equations. According to this theory the porous medium equation is reduced to the solution of a non-linear singular integral equation which is then numerically evaluated by using a non-linear programming method.

Existing methods of well test analysis, are using too as a start the porous medium equation, but as this is a complicated differential equation are giving only some analytical solutions for very simple cases or numerical solutions for homogeneous reservoir materials..

2. The new method, as it is a complicated non-linear numerical method can give results for heterogeneous porous media (which of course are the solids in reality) and not only for homogeneous solids as are giving the analytical or numerical existing methods.

So the estimation of the properties and the future petroleum production from a new oil reservoir could be done exactly, and not estimated as by the existing methods.

From the above two points it can be understood the evidence of the applicability of the new method, as it is based on non-linear software. Also its novelty, as it is based on the theory of non-linear singular integral equations. In general an oil reservoir well test in a single-phase reservoir is calculated by using the porous medium equation:

$$\nabla \bullet (\frac{\lambda}{\phi \xi} \nabla p) = c_t \frac{\partial p}{\partial t} \tag{A.2.1}$$

in which λ denotes the permeability, ϕ the porosity, ξ the viscosity, p the pressure of the reservoir, t the time and c_t the compressibility. By replacing variables as follows:

$$u = (\frac{\lambda}{\phi \xi})^{1/2} p \tag{A.2.2}$$

then (A.2.1) can be written as:

$$\nabla^2 u + \lambda' u = 0 \tag{A.2.3}$$

Hence, (A.2.3) is a Helmholtz differential equation.

By applying the Green Element Method, then the problem reduces to the solution of a *non-linear singular integral equation*:

$$-\frac{\theta}{2\pi}p(r_i)+\int\limits_{\partial\Omega}\left(p\frac{\partial[\ln(r-r_i)]}{\partial n}-\ln(r-r_i)\frac{\partial p}{\partial n}\right)dS+$$

$$+\iint\limits_{\Omega}\ln(r-r_i)\left[-\nabla\ln\Lambda\bullet\nabla p+\frac{1}{\Lambda}\frac{\partial p}{\partial t}\right]d\Omega=0 \tag{A.2.4}$$

In order the non-linear singular integral equation (A.2.4) to be numerically evaluated, then the Non-linear Singular Integral Operators Method (N.S.I.O.M.) will be used.

A.3 Non-linear ESP Artificial Lift Method by Multiple Pumps

Artificial lift is a process used on petroleum wells to increase pressure within the reservoir and encourage petroleum to the surface. When the natural drive energy of the reservoir is not strong enough to push the petroleum to the surface, artificial lift is employed to recover more production. While some wells contain enough pressure for oil to rise to the surface without stimulation, most don't, requiring artificial lift. In fact, 95% of the oil wells worldwide require artificial lift from the very beginning. Even those wells that initially posses natural flow to the surface, that pressure depletes over time, and artificial lift is then required. Consequently, artificial lift is generally performed on all wells at some time during their production life.

For the new and the existing oilfields there is an absolute need for the improvement of the existing methods of well development. For this reason, by the current investigation the *"Non-linear ESP Artificial Method by Multiple Pumps"* is proposed and investigated. According to the above new technology the ESP Artificial Lift Method will be extended to non-linear forms by adding multiple electric submersible pumps (ESP), in order to increase the production of each well to 500,000 bpd, or even up to 1 million bpd. The above multiple ESP pumps are used in a definite range of pumping rates. The new method has many benefits beyond the existing ESP Artificial Lift Method [51]-[53], as the oil production for each well is increased very much and so there no limits for the oil well production any more.

The power *P (*in *KW)* of an ESP pump is given by the following formula:

$$P=\frac{Q(\gamma H-p_{\text{int }ake})}{\eta\cdot\eta_{surf}} \tag{A.3.1}$$

where Q is the pumping rate ($m^3/\sec$), H the head of the pump (m), γ is the specific gravity of the produced liquid (KN/m^3), $p_{\text{int }ake}$ (KN/m^2) is the pump suction pressure, called pump intake pressure, η is pump's efficiency and η_{surf} (usually 0.97) is the power efficiency of the surface equipment.

References

1. *Aki K. and Richards P., 'Quantitative Seismology, Theory and Methods',* Freeman Press, San Francisco, *1980.*
2. *Hale D.,* 'Dip-move out by Fourier transform', *Geophysics, **49** (1984), 741 – 757.*
3. *Thomsen, L.,*'Reflection seismology over azimuthally anisotropic media', *Geophysics, **51** (1988), 304 –313.*
4. *Thomsen L.,* 'Converted-wave reflection seismology over inhomogeneous, anisotropic media', *Geophysics, **64** (1999), 678 - 690.*
5. *Dellinger J. A., Muir F. and Karrenbach M.,* 'Anelliptic approximations for TI media', *J. Seismic Exploration, **2** (1993),.23 – 40.*
6. *Harrison M. and Stewart R.,* 'Poststack migration of P-SV seismic data', *Geophysics, **8** (1993), 1127 – 1135.*
7. *Tsvankin I. and Thomsen L.,* 'Nonhyperbolic reflection moveout in anisotropic media', *Geophysics, **59** (1994), 1290 – 1304.*
8. *Alkhalifah T. and Tsvankin I.,* 'Velocity analysis for transversely isotropic media', *Geophysics, **60** (1995), 1550 – 1566.*
9. *Gaiser J. E., '3-D converted shear wave rotation with layer stripping',* U.S. Patent. 5 610 875, *1997.*
10. *Ladopoulos E.G.,* 'Non-linear Singular Integral Representation for Petroleum Reservoir Engineering', *Acta Mech, **220** (2011), 247-255.*
11. *Ladopoulos E.G.,* 'Petroleum Reservoir Engineering by Non-linear Singular Integral Equations', *Mech Engng Res., **1** (2011), 2-11.*
12. *Ladopoulos E.G.,* 'Oil Reserves Exploration by Non-linear Real-Time Expert Seismology', *Oil Asia J., **32** (2012), 30-35.*
13. *Ladopoulos E.G.,* 'Hydrocarbon Reserves Exploration by Real-Time Expert Seismology and Non-linear Singular Integral Equations', *Int. J. Oil Gas Coal Tech., **5** (2012), 299-315.*
14. *Ladopoulos E.G.,* 'New Aspects for Petroleum Reservoir Exploration by Real-time Expert Seismology', *Oil Gas Busin. J., **2012** (2012), 314-329..*
15. *Ladopoulos E.G.,* 'Petroleum & Gas Reserves Exploration by Real-Time Expert Seismology and Non-linear Seismic Wave Motion', *Adv. Petrol. Explor. Develop., **4** (2012), 1-13.*
16. *Ladopoulos E.G.,* 'Non-linear Singular Integral Equations for Multiphase Flows in Petroleum Reservoir Engineering', *J. Petrol. Engng Tech., **2** (2012), 29-39.*
17. *Ladopoulos E.G.,* 'Real-time Expert Seismology by Non-linear Oil Reserves Expert System', *J Petrol Gas Engn,**4**(2013), 28-34.*
18. *Ladopoulos E.G.,* 'New Sophisticated Model for Exact Petroleum Reserves Exploration by Non-linear Real-Time Expert Seismology', *Univ. J. Petrol. Scien., **1** (2013), 15-29.*

19. *Ladopoulos E.G.,* 'Real-Time Expert Seismology and Non-linear Singular Integral Equations for Oil Reserves Exploration', *Univ. J. Nonlin. Mech., **1** (2013), 1-17.*
20. *Ladopoulos E.G.,* 'Non-linear Real-Time Expert Seismology for Petroleum Reservoir Exploration', *Univ. J. Nonlin. Mech., **1** (2013), 18-29.*
21. *Ladopoulos E.G.,* 'General Form of Non-linear Real-Time Expert Seismology for Oil and Gas Reserves Exploration', *Univ. J. Petrol. Scien., **1** (2013), 1-14.*
22. *Ladopoulos E.G.,* 'Oil and Gas Reserves Exploration by Generalized Form of Non-linear Real-Time Expert Seismology', *Univ. J. Engng Mech., **1** (2013), 17-30.*
23. *Ladopoulos E.G.,* 'Multiphase Flows in Oil Reservoir Engineering by Non-linear Singular Integral Equations', *Univ. J. Fluid Mech.,**1** (2013), 1-11.*
24. *Ladopoulos E.G.,* 'Very Deep Drillings for Oil and Gas Reserves Exploration by Non-linear Real-Time Expert Seismology', *Univ. J. Comp. Anal., **1** (2013), 9-23.*
25. *Ladopoulos E.G.,* 'Non-linear Real-Time Expert Seismology for Very Deep Drillings in Petroleum Reserves Exploration', *Univ. J. Nonlin. Mech., **1** (2013), 18-29.*
26. *Ladopoulos E.G.,* 'Non-linear Seismic Wave Motion in Elastodynamics with Application to Real-Time Expert Seismology', *Univ. J. Int. Eqns., **1** (2013), 13-27.*
27. *Ladopoulos E.G.,* 'Elastodynamics for Non-linear Seismic Wave Motion in Real-Time Expert Seismology', *Int. J. Acous. Vibr., **19** (2014), 1-8.*
28. *Ladopoulos E.G.,* 'Non-linear Real–Time Expert Seismology by the Abiotic Theory of Hydrocarbon Generation', *Univ. J. Petrol. Scien., **2** (2014), 1-15.*
29. *Ladopoulos E.G.,* 'Three-dimensional Non-linear Real-Time Expert Seismology for Oil and Gas Exploration', *Univ. J. Petrol. Scien., **2** (2014), 16-30.*
30. *Ladopoulos E.G.,* 'Non-linear Real-Time Expert Seismology for Three-dimensional On-shore and Off-shore Petroleum Exploration', *Univ. J. Non-lin. Mech., **2** (2014), 1-15.*
31. *Ladopoulos E.G.,* 'Three-dimensional Oil and Gas Exploration by Non-linear Real-Time Expert Seismology', *Univ. J. Non-lin. Mech., **2** (2014), 16-30.*
32. *Ladopoulos E.G.,* 'Three-dimensional Multiphase Flows by Non-linear Singular Integral Equations in Petroleum Engineering', *Univ. J. Int. Eqns, **2** (2014), 1-11.*
33. *Ladopoulos E.G.,* 'Non-linear Three-dimensional Porous Medium Analysis in Petroleum Reservoir Engineering', *Univ. J. Fluid Mech., **2** (2014), 1-11.*
34. *Ladopoulos E.G.,* 'Non-linear Real-Time Expert Seismology for Three-dimensional Abiotic Oil Generation', *Univ. J. Fluid Mech, **2** (2014), 12-26.*
35. *Ladopoulos E.G.,* 'Non-linear Elastodynamics by Seismic Wave Motion in Real-Time Expert Seismology', *Univ. J. Engng Mech., **2** (2014), 1-15.*
36. *Ladopoulos E.G.,* 'Non-linear Singular Integral Equations & Real-Time Expert Seismology for Petroleum Reserves Exploration', *Univ. J. Engng Mech., **2** (2014), 16-32.*
37. *Ladopoulos E.G.,* 'Computational Methods for Three-dimensional Analysis of Non-linear Real-Time Expert Seismology for Petroleum Exploration', *Univ. J. Comp. Anal., **2** (2014), 1-15.*
38. *Ladopoulos E.G.,* 'Non-linear Real-Time Expert Seismology for Four-dimensional Petroleum Exploration', *Univ. J. Non-lin. Mech., **3** (2015), 1-16 .*
39. *Ladopoulos E.G.,* 'Four-dimensional Petroleum and Gas Exploration by Non-linear Real-Time Expert Seismology', *Univ. J. Petrol. Scien., **3** (2015), 8-23.*
40. *Ladopoulos E.G.,* 'Non-linear Singular Integral Equations in Oil and Gas Engineering by Four-dimensional Multiphase Flows', *Univ. J. Int, Eqns, **3** (2015), 1-11.*
41. *Ladopoulos E.G.,* 'Petroleum & Gas Reservoir Engineering by Four-dimensional Non-linear Porous Medium Analysis', *Univ. J. Fluid Mech., **3** (2015), 8-18.*
42. *Ladopoulos E.G.,* 'Four-dimensional Real-Time Expert Seismology & Non-linear Singular Integral Equations for Oil Reserves Exploration', *Univ. J. Engng. Mech., **3** (2015), 15-32.*
43. *Ladopoulos E.G.,* 'Four-dimensional Petroleum Exploration & Non-linear ESP Artificial Lift by Multiple Pumps for Petroleum Well Development', *Univ. J. Hydr., **3** (2015), 1-14.*
44. *Ladopoulos E.G.,* 'Four-dimensional Multiphse Flows by Non-linear Singular Integral Equations in Petroleum Reservoir Engineering', *Univ. J. Non-lin. Mech., **3** (2015), 17-27.*
45. *Ladopoulos E.G.,* 'Elastodynamics in Four-dimensional Non-linear Real-Time Expert Seismology', *Univ. J. Struct. Anal., **3** (2015), 1-15.*
46. *Jahanian F. and Mok A., 'Safety Analysis of Timing Properties in Real Time Systems',* Dep. Comput. Scien., University of Texas at Austin, *1985.*
47. *Jahanian F. and Mok A.,* 'A Graph-Theoretic Approach for Timing Analysis in Real-Time Logic', *Proc. Real-Time Systems Symp. (IEEE), p.p. 98-108, New Orleans, LA, 1986.*
48. *Emnis R. et al, 'A Continuous Real-Time Expert System for Computer Operations',* IBM J. Research Devel., *1986.*
49. *Fritz W., Haase V.H. and Kalcher R, 'The use of standard software in real time programming - an example demonstrating the integration of ADA, Oracle and GKS', in Puente J. (ed)* Proc. 15th IFAC/IFAP Workshop on Real Time Program, Pergamon, *1988.*
50. *Haase V.H., ''The use of AI-Methods in the implementation of real-time software products',* IFAC 11 th Triennial World Con., Tallium, Estonia, *1990.*
51. *Brown K.E., ' The technology of artificial lift methods',*Vol 2b, PennWell Books, Tulsa, *1980.*
52. *Divine D.L.,* 'A variable speed submersible pumping system', *in: Paper SPE 8241 presented at the 54th annual technical conference and exhibition held in Las Vegas, September 23-26, 1979.*
53. *Lea J.F., Rowlan L., McCoy J.,* 'Artificial lift power efficiency', *in: Proceedings of 46th Annual Southwestern Petroleum Short Course, Lubbock, pp 52-63, 1999.*

On Nanobiotechnology's Unique Role in Combating the COVID-19 Pandemic

by Alain L. Fymat, Member EUAS

Short Biography

DR. ALAIN L. FYMAT is a medical-physical scientist and an educator. He is the current President/CEO and Institute Professor at the International Institute of Medicine & Science with a previous appointment as Executive Vice President/Chief Operating Officer and Professor at the Weil Institute of Critical Care Medicine, California, U.S.A. He was formerly Professor of Radiology, Radiological Sciences, Radiation Oncology, Critical Care Medicine and Physics at several U.S. and European Universities. Earlier, he was Deputy Director (Western Region) of the U.S. Department of Veterans Affairs (Office of Research Oversight). At the Loma Linda Veterans Affairs Medical Center, he was Scientific Director of Radiology, Director of the Magnetic Resonance Imaging Center and, for a time, Acting Chair of Radiology. Previously, he was Director of the Division of Biomedical and Biobehavioral Research at the University of California at Los Angeles/Drew University of Medicine and Science. He was also Scientific Advisor to the U.S. National Academy of Sciences, National Research Council, for its postdoctoral programs tenable at the California Institute of Technology, Jet Propulsion Laboratory. He is Health Advisor to the American Heart & Stroke Association, Coachella Valley Division, California. He is a frequent Keynote Speaker and Organizing Committee member at several international scientific/medical conferences. He has lectured extensively in the U.S.A, Canada, Europe, Asia and Africa. He has published ~ 575 scholarly scientific publications and books. He is also Editor-in-Chief, Honorable Editor or Editor of numerous medical/scientific Journals to which he regularly contributes. Dr. Fymat is a Board member of several institutions, a member of the New York Academy of Sciences and a reviewer for the prestigious UNESCO Newton Prize, United Kingdom National Commission for UNESCO.

In an earlier research career, at the California Institute of Technology (Jet Propulsion Laboratory, a contractor of the U.S. National Aeronautics & Space Administration), Dr. Fymat was actively engaged in atmospheric sciences, the environment, climatology, and space exploration. He was an investigator in several Earth- and space-based experiments within the U.S. Earth and space exploration programs. His industrial experience was in the context of the U.S. Strategic Defense Initiative or "Star Wars" (Ballistic Missile Defense Program) researching and designing atmospheric probes and electromagnetic sensors operating in benign and stressful nuclear environments. He was also a Member of the North Atlantic Treaty Organization (NATO), Advisory Group for Research & Development (AGARD).

Research interests

Dr. Fymat's current research interests lie at the interface between medicine and science, particularly human genetics/epigenetics/ecogenetics; neurology & neuroscience; cancer; nanomedicine/ nanobiotechnology; molecular/personal/precision medicine; critical care medicine; and emerging infectious diseases including pandemics. These are represented in part in his latest

*books: "**The Odyssey of Humanity's Diseases:** Epigenetic and Ecogenetic Modulations from Ancestry through Inheritance, Environment, Culture, and Behavior**"** Volumes 1, 2, and 3; "**From the Heart to the Brain**: My Collected Works in Medical Science Research (2016-2018)"; **"The Human Brain:** Wonders and Disorders"; "**Alzhei ...Who?** Demystifying the Disease and What You Can Do About It"; "**Parkin..ss..oo..nn**: Elucidating the Disease and What You Can Do About It"; "**Dementia:** Fending-off the Menacing Disease... and What You Can Do About It"; "**Epilepsy:** The Electrical Storm in the Brain"; "**Multiple Sclerosis:** The progressive demyelinating autoimmune disease"; "**Multiple System Atrophy:** The chronic, progressive, neurodegenerative synucleinopathic disease"; "**Cancer:** The Pernicious, Clonally-Evolving Disease Braided in Our Genome"; **"Nanomedicine:** My Collected Works in Nanomedicine Research"; "**Lyme disease:** The Great Invader, Evader, and Imitator"; **"Pandemics:** Prescription for Prediction and Prevention"; and "**COVID-19**: Perspectives Across Africa" (authored and co-edited with Norma R.A. Romm and Joachim Kapalanga).*

The following contribution is a brief study of the several types of mRNA vaccines employed during COVID-19, how they are synthesized, and how they worked in abating the dangerous effects of the pandemic. All these benefits, however, could not have accrued without the immeasurable contribution of nanobiotechnology (NBT) that played the critical role in governing how the vaccines are developed and produced.

On Nanobiotechnology's Unique Role in Combating the COVID-19 Pandemic

Vaccines have long been an integral part of public health programs around the world, reducing the spread and severity of infectious diseases. The success of immunization strategies to protect children and adults alike from various such diseases can be seen globally. More immediately, the COVID-19 pandemic created an urgent need for an effective vaccine (see my treatise on pandemics titled: "*Pandemics: Prescription for Prediction and Prevention", 2021*). Yet, despite their long history of research and development, messenger RNA (mRNA) vaccines have been revolutionary. They are characterized as a next-generation technology platform, thereby gaining extraordinary prominence. Decades of research and clinical development into synthetic messenger RNA (s-mRNA) platforms for cancer treatments and vaccines for infectious diseases (like influenza, malaria, rabies, etc.) finally paid off as both Moderna's and Pfizer/BioNTech's COVID-19 mRNA vaccines initially and quickly received emergency use authorization (EUA) and, only a few months later, final use authorization (FUA). As a result, mRNA technologies have been catapulted into the public spotlight, projecting enhanced visibility on the pharmaceutical companies producing them.

The four types of messenger-RNA vaccines

There are four well-known types of mRNA vaccines, namely:

1. ***Non-replicating mRNA (nr-mRNA):*** This is the simplest type of RNA vaccine in which an mRNA strand is packaged and delivered to the body. It is taken-up by the body's cells to make the antigen that would trigger the production of antibodies, stimulating an immune response;

2. **In vivo *self-replicating mRNA (sr-mRNA):*** The pathogen-mRNA strand is packaged with additional RNA strands that ensure it will be copied once the vaccine is inside a cell. This means that greater quantities of the antigen are made from a smaller amount of vaccine, helping to ensure a more robust immune response;

3. **In vitro *dendritic cell non-replicating mRNA (dnr-MRNA):*** Dendritic cells are immune cells that can present antigens on their cell surface to other types of immune cells to help stimulate an immune response. These cells are extracted from the patient's blood, transfected with the mRNA vaccine, and then given back to the patient to stimulate an immune reaction; and

4. ***Self-amplifying mRNA (sa-mRNA):*** They may only require a single low dose to achieve the same level of protection. In a cell, these self-amplifying mRNA vaccines can copy the mRNA code. This means that more antigen can be produced from less mRNA. Several COVID-19 mRNA vaccines currently in clinical trials are exploring this technology.

All of the above vaccines are encapsulated in lipid nanoparticles for delivery at the injection sites. Other nanobiotechnologic (NBT) delivery vehicles exist but have not yet been fully exploited. How synthetic mRNA is developed into vaccines is next considered.

Developing synthetic mRNA into vaccines

Ribonucleic acid (RNA) is a natural molecule found in all cells. There are many types of RNA, each with distinct functions. As the name implies, mRNA acts as an important messenger in human cells. These molecules carry unique codes that tell cells which proteins to make and when to make them. The code is copied from a strand of DNA in the nucleus of the cell, in a process called 'transcription'. The mRNA is then transported into the cytoplasm (the solution contained in the cell) where the message is 'read' and 'translated' by the cell's protein production machinery. The result is an important protein, such as an enzyme, an antibody, a hormone, or a structural component of the cell.

Nearly 40 years ago, scientists found that they could mimic transcription and produce synthetic mRNA (s-mRNA) without a cell. The process, known as '*in-vitro* transcription', can generate many mRNA molecules from a strand of DNA in a test tube. This requires an enzyme (called RNA polymerase) and nucleotides (the molecules that are the building blocks of DNA and RNA). When mixed together, the polymerase reads the strand of DNA and converts the code into a strand of mRNA by linking different nucleotides together in the correct order.

When *in vitro* transcribed mRNA is introduced into a cell, it is 'read' by the cell's protein production machinery in a similar manner to how natural mRNA functions. In principle, the process can be used to generate s-mRNA that codes for any protein of interest. In the case of vaccines, the mRNA codes for a piece of a viral protein known as an 'antigen'. Once translated, the antigen triggers an immune response to help confer protection against the virus. mRNA is short-lived and does not change the cell's DNA. So it is safe for the development of vaccines and therapies.

A major advantage of '*in vitro* transcription' is that it does not require cells to produce the mRNA. It has certain manufacturing advantages over other vaccine technologies such

as, for example, rapid turnaround times and reduced biological safety risks. Thus, it took only 25 days to manufacture a clinical batch of Moderna's lipid nanoparticle (LNP) mRNA vaccine candidate that, in March 2020, became the first COVID-19 vaccine to enter human clinical trials.

Some of the newly developed COVID-19 vaccines contain mRNA. Just like the mRNA molecules the body already makes, the mRNA in COVID-19 vaccines tells the body how to make proteins. In this case, the vaccine mRNA contains the instructions for making a coronavirus 'spike protein', which is a surface protein on the virus that causes COVID-19. These spikes protrude from the outside of coronaviruses (Figure 1) and help them infect cells. Having developed vaccines, how do they actually work is the subject of the next section.

How do COVID-19 vaccines work?

Different types of vaccines work in different ways to offer protection. Each type of vaccine prompts our bodies to recognize and protect us from the SARS-CoV2 virus that causes COVID-19. Let us consider the three recognized ways in which they work:

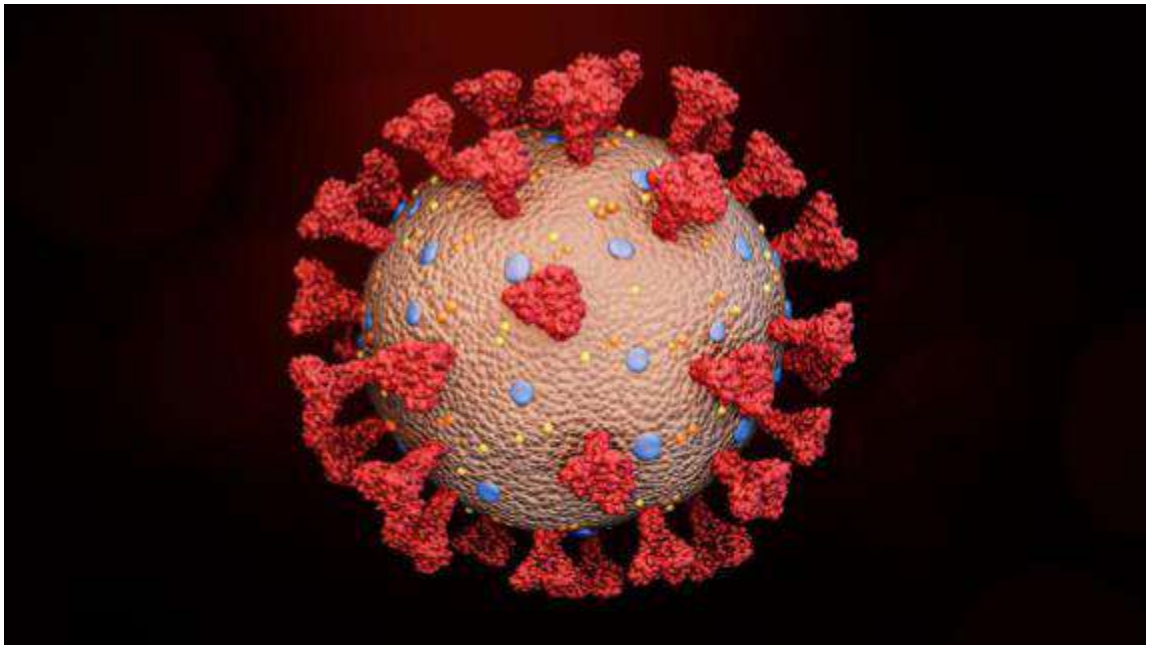

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Figure 1 – Spike proteins on the surface of the SARS-CoV2 virus causing COVID-19

- ***mRNA vaccines:*** They contain material from SARS-CoV2 that gives cells instructions for how to make a harmless protein (the 'spike protein') that is unique to the virus. After copies of the protein are made, they destroy the genetic material from the vaccine. Recognizing that the protein should not be there, our bodies build T- and B-lymphocytes that will remember how to fight the causal virus if we are infected in the future.

- ***Protein subunit vaccines;*** They include harmless pieces (proteins) of the virus

that causes COVID-19 instead of the entire virus. Once vaccinated, our bodies recognize that the protein should not be there, prompting them to build T-lymphocytes and antibodies that will remember how to fight the virus that causes COVID-19 in the case of a future infection.

- ***Vector vaccines:*** They contain a modified version of a different virus than the one that causes COVID-19. Inside the shell of the modified virus, there is material from the SARS-CoV2 virus that causes COVID-19. This is called a 'viral vector'. Once the viral vector is inside our cells, the genetic material gives cells instructions to make a protein that is unique to SARS-CoV2. Using these instructions, our cells make copies of the protein. This prompts our bodies to build T- and B-lymphocytes that will remember how to fight that virus in a future infection.

Let us now discuss how the above vaccines differ from the more conventional ones.

How do mRNA vaccines differ from other vaccines?

A vaccine teaches the immune system to recognize an invading pathogen (virus, microbe, fungus, parasite) that could cause an infection by imitating the infection in the body so the body can practice recognizing the pathogen and fighting it off. This is very much like a “dry run” or a “training exercise” for the immune system.

Most vaccines — like the flu shot — are made from dead or inactivated virus parts that are injected into the body. This helps the immune system learn to recognize the virus without the risk of getting sick. After the vaccination, the body begins to make antibodies, which are special proteins that help the body fight off a virus. Depending on the vaccine, the immune system remembers how to make these antibodies for months or even years thereafter, which helps avoid being infected if exposed to the virus in the future. How do mRNA vaccines work is next discussed.

How do mRNA vaccines work?

The mRNA vaccines we are familiar with today have benefited from many years of research, design, and optimization. Understanding how synthetic RNA is recognized in cells has proven essential in developing effective vaccines. Typically, the mRNA codes for a known viral antigen. In the case of COVID-19 mRNA vaccines, sequences coding for the SARS-CoV2 spike protein or the receptor-binding domain (RBD) have been used. These antigen-encoding mRNA molecules are incorporated into very small particles made primarily of lipids (fats).

The lipid nanoparticles (LNP) have two main functions:

- ***They protect the mRNA from degradation;*** and
- ***They help to detect infected cells.***

Once in the cytoplasm, the mRNA is translated into the antigen which triggers an immune response. This process normally takes a few weeks for the adaptive immunity to mature and synchronize. mRNA vaccines have been shown to stimulate both arms of the adaptive

immune response, which are important for establishing protection:

- ***Cellular T-cell immunity:*** It helps to detect infected cells;

- ***Humoral B-cell immunity:*** It produces antibodies.

The current mRNA COVID-19 vaccine schedule used a two dose (prime-boost) approach, which aims to strengthen the adaptive immune response towards the SARS-CoV2 virus.

Both mRNA and self-amplifying mRNA have shown potential as vaccines for multiple infectious diseases including influenza, respiratory syncytial virus, rabies, Ebola, malaria and HIV-1. Coupled with therapeutic applications, most notably as immunotherapy for the treatment of cancers, mRNA technologies will continue to improve and expand, forming an integral pat of future development.

The mRNA COVID-19 vaccines do the same job, namely, teaching the body to recognize the causal SARS-CoV2 virus and protect from getting infected. However, they do not contain dead or inactive virus parts and, thus, work differently. They contain small mRNA molecules that provide instructions for making a harmless part of the coronavirus inside the cells. Just like with other vaccines, the immune system responds by making antibodies (Figure 2). Antibodies are specialized Y-shaped proteins that bind like a lock-and-key to the body's foreign invaders (the antigens) and signal the immune system to get to work. They are the "search" battalion of the search-and-destroy immune system, tasked with finding an enemy and marking it for destruction. When they find their target, they bind to it, triggering a cascade of actions that vanquish the invader.

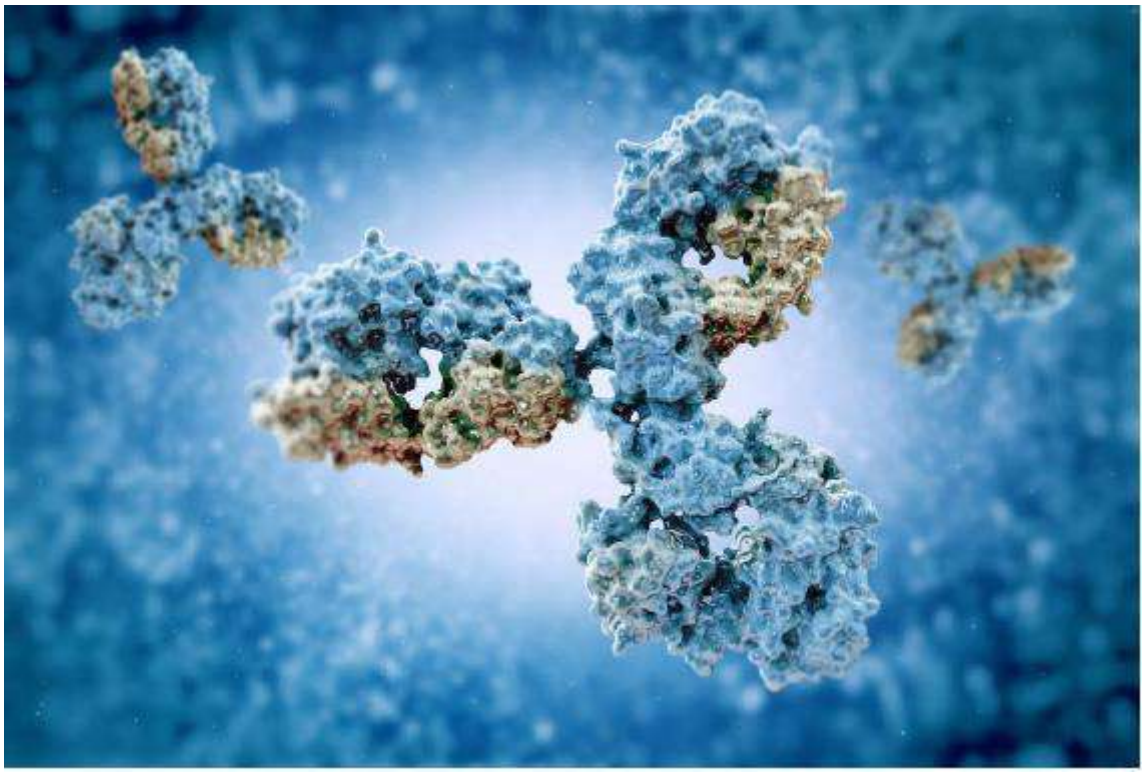

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Figure 2 – Antibodies against the SARS-CoV2 virus

In the case of SARS-CoV2, which has unique 'spikes' on its outer coat, some antibodies

bind to and recognize these spike proteins. The bottom of the Y (also referred to as the “stalk”) binds to several other immune-system compounds that can help kill the antigen or mobilize the immune system in other ways. One set of these, for instance, triggers the “complement cascade”, which is actually the executioner that punches holes in the membrane of the virus. The two arms at the top of the antibody's Y shape bind to what is known as the antigen (a molecule, or a molecular fragment — often some part of the virus).

Antibodies - also called immunoglobulins (Ig), all have the same basic Y-shape, but there are five variations on this theme — called IgG, IgM, IgA, IgD and IgE. Each variation looks slightly different and plays slightly different roles in the immune system. For instance, immunoglobulin G, or IgG, is just one Y, whereas IgM looks a bit like the 10-armed Hindu goddess Durga, with five Ys stacked together, and each prong can bind one antigen. IgG and IgM are the antibodies that circulate in the bloodstream and go into solid organs; IgA is "squirted out of the body" in mucus or secretions; IgE is the antibody that typically triggers allergic responses.

The development and production of vaccines is outlined in the next section.

On vaccine development and production

As '*in vitro* transcription' is cell-free, the manufacturing pipeline for synthetic mRNAs is flexible and new vaccines or therapies can be streamlined into existing facilities. By replacing the DNA code, facilities can easily switch from producing one kind of mRNA vaccine to another. This not only future-proofs existing mRNA production facilities but could prove vital for rapid vaccine responses to new pandemics and emerging disease outbreaks.

• Vaccine development

Having safe and effective COVID-19 vaccines available will be an important tool to help with the long-term management of COVID-19. The development of vaccines for COVID-19 has progressed quickly for many reasons, including: advances in science and technology; international collaboration among scientists, health professionals, researchers, industry and governments; and increased dedicated funding. There are currently more than 150 potential COVID-19 vaccines at different stages of development around the world.

• Vaccine production

Producing a vaccine is complex. It requires significant investments to ensure it can be produced on a large scale with good quality and consistency. Manufacturers manage the process for vaccine production. Both private and large public investments from governments around the world are being put toward research and development of COVID-19 vaccines. This partnership between private industry and the public led to more affordable and ground-breaking health products.

Summary and conclusions

- Vaccines have long been an integral part of public health programs around the

world, reducing the spread and severity of infectious diseases. The COVID-19 pandemic created an urgent need for an effective vaccine. Differing from other vaccines, mRNA vaccines represent a next-generation technology that gained substantial prominence.

- Decades of research and clinical development into synthetic mRNA platforms for cancer treatments and vaccines for infectious diseases resulted in mRNA technologies that have been catapulted into the public spotlight.
- There are four types of messenger-RNA vaccines: 'Non-replicating mRNA'; '*in vivo* self-replicating mRNA': '*in vitro* dendritic cell non-replicating mRNA'; and 'self-amplifying RNA'.
- Ribonucleic acid is a natural molecule found in all cells. There are many types of such molecules, each with distinct functions. These molecules carry unique codes that tell cells which proteins to make and when to make them. The code is copied from a strand of DNA in the nucleus of the cell, in a process called 'transcription'. The mRNA is then transported into the cytoplasm where the message is 'read' and 'translated' by the cell's protein production machinery. The result is an important protein.
- The process, known as '*in-vitro* transcription', can generate many mRNA molecules from a strand of DNA in a test tube.
- When *in vitro* transcribed mRNA is introduced into a cell, it is 'read' by the cell's protein production machinery in a similar manner to how natural mRNA functions. The process can be used to generate synthetic mRNA that codes for any protein of interest. In the case of vaccines, the mRNA codes for a piece of a viral protein known as an 'antigen'. Once translated, the antigen triggers an immune response that helps confer protection against the virus. Being short-lived and not changing the cell's DNA, mRNA vaccines are safe for the development of vaccines and therapies.
- The process of '*in vitro* transcription' does not require cells to produce the mRNA. It has certain manufacturing advantages over other vaccine technologies.
- There are four different types of vaccines that work in different ways to offer protection. Each type of vaccine prompts our bodies to recognize and protect us from the SARS-CoV2 virus that causes COVID-19: mRNA vaccines; protein subunit vaccines; vector vaccines: and self-amplifying RNA vaccines.
- Understanding how synthetic RNA is recognized in cells has proven essential in developing effective vaccines. Typically, the mRNA codes for a known viral antigen. In the case of COVID-19 mRNA vaccines, sequences coding for the SARS-CoV-2 spike protein or the receptor-binding domain have been used. These antigen-encoding mRNA molecules are incorporated into very small particles made primarily of lipids (fats).
- The lipid nanoparticles have two main functions, namely, to protect the mRNA from degradation and to help detect infected cells.
- Once in the cytoplasm, the mRNA is translated into the antigen which triggers an immune response. mRNA vaccines have been shown to stimulate both arms of the adaptive immune response, which are important for establishing protection: cellular T-cell immunity to detect infected cells and humoral B-cell immunity to produce antibodies.
- The mRNA COVID-19 vaccines contain small mRNA molecules that provide instructions for making a harmless part of the coronavirus inside the cells. Just like with other vaccines, the immune system responds by making antibodies, which are

specialized Y-shaped proteins that bind like a lock-and-key to the body's foreign invaders (the antigens) and signal the immune system to get to work.

- As '*in vitro* transcription' is cell-free, the manufacturing pipeline for synthetic mRNAs is flexible and new vaccines or therapies can be streamlined into existing facilities.
- Having safe and effective COVID-19 vaccines available will be an important tool to help with the long-term management of COVID-19. The development of vaccines for COVID-19 has progressed quickly for many reasons, including: advances in science and technology; international collaboration among scientists, health professionals, researchers, industry and governments; and increased dedicated funding.
- There are currently more than 150 potential COVID-19 vaccines at different stages of development around the world.
- Producing a vaccine is complex. It requires significant investments to ensure it can be produced on a large scale with good quality and consistency. Manufacturers manage the process for vaccine production. Both private and large public investments from governments around the world are being put toward research and development of COVID-19 vaccines. This partnership between private industry and the public led to more affordable and ground-breaking health products.

References

Abu-Raya B, Gantt, S and Sadarangani M. (2020). "Challenges in evaluating SARS-CoV2 vaccines during the COVID-19 pandemic." *Canadian Medical Association Journal* (Journal de l'Association Medicale Canadienne). https://doi.org/10.1503/cmaj.201237.

Burton DR and Topol E (2021a). "Invest in vaccines now to prevent the next pandemic", *Nature* **590:**386-8 (18 February 2021).

Burton DR and Topol EJ (2021b). "Variant-proof vaccines – invest now for the next pandemic", *Nature* **590**(7846):386-388. doi: 10.1038/d41586-021-00340-4.

Burton DR and Walker LM. (2020). "Rational vaccine design in the time of COVID-19. Cell host" *Microbe* (13 May 2020) **13;**27(5):695-698. doi: 10.1016/j.chom.2020.04.022.

Callaway E (2021). "COVID vaccines and kids: five questions as trials begin", *Nature* **592**:670-1.

Callaway E and Ledford H (2021). "How to redesign COVID vaccines so they protect against variants", *Nature* **590:**15-6.

Callaway E and Mallapaty S (2021). "What scientists do and don't know about the Oxford-AstraZeneca COVID vaccine", *Nature* **592:**15-7 (1 April 2021).Carrat, F. *et al.* (2021). *Eur. J. Epidemiol*. Collier DA, De Marco A, Ferreira IATM *et al.* (2021). "Sensitivity of SARS-CoV2 B.1.1.7 to mRNA vaccine-elicited antibodies". *Nature* **593:**136-41 (6 May 2021Dolgin E (2021). "Stocking the shelves for the next pandemic", *Nature* **592:**340-3.

Fymat AL (2018). "The odyssey of human vaccination and Africa", in Advancing Africa's Sustainable Development, *Proceedings of the Fourth Annual International Conference of the Society for the Advancement of Science in Africa, Nairobi, Kenya, August 2016,* Alain L. Fymat and Joachim Kapalanga (Editors), Cambridge Scholars Publishers, Chapter VII, pp 89-117, 2018.

Fymat AL (2021a). "Paradigm for pandemic prediction and prevention", *Universal Journal of Applied Mathematics & Computation* **9:**27-42, 2021. (Also presented at the European Union Academy of Sciences "Pandemics e2021 Symposium, Brussels, Belgium, July 15, 2021.)

Fymat AL (2021b). "Pandemics: Prescription for Prediction and Prevention", Tellwell Talent Publishers, ***352 pages.*** *ISBN: 978-0-2288-6721-0 (hardcover); 978-0-2288-6720-3 (paperback).*

Fymat AL, Romm NAR, and Kapalanga J (2022. ")COVID-19: Perspectives Across Africa", ellwell Talent Publishers, *pp 466, 24 March 2022,* ISBN: 978-0-2288-7440-9 (Hardcover); 978-0-2288-7439-3 (Paperback).

Hotez P (2021). "COVID vaccines: time to confront anti-vax aggression". *Nature* **592**;661.

Ikegame, Lee B *et al.* (2021). "Sputnik vaccine is no match for a fast-spreading variant", *Nature* **592:**331

(15 April 2021).
Irwin A (2021). "What it will take to vaccinate the world against COVID-19", *Nature* **592:**176-8.
Koff WC and Berkley SF (2021). "A universal coronavirus vaccine", *Science* **371**(6531):759.doi: 10.1126/science.abh0447.
Ledford H (2021a). "Why COVID vaccines are so difficult to compare". *Nature* **591:**16-7.
Ledford H (2021c). "Scientists probe how a COVID vaccine could cause blood clots", *Nature* **592:**334-5.
Ledford H (2021d). "COVIG vaccines and blood clots: Five key questions", *Nature* **592:**495-6.
Rappuoli R (2021). "COVID19 vaccines: sprint predicted a decade ago". *Nature* **590:**36.
Reed CC, Schultheis K, Andrade, *et al.* (2021). "Design and immunogenicity of a Pan-SARS-CoV2 synthetic DNA vaccine". *bioRxiv.* doi: 10.1101/2021.05.11.443592.
Saunders KO, Lee E, Parks R, *et al.* (2021). "Neutralizing antibody vaccine for pandemic and pre- emergent coronaviruses", *Nature* (10 May 2021). doi: 10.1038/s41586-021-03594-0.
Wang Z, Schmidt F, Wisblum Y et al. (2021). "mRNA vaccine-elicited antibodies to SARS-CoV2 and circulating variants", *Nature* **592:**616-22.
Wylliard C (2020). "Aging and COVID vaccines". *Nature* **586:**352-4.

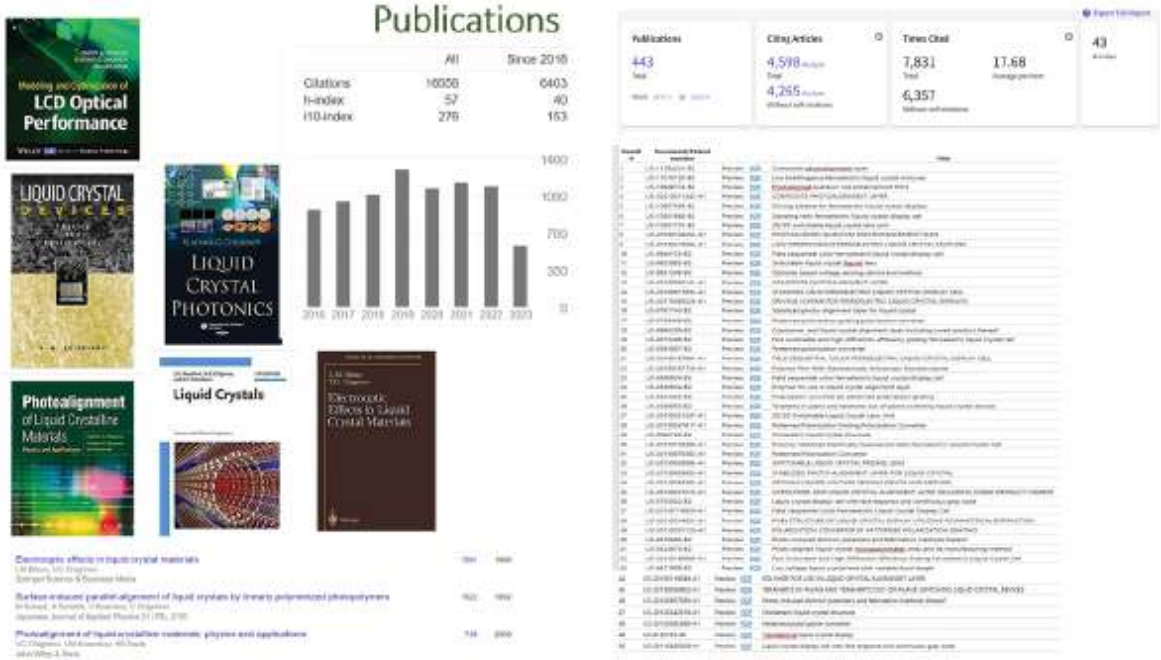
Computer Modeling of various Electrooptical Effects in Liquid Crystals

by Vladimir Chigrinov, Member EUAS

Short Biography

Professor Vladimir G. Chigrinov is Professor of Hong Kong University of Science and Technology since 1999. He is an Expert in Flat Panel Technology in Russia, recognized by the World Technology Evaluation Centre, 1994, and SID Fellow since 2008. He is an author of 6 books, 31 reviews and book chapters, about 330 journal papers, more than 707 Conference presentations, and 121 patents and patent applications including 50 US patents in the field of liquid crystals since 1974. He got Excellent Research Award of HKUST School of Engineering in 2012. He obtained Gold Medal and The Best Award in the Invention & Innovation Awards 2014 held at the Malaysia Technology Expo (MTE) 2014, which was hosted in Kuala Lumpur, Malaysia, on 20-22 Feb 2014. He is a Member of EU Academy of Sciences (EUAS) since July 2017. He got A Slottow Owaki Prize of SID in 2018 http://www.ee.ust.hk/ece.php/enews/detail/660. He is 2019 Distinguished Fellow of IETI (International Engineering and Technology Institute). http://www.ieti.net/news/detail.aspx?id=184 http://www.ieti.net/memberships/Fellows.aspx

Since 2018 he works as Professor in the School of Physics and Optoelectronics Engineering in Foshan University, Foshan, China. 2020-2024 Vice President of Fellow of Institute of Data Science and Artificial Intelligence (IDSAI) Since 2021 distinguished Fellow of Institute of Data Science and Artificial Intelligence.



RESEARCH INTERESTS

- Computer modeling of various electrooptical effects in Liquid Crystals (LC).
- Liquid crystals: physics and applications.
- Photo-aligning and photo-patterning by azodye nanolayers technique for LC application in displays and photonics such as: (i) fast high resolution LC display devices, such as field sequential color ferroelectric LCD; (ii) LC sensors, including LC biosensors; (iii) LC lenses with a variable focal distance; (iv) LC E-paper devices, including electrically and optically rewritable LC E-paper, fast bi and multistable ferroelectric LC devices; (v) photo induced semiconductor quantum rods alignment for new LC display applications; (vi)100% polarizers based on photoalignment; (vii) LC smart windows based on photopatterned diffraction structures; (vii) LC antenna elements with a voltage controllable frequency; (viii) security films.
- LC devices in fiber optics: LC based bandgap fibers, Spectral filters, Tunable waveplates, Tunable gratings, Polarimeter, beam steering devices

The following research has been done recently (year 2022):

Papers

1. Sang, Jing-Xin,Liang, Li-Bing,Zhang, Yong-Fang, Liu, Yang, Sun, Jia-Tong, Zhao, Shu-Guang,Chigrinov, Vladimir, Effect of nickel oxide doping on the optically driving liquid crystal display, Chinese Journal of Liquid Crystals and Displays, Volume 38, Issue 1, Pages 41 – 48, 2023.
2. Aleksey Kudreyko, Fan Fan, Vladimir Chigrinov & Wanqing Song, Liquid Crystals, Optimisation of stratified anisotropic media for security films,

https://doi.org/10.1080/02678292.2023.2208552 (2023).
3. Aleksey Kudreyko , Vladimir Chigrinov, Gurumurthy Hegde and Denis Chausov, hotoaligned Liquid Crystalline Structures for Photonic Applications, Crystals, 2023, 13, 965, https://doi.org/10.3390/cryst13060965.
4. Vladimir Chigrinov , Aleksey Kudreyko, and Jiatong Sun, Flexible Optically Rewritable Electronic Paper, Crystals, 2023, 13, 1283. https://doi.org/10.3390/cryst13081283.
5. Chigrinov, V.G. (2023). Ferroelectric Liquid Crystal Cells for Modern Applications in Displays and Photonics. In: Shamey, R. (eds) Encyclopedia of Color Science and Technology. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-27851-8_183-2

Conference

1. Vladimir G. Chigrinov, Liquid Crystal Photoaligning and Photopatterning by Azodye Nano Layers: Photonics and Displays Devices, Key Note, MPFORUM2023 International Forum on Condensed Matter Physics, February 2023.
2. Vladimir G. Chigrinov, Liquid crystal photoalignment and photopatterning based on nanosize azodye layers, Condensed Matter Physics, V-CONMAT 2023, February, 2023.
3. Vladimir G. Chigrinov, Key Note: Photoalignment and photopatterning based on nanosize azodye layers for new liquid crystal display and photonics devices, V-Laser 2023, 4th Edition of Laser, Optics and Photonics Virtual, February 2023.
4. Vladimir G. Chigrinov, Key Note: Photoalignment And Photopatterning By Nanosize Azodye Layers: Physics And Applications, International Conference on Laser, Optics and Photonics, March 2023, Paris, France.
5. Vladimir G. Chigrinov, Invited: Vladimir G. Chigrinov, Key Note: Photoalignment And Photopatterning By Nanosize Azodye Layers: Physics And Applications, ICDT 2023, Nanjing China, April 2023
6. Vladimir G. Chigrinov, Invited: Vladimir G. Chigrinov, Key Note: Liquid Crystal Photoaligned by Azodye Nano Layers: Physics & Applications, International Forum on Metamaterials and Plasmonics, Metaforum 2023, April 2023.
7. Vladimir G. Chigrinov, Invited: Vladimir G. Chigrinov, Invited: Photoaligning and Photopatterning: New Technology for Liquid Crystal Devices, The 3rd International Conference on Multidisciplinary Research 24-26 April 2023, Pharaoh Azur Resort, Hurghada
8. Vladimir G. Chigrinov, Key Note: Photoalignment and photopatterning nanosize azodye layers for new liquid crystal devices, WORLD NANOTECHNOLOGY CONFERENCE, Orlando, Florida, 24-25 April, 2023.
9. Vladimir G. Chigrinov, Photoalignment and photopatterning nanosize azodye layers: New trend for liquid crystal devices, ACFM Congress, International association of Advanced Materials, Orlando, Florida, 27-30 April, 2023.
10. Vladimir G. Chigrinov, Photoalignment and photopatterning nanosize azodye layers : new trends for liquid crystal technology, Materials World 2023, May 2023 https://materialsscience.scientifink.com/.
11. Vladimir G. Chigrinov, Nanosize Azodye Layers for Liquid Crystal Photoaligning and Photopatterning, NOMA 2023, Cetraro, Italy, June 2023
12. Vladimir G. Chigrinov, Key Note: Photoalignment and photopatterning nanosize azodye layers : new liquid crystal technology, NANOSCIENCE & NANOTECHNOLOGY https://nanotech.pagicle.com/, June 2023.
13. Vladimir G. Chigrinov, Plenary Talk: Nanosize Azodye Layers for New Liquid Crystal Devices, Global Webinar on Nanotechnology and Nanoscience, http://www.globalscientificguild.com/, June 2023.
14. Vladimir G. Chigrinov, New Liquid Crystal Devices based on Azodye

Nanosize Photoaligning and Photopatterning, 40th Global Summit on Nanoscience and Technology, Webinar, June 2023.

15. Vladimir G. Chigrinov Key Note:, Liquid Crystal Photoalignment by Azodye Nanolayers: Physics and Applications, Advanced Nanotechnology and Nanomaterials International Conference, August 2023.

Recent Improvements of Fluid Flow in Porous Media

by Russell Johns, Member EUAS

Short Biography

Russell T. Johns is the George E. Trimble Chair of Energy and Mineral Sciences at the Department of Energy and Mineral Engineering at The Pennsylvania State University. He recently served as Chair of the Petroleum and Natural Gas Engineering Program from 2015 to 2018, Distinguished SPE Lecturer for 2019 – 2020, and Editor-In-Chief for all SPE technical journals from 2018 - 2020. He is currently the Acting Head of the Department of Energy and Mineral Engineering at Penn State.

Prior to his current position, he served on the petroleum engineering faculty at The University of Texas at Austin from 1995 to 2010. He also has nine years of industrial experience as a petrophysical engineer with Shell Oil and as a hydrogeologist for Colenco Power Consulting in Baden, Switzerland. He holds a BS degree in electrical engineering from Northwestern University and MS and PhD degrees in petroleum engineering and water resources from Stanford University. He has over 250 publications in enhanced oil recovery, thermodynamics and phase behavior, unconventional gas engineering, multiphase flow in porous media, water resources, and well testing. Dr. Johns received the SPE Ferguson medal in 1993, the Society of Petroleum Engineers (SPE) Distinguished Member award in 2009, the SPE Faculty Pipeline award in 2013, the 2016 SPE international award in Reservoir Description and Dynamics, the Wilson Excellence in Research award from the College of Earth and Mineral Sciences in 2018, the prestigious IOR Pioneer Award from SPE in 2022, and more recently the SPE international award for technical leadership, the Anthony F. Lucas Gold medal. He is currently director of the Enhanced Oil Recovery consortium in the EMS Energy Institute at Penn State University.

The research group of Dr. Johns is noted for its development of the first flash calculation algorithm for microemulsion phases where all Winsor regions (single, two, and three-phase) are modelled simultaneously. His group is also recently recognized as developing state function theory of relative permeability to fit experimental data and predict relative permeabilities away from that data set. As a part of that research, they developed an analytical function that includes connectivity (Euler number) in the relative permeability model. Finally, his group has been recognized as a leader in developing miscibility theory for gas injection applications such as injection of carbon dioxide into oil reservoirs. They developed analytical theory for solving hyperbolic equations to predict the minimum miscibility pressure (MMP) for any number of components.

Dr. Johns currently teaches required undergraduate courses in secondary recovery and pressure transient analysis, along with a required graduate course in thermodynamics. He also teaches elective graduate courses in gas and chemical flooding for enhanced oil recovery. He is a member of numerous Penn State and professional committees. Selected abstracts from publications this year from his group are included below.

Modeling of High-Pressure and High-Temperature Microemulsion Experiments using HLD-NAC-Based Equation of State

D. Magzymov, Johns, R.T., Hashim, H., and Dindoruk, B.

SPEJ (2022)

Abstract

Surfactant flooding is a promising technique that can reduce interfacial tension (IFT) between oil and water to ultralow values, mobilizing previously trapped oil. For reservoirs at moderate to high pressures, understanding and modeling how pressure affects the phase behavior of a surfactant-brine-oil system is important to the design and implementation of an efficient/cost-effective surfactant flooding project. Typically, however, phase behavior experiments and models of that phase behavior are made only at low pressures. The main objective of this paper is to show how to model experimental data in a unified way for a large range of pressure, temperature, and other parameters, using hydrophilic-lipophilic deviation (HLD) and net-average curvature (NAC)-based equation-of-state (EOS).

Pressure and temperature scans show that pressure has a significant effect on the surfactant microemulsion phase behavior, shifting it from an optimal three-phase system at low pressure to a nonoptimal two-phase system at high pressure. Further, multiple scans at different water/oil ratios (WORs) show a shift in the optimum indicating that phase behavior partitioning of the various components is changing with oil saturation. We obtained good fits of all experimental data including all two- and three-phase regions using a single tuned HLD-NAC EOS for a wide range of simultaneous variations in pressure, temperature, salinity, and overall composition. Such a simultaneous match and prediction by a single set of model parameters has never been done before. We also demonstrate the type of data needed for an accurate EOS. When input into a numerical simulator, the tuned EOS improves the predictions of the resulting phase behavior (size and shape of the two-phase lobes and three-phase regions) and IFTs with changing pressure, temperature, salinity, WORs, and surfactant/alcohol concentrations.

Sensitivity Analysis of Fluid–Fluid Interfacial Area, Phase Saturation and Phase Connectivity on Relative Permeability Estimation Using Machine Learning Algorithms

S. Mukherjee and Johns, R.T.

Energies (2022)

Abstract

Recent studies have shown that relative permeability can be modeled as a state function which is independent of flow direction and dependent upon phase

saturation (S), phase connectivity (X), and fluid–fluid interfacial area (A). This study evaluates the impact of each of the three state parameters (S, X, and A) in the estimation of relative permeability. The relative importance of the three state parameters in four separate quadrants of S-X-A space was evaluated using a machine learning algorithm (out-of-bag predictor importance method). The results show that relative permeability is sensitive to all the three parameters, S, X, and A, with varying magnitudes in each of the four quadrants at a constant value of wettability. We observe that the wetting-phase relative permeability is most sensitive to saturation, while the non-wetting phase is most sensitive to phase connectivity. Although the least important, fluid–fluid interfacial area is still important to make the relative permeability a more exact state function.

Inclusion of variable characteristic length in microemulsion flash calculations

D. Magzymov and Johns, R.T.

Computational Geosciences (2022)

Abstract

Recent developments in predicting microemulsion phase behavior for use in chemical flooding are based on the hydrophilic-lipophilic deviation (HLD) and net-average curvature (NAC) equation-of-state (EoS). The most advanced version of the HLD-NAC EoS assumes that the three-phase micelle characteristic length is constant as parameters like salinity and temperature vary. In this paper, we relax this assumption to improve the accuracy and thermodynamic consistency of these flash calculations. We introduce a variable characteristic length in the three-phase region based on experimental data that is monotonic with salinity or other formulation variables, such as temperature and pressure. The characteristic length at the boundary of the three-phase region is then used for flash calculations in the two-phase lobes for Winsor type I/II. The functional form of the characteristic length is made consistent with the Gibbs phase rule. The improved EoS can capture asymmetric phase behavior data around the optimum, whereas current HLD-NAC based models cannot. The variable characteristic length formulation also resolves the thermodynamic inconsistency of existing phase behavior models that give multiple solutions for the optimum. We show from experimental data and theory that the inverse of the characteristic length varies linearly with formulation variables. This important result means that it is easy to predict the characteristic length in the three-phase region, which also improves the estimation of surrounding two-phase lobes. The results show that the optimum solubilization ratio can change significantly by a factor of two when variable characteristic length is included as temperature and pressure change. This can in turn greatly impact the interfacial tension (IFT) at optimum. This improved physical understanding of microemulsion phase behavior should aid in the design of surfactant blends and improve recovery

predictions in a chemical flooding simulator.

Journal Publications (Last Five Years)

1. Magzymov, D., Johns, R. T., Hashim, H., and Dindoruk B. 2022. Modeling of High-Pressure and High-Temperature Microemulsion Experiments using HLD-NAC-Based Equation of State. SPE J. SPE-209470-PA (in press; posted 5 December 2022). https://doi.org/10.2118/209470-PA.
2. Magzymov, D., Ratnakar, R., Dindoruk, B., and Johns, R.T., Evaluation of Machine Learning Algorithms Using Simple Physics Based Conceptual Models for Flow in Porous Media, JPSE, September 16, 2022, Online, https://doi.org/10.1016/j.petrol.2022.111056
3. Tawfik, M., Karpyn, Z., and Johns, R.T., Effect of Oil Chemistry on the Performance of Low Salinity Waterflooding: An Integrated Experimental Approach, SPE Annual Technical Conference and Exhibition, JFUE-D-22-00864R1, Fuel (2022).
4. Mukherjee, S., and Johns, R.T., Sensitivity Analysis of Fluid–Fluid Interfacial Area, Phase Saturation and Phase Connectivity on Relative Permeability Estimation Using Machine Learning Algorithms, Energies 2022, 15, 5893. https://doi.org/10.3390/en15165893.
5. Magzymov, D., Johns, R.T. Inclusion of variable characteristic length in microemulsion flash calculations. Comp. Geosci (2022). pp 16. https://doi.org/10.1007/s10596-022-10158-2
6. Magzymov, D., Purswani, P., Johns, R.T., and Z.T. Karpyn, Modeling the Effect of Reaction Kinetics and Dispersion During Low-Salinity Waterflooding, SPE J, Vol. 26 (05), pp. 3075-3093. 2022.
7. Tawfik, M., Karpyn, Z., and Johns, R.T., Comparative Study of Common Denoising Protocols in Geoscience Applications, Frontiers, Lausanne, Switzerland, 2021. Front. Water 3, 2022 https://doi.org/10.3389/frwa.2021.800369
8. Duffy, T. S., Gamwo, I. K., Johns, R. T., S. N. Lvov, Modeling Contact Angle vs. Temperature for the Quartz-Water-Decane System. SPE J, Vol. 26 (06), 2022. https://doi.org/10.2118/205518-PA.
9. Dindoruk, B, Johns, R.T., and Orr, F.M. Jr., Measurement and Modeling of Minimum Miscibility Pressure: A State of the Art Review, SPEREE, Vol. 24 (02), pp. 367 - 389. DOI: https://doi.org/10.2118/200462-PA, 2021.
10. Magzymov, D., Clemens, T., Schumi, B. et al. 2021. Experimental Analysis of Alkali-Brine-Alcohol Phase Behavior with High Acid Number Crude Oil. SPE Reservoir Evaluation & Engineering. Vo. 24 (02), pp. 390-408, SPE-201369-PA, https://doi.org/10.2118/201369-PA. 2021
11. Duffy, T, Li, J., L, Johns, R.T., and Lvov, S.N. Capillary Contact Angle for the Quartz-Distilled Water-Normal Decane Interface at Temperatures up to 200 °C, Colloids and Surfaces A: Physicochemical and Engineering Aspects, Vol. 609 125608, **https://doi.org/10.1016/j.colsurfa.2020.125608 .** Vol. 609, 2021.
12. Khorsandi, S., Li, L, and Johns, R.T., A New Way of Compositional Simulation Without Phase Labeling, SPE J., 26 (02), pp. 940-958. 2021.
13. Purswani, P., Johns, R. T., Karpyn, Z. T., & Blunt, M.. Predictive Modeling of Relative Permeability Using a Generalized Equation of State. SPE Journal, https://doi.org/10.2118/200410-PA, 26(01), pp. 191-205, 2021.
14. Cronin, M., Emami-Meybodi, H., & Johns, R. T. (2020, May 1). Multicomponent Diffusion Modeling of Cyclic Solvent Injection in Ultra-Tight Reservoirs. SPEJ 26 (03), pp. 1213-1232, doi:10.2118/196008-PA. 2021.
15. Khodaparast, P., and Johns, R.T., A Continuous and Predictive Viscosity Model Coupled to a microemulsion Equation of State, doi:10.2118/190278-PA, SPEJ, 25(03), pp. 1070-1081, 2020.
16. Zhang, K., Nojabaei, B., Ahmadi, K., and Johns, R. T., Effect of Gas/Oil Capillary Pressure on Minimum Miscibility Pressure for Tight Reservoirs. Society of Petroleum Engineers. doi:10.2118/199354-PA, *SPEJ*, 25(02), pp. 820-831, 2020.
17. Purswani, P., Tawfik, M.S., Karpyn, Z.T. and Johns, R.T., On the development of a relative permeability equation of state. *Comput Geosci*, https://doi.org/10.1007/s10596-019-9824-2, 24(2), pp. 807-818, 2020.
18. Cronin, M., Emami-Meybodi, H., and Johns, R. T. Unified Theory of Ultimate Hydrocarbon Recovery for Primary and Cyclic Injection Processes in Ultra-Tight Reservoirs (reference number: SREP-19-17522), Scientific Reports, 9(1), pp. 1-14, 2019
19. Duffy, T., Raman, B., Hall, D., Machesky, M., R.T. Johns, and Lvov, S., Experimentation and Modeling of Surface Chemistry of the Silica-Water Interface for Low Salinity Waterflooding at Elevated Temperatures, Colloids and Surfaces A: Physicochemical and Engineering Aspects, 570, pp. 233-243, doi: 10.1016/j.colsurfa.2019.03.007, March 4, 2019.
20. Khorsandi, S., Johns, R. T., Robust Flash Calculation Algorithm for Microemulsion Phase Behavior, Journal of Surfactants and Detergents, Errata, 10.1002/jsde.12265, 22(4), pp. 929-930. 2019.
21. Cronin, M., Emami-Meybodi, H., and Johns, R. T., Diffusion-Dominated Proxy Model for Solvent Injection in Ultra-Tight Oil Reservoirs. Society of Petroleum Engineers. doi:10.2118/190305-PA, 24(02), pp. 660-680, April 1, 2019.
22. Torrealba, V. A., Johns, R. T., and Hoteit, H.. Curvature-Based Equation of State for Microemulsion-Phase Behavior. *SPEJ*, 24(02), pp. 647-659, doi:10.2118/194022-PA, April 1, 2019.
23. Torrealba, V. A., and Johns, R. T., Partition-Coefficient Relations for Improved Equation-of-State Description of Microemulsion-Phase Behavior. *SPEJ*, doi:10.2118/179845-PA, 23(05), pp. 1899-1908, October 1, 2018.

24. Torrealba, V., Hoteit, H., and Johns, R., Description of Micellar Radii for Phase Behavior and Viscosity Modeling of Aqueous Surfactant Solutions and Microemulsions, Langmuir. 10.1021/acs.langmuir.8b02828, pp. 15327 – 15334, 34(50), 2018.
25. Rezaveisi, M., Sepehrnoori, K., Pope, G. A., and Johns, R.T. Thermodynamic Analysis of Phase Behavior at High Capillary Pressure. SPE Journal. https://doi.org/10.2118/175135-PA, 23(06), pp. 1977-1990, December 1, 2018.
26. Ghosh, S., and Johns, R. T. A Modified HLD-NAC Equation of State To Predict Alkali/Surfactant/Oil/Brine Phase Behavior. Society of Petroleum Engineers. *SPEJ*, doi:10.2118/175132-PA, 23(02), pp. 550-566, February 1, 2018.
27. Tayari, F., Blumsak, S., Johns, R.T., Tham, S. and Ghosh, S, Techno-economic assessment of Reservoir Heterogeneity and Permeability Variation on Economic Value of Enhanced Oil Recovery by Gas and Foam Flooding, JPSE, 166, 913-923, 2018.
28. Torrealba, V, and Johns, R.T., Coupled Interfacial Tension and Phase Behavior Model Based on Micellar Curvatures, Langmuir, 33 (47), pp 13604–13614, DOI: 10.1021/acs.langmuir.7b03372 November, 2017.
29. Venkatraman, A., Dindoruk, B., Elshahawi, H., Lake, L. W., and Johns, R. T. Modeling Effect of Geochemical Reactions on Real-Reservoir-Fluid Mixture During Carbon Dioxide Enhanced Oil Recovery. SPEJ, Society of Petroleum Engineers. 22 (05), pp. 1519-1529, doi:10.2118/175030-PA, October 1, 2017.
30. Mohebbinia, S., Sepehrnoori, K., Johns, R.T., and Korrani, A.N., Simulation of Precipitation During Gas Injection Using PC-SAFT EOS, Journal of Petroleum Science and Engineering, Volume 158, pp. 693-706, 2017.
31. Khorsandi, S., Li, L., and Johns, R. T. Equation of State for Relative Permeability, Including Hysteresis and Wettability Alteration. SPEJ, Society of Petroleum Engineers. doi:10.2118/182655-PA, 22(06), pp. 1915-1928, August 1, 2017
32. Khorsandi, S., Qiao, C., and Johns, R. T. Simulation of Surfactant/Polymer Floods with a Predictive and Robust Microemulsion Flash Calculation, *SPEJ*, 22 (02), 470-479, doi:10.2118/179566-PA. April 1, 2017.
33. Torrealba, V. A., & Johns, R. T. Microemulsion Phase Behavior Model Using Empirical Trends in Chemical Potentials. SPEJ, 23 (03), 819-830, doi:10.2118/184555-MS, April 3, 2017.
34. Khorsandi, S., Qiao, C., and Johns, R. T., Displacement Efficiency for Low-Salinity Polymer Flooding Including Wettability Alteration. Society of Petroleum Engineers. *SPEJ*, doi:10.2118/179695-PA, 22(03), pp. 417-430, April 1, 2017.
35. Siripatrachai, N., Ertekin, T., and Johns, R. T. Compositional Simulation of Hydraulically Fractured Tight Formations Considering the Effect of Capillary Pressure on Phase Behavior. Society of Petroleum Engineers. *SPEJ*. 22 (04), 1046-1063, doi:10.2118/179660-PA, March 1, 2017.

Recent Aspects in Organic Chemistry, Inorganics Chemistry & Materials Chemistry

by Ed Billups, Member EUAS

Short Biography

Date and Place of Birth:

- *April 7, 1939, Huntington, West Virginia*

Education:

- *Hurricane High School, Hurricane, West Virginia, 1957*
- *Marshall University, Huntington, West Virginia, B. S. 1961,*
- *Pennsylvania State University, University Park, PA, Ph.D. 1970*

Positions Held:

- *Research Chemist, Union Carbide Corporation, 1961-1968*
- *Assistant Professor of Chemistry, Rice University, September 1970-1975*
- *Associate Professor of Chemistry, Rice University, July 1975-1981*
- *Professor of Chemistry, Rice University, July 1981*
- *Department Chair, July 1985-December 1991*

Professional Society Memberships, Honors, and Awards:

- *Phi Kappa Phi*
- *Shell Oil Companies Fellow*
- *Alfred P. Sloan Fellowship*
- *Lilly Grantee in Organic Chemistry Program, 1973*
- *Alexander von Humboldt Senior Scientist Award, 1991*
- *2003 Award of the American Chemical Society, Greater Houston Section of the American Chemical Society*

Special Field:

- *Organic Chemistry*

Research Interests:

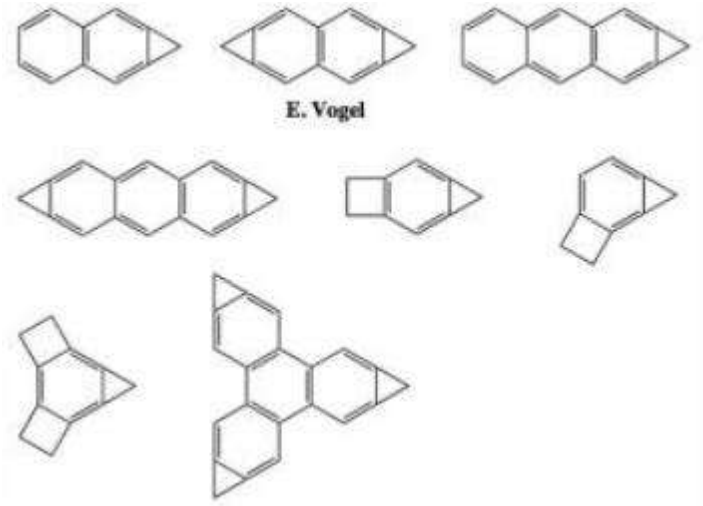
- *Chemistry of small ring systems; reactive intermediates; synthetic organo-transition metal chemistry; chemistry of free metal atoms; fullerene, carbon nanotube and graphite chemistry, soluble nanocoal*

Other Professional Activities:

- *Consultant, UNESCO (1980)*
- *Consultant, Exxon (1982)*
- *Consultant, 3M (1984-1990)*
- *Consultant, Halliburton (2007)*

Dr. Billups' research has covered a wide variety of areas in organic chemistry, inorganic chemistry and materials chemistry. His early work focused on the synthesis and thermal rearrangements of cyclopropabenzene.

Application of this chemistry to the synthesis of other cycloproparenes soon followed. Representative compounds that have been synthesized either in the Billups laboratory or elsewhere are illustrated below. Detailed studies on the chemistry of these compounds have been investigated including a determination of structures and strain energies.

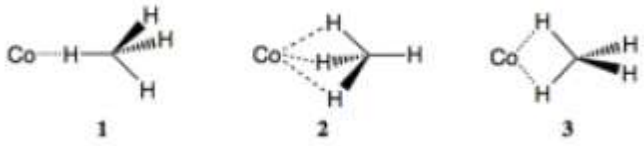


As the program evolved, a major focus centered on the synthesis of new molecular systems of theoretical interest. The development of a vacuum gas phase procedure for the synthesis of small ring cycloalkenes using reagents adsorbed on inert surfaces to affect elimination reactions played a major role in this work. This approach allows the reactive species to be isolated at low temperature, and eliminates many of the undesired bimolecular side reactions that would normally be encountered in solution. Energetic compounds can thus be collected readily in cold traps for further chemical studies or spectral characterization. Representative molecules whose syntheses have been accomplished include methylenecyclopropene, spiropentadiene, and spiroheptatriene, 3,3'-bicyclopropenyl, the last (CH_6) isomer of benzene to be synthesized, and oxaspiropentene.

X-ray structural parameters of unstable low melting compounds were secured in collaboration with Dr. Roland Boese in Essen, Germany. Collaborative work with Boese and an industrial sponsor led to the nucleation, growth, and structure determination of gas hydrates by X-Ray crystallography. Gas hydrates cause serious problems in long distance natural gas pipelines.

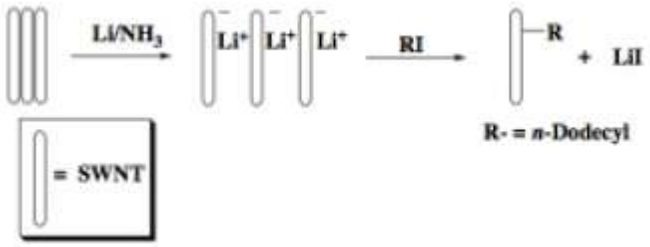
Another area involved studies on the activation of carbon-hydrogen bonds by first row transition metals. For example, photoexcited cobalt atoms were found to insert into the carbon-hydrogen bonds of methane to yield CH_3CoH. This same species can be microsynthesized and characterized using FTIR spectroscopy by

cocondensing the metal with CH_2N_2, H_2, and argon at 11 K. Photolysis of CH_3CoH using 400 nm light leads to extrusion of the metal with the formation of the spectroscopically detectable $Co(CH_4)$ sigma-complex **2** shown to have C_{3v} symmetry. Photolysis of this complex using a UV source regenerates the insertion product CH_3CoH. Deuterium labeling studies have shown that the methane rotates freely on the cobalt. These studies were carried out in collaboration with the late Professor John Margrave and his coworkers.



Billups research has involved all of the major allotropes of carbon. For example, the first reaction of the fullerene C_{60}, a Birch reduction, carried out in collaboration with Marco Ciufolini gave $C_{60}H_{36}$. *3*He NMR spectroscopy played an important role in the characterization of these materials. These studies were carried out in collaboration with Professor Martin Saunders at Yale University.

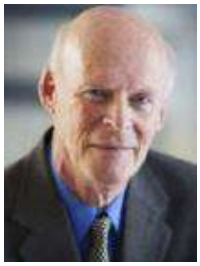
Current studies have focused on the development of routes to soluble carbon nanotubes and graphene. Studies on the sidewall functionalization of carbon nanotubes by reductive alkylation gives nearly complete exfoliation, without sonication, when dodecyl groups are added to the nanotubes.



Graphene/graphite has also been functionaized under an expansive set of conditions. Water-soluble graphene proved to be especially interesting since functionalization of graphite by the addition of phenyl groups followed by sulfonation gave material that exhibited high solubility in water (2.1mg/mL). STM images showed that the phenyl groups added to the edges of the graphene. This leaves the basal plane free of defects.

Laser Processing Technology: Nano - to Macro – Structures

by Walter W. Duley, Member EUAS



Short Biography

Walter Duley graduated with a B. Eng. Physics degree from McGill University and was awarded an Athlone Fellowship in Engineering held at Imperial College where he received DIC and PhD degrees. In 1983 he was awarded a DSc degree from the University of London for his research activities. Professor Duley's current research interest is focussed on nanotechnology and the properties of nano-systems, including the use of nanogenerators to produce electrical power and the development of new methods for in-situ modification of nano-devices. He is the author of four books on laser materials processing including CO2 Lasers (1976), Laser Processing and Analysis of Materials (1981), UV Lasers (1996) and Laser Welding (1999) and is also co-inventor on over 20 patents. He has pioneered the development of technology related to industrial laser applications, including laser welding of tailor blanks, which are used to reduce emissions and improve safety in the automobile industry. As an entrepreneur, Dr. Duley founded Powerlasers Ltd., now part of ArcelorMittal Tailor Blanks (AMTB). AMTB is one of the foremost suppliers of laser welded tailor blanks. Walter Duley is presently an adjunct professor in the Department of Physics and Astronomy and the Centre for Advanced Materials Joining at the University of Waterloo. He has held academic positions at a variety of institutions including UCB, ETH Zurich, York University, University of York, University of Liverpool, UNSW at ADFA, UMIST, University of Florida, University of Toronto, University of Hawaii and Oxford University and is a fellow of the Laser Institute of America (LIA). He received the Schawlow Award in 2001 for the promotion of collaboration between education, industry, and government. He is the author/co-author of over 480 research publications with > 15300 citations and an H-index of 64. These publications cover a variety of topics in science and engineering ranging from the properties of nanoparticles in the interstellar medium to fundamental studies of the interaction of intense laser radiation with materials.

Selected abstracts from recent publications.

Selective Breaking and Re-Joining of CuO Nanowires by Nanosecond Laser Irradiation

Maryam Soleimani, Peng Peng, Walter Duley, Norman Zhou. **Journal of Applied Physics 133 (7), 2023**

We show that the electrical and mechanical properties of CuO nanowire (NW) networks can be adjusted through sequential processing with nanosecond laser radiation. This new two-stage process involves selective breakage/cleaving of CuO NWs with an initial set of laser pulses, followed by irradiation with a second set of laser pulses applied in an optimized orientation to tailor bonding and junction formation between pairs and bundles of previously separated CuO NWs. We find that stage one processing introduces a high concentration of oxygen vacancies in the NWs leading to the nucleation of dislocations and high strain. This localized strain is responsible for the breaking of individual NWs, while the high oxygen vacancy concentration modifies the electrical conductivity within each NW. The second stage involves re-orientation of the laser beam, followed by additional laser irradiation of the NW network.

Engineering the defect distribution in ZnO nanorods through laser irradiation

Shuo Zheng, Zuolong Chen, Walter W Duley, Yimin A Wu, Peng Peng and Y Norman Zhou

Nanotechnology, 34, 495703, 2023

Laser irradiation has emerged as a promising post-deposition technique to further modulate the properties of defects yet there is still limited information. In our work, defects such as oxygen vacancies are tailored in ZnO nanorods through nanosecond (ns) laser irradiation. Raman spectra indicate that the concentration of the oxygen vacancies in the ZnO is temperature-dependent and can be controlled by changing the laser fluence and exposure time. This is supported by the absorption spectra and the photoluminescence spectra of ZnO NRs irradiated under these conditions. The distribution of oxygen vacancies was studied by XPS depth profiling, and it is found that the surface-to-bulk ratio of oxygen vacancies can be modulated by varying the laser fluence and exposure time. Based on these results, four distinct regimes containing different ratios of surface-to-bulk oxygen vacancies have been identified. Laser-processed ZnO nanorods were also used as the catalyst for the photocatalytic degradation of rhodamine B (RhB) dye to demonstrate the efficacy of this laser engineering technique.

Simple Self-Powered Sensor for the Detection of D_2O and Other Isotopologues of Liquid Water

Xiaoye Zhao, Hanwen Yang, Walter W. Duley, Shuo Zheng, Tao Guo and Norman Y. Zhou

ACS Sensors, Sept. 19, 2023

Distinguishing between heavy water and regular water has been a continuing challenge since these isotopologues of water have very similar physical and chemical properties. We report the development and evaluation of a simple, inexpensive sensor capable of detecting liquid D_2O and other isotopologues of liquid water through the measurement of electrical

signals generated from a nano-porous alumina film. This electrical output, consisting of a sharp voltage pulse followed by a separate broad voltage pulse, is present during the application of microliter volumes of liquid. The amplitude and temporal characteristics of these pulses have been combined to enable four diagnostic parameters for sensing D_2O and $H_2{}^{18}O$. The sensing mechanism is based on different modification effects on alumina surface by H_2O and D_2O, spatially localized variations in the surface potential of alumina induced by isotopically substituted water molecules, combined with the effect of isotopic composition on charge transfer. As a proof-of-concept demonstration, a sensing system has been developed that provides real-time detection of liquid D_2O in a stand-alone system.

Water-Enabled Electricity Generation: A Perspective

Xiaoye Zhao, Daozhi Shen, Walter W. Duley, Caiwang Tan, Y. Norman Zhou. **Advanced Energy and Sustainability Research, 07 Feb., 2022**

This review paper gives some perspective on the development of water-enabled electricity generation. Current methods for water-enabled electricity generation and relevant functional materials are summarized, including the development of new materials and systems. We show how these advances have led to significant improvements in the electrical power output for these devices. Some recent progress that has resulted in a dramatic increase in the electrical output available from water-enabled electrical generators (WEEGs) is also discussed and future trends in the development of WEEGs are outlined. Practical applications and commercialization of these devices are evaluated.

The effect of laser impingement angle on the optimization of melt pool geometry to improve process stability during high-speed laser welding of thin-gauge automotive steels.

Shehryar Khan, Sarim Ali, Daniel Westerbaan, Walter Duley, Elliot Biro, Y. Norman Zhou. **Journal of Manufacturing Processes, Volume 78, June 2022, Pages 242-253**

Automated laser welding is a popular fusion joining method used for numerous applications involving the joining of similar and dissimilar materials of varying thicknesses. Laser welding offers several advantages over other fusion joining methods such as: high reliability and consistency in the quality of the welds, high production rates, ease of process optimization, higher power density and lower heat input, significantly reduced heat affected zone due to the ability to effectively deliver energy to a highly localized area, and most importantly, improved joint efficiency. However, without proper optimization, the laser welded joints can have significant external and internal defects such as porosity, humping, concavity, and undercut which are widely known to adversely affect the mechanical performance of the joint. The laser welding process is most commonly optimized by adjusting the laser power and the welding speed, but this usually increases the processing time which can be costly in an industrial setting. This work explores the optimization of high-speed laser welding of thin-gauge automotive steels by changing the laser impingement angle during open-keyhole mode welding. The numerical simulations and the experimental results presented in this study clearly show that by optimizing the laser impingement angle, the melt pool geometry can be effectively controlled which eliminates surface defects such as weld concavity and undercut when welding thin-gauge steels at high-speeds without the need for expensive consumables and tighter setups needed

for wire-feeding capabilities. The findings presented in this paper hold a major relevance to industries that employ fiber laser systems in welding and additive manufacturing applications which can benefit from improved process efficiencies while minimizing defects.

Laser-induced joining of nanoscale materials: processing, properties, and applications

Ming Xiao, Shuo Zheng, Daozhi Shen, Walter W Duley, Y Norman Zhou. **Nanotoday, 35, 100959, 2020**

The rapid development of flexible and wearable nanodevices for a variety of commercial applications has identified a pressing need for targeted research on nanomaterials for use as building blocks in the fabrication of functional devices via bottom-up assembly. In the search for new fabrication technology, nano-joining or nano-welding has been selected as a promising method in this bottom-up approach. While there are several methods that can be used for nano-joining, laser processing is of interest because laser nano-joining combines high-precision property with a flexible manufacturing platform. In this review we discuss how this technology can be implemented in practical applications and outline the advantages and limitations of laser-induced nano-joining. We emphasize how laser nano-joining introduces reliability and reproducibility to the joining process and show that this is due to precise control of heat-input in nanoscale dimensions. We also review the ways in which laser nano-joining can be integrated with other commercial fabrication operations in practical applications. To illustrate the flexibility of laser nano-joining, we give a detailed summary of joining involving a wide variety of multidimensional heterogeneous nanomaterials in the form of zero-dimension, one-dimension and two-dimension as well as the hybrid combination of these building blocks. We also discuss how laser processing can be used to generate hybrid materials with new functionalities as electrodes for various devices, optical systems and in functional circuits. The mechanisms and strategies in laser-induced joining of nanomaterials are systematically discussed in this paper along with a review of the properties and applications of the joined nanostructures. We also review some challenges in the implementation of this technology and discuss some possible directions for future research into laser-induced nano-joining.

Operando Monitoring of Thermal Runaway in Commercial Lithium-Ion Cells via Advanced Lab-on-fiber Technologies

by Jinhua Sun, Member EUAS

Short Biography

Education and Positions

2022~ Chair Professor, University of Science and Technology of China
2019~ Chairman, Sub-Academic Advisory Committee of USTC
2004~2019 Vice Director of State Key Laboratory of Fire Science of China, CHINA
2014~ Director of Energy Fire Safety Institute, SKLFS, CHINA
2002~ Professor, University of Science & Technology of China, CHINA
1999~2002 Research Professor, Japan Science and Technology Agency, JAPAN
1996~1999 Ph.D., The University of Tokyo, JAPAN
1988~1996 Associate Professor, Anhui University of Science & Technology, CHINA
1986~1988 M. Sc., Nanjing University of Science and Technology, CHINA
1983~1986 Assistant Professor, Anhui University of Science & Technology, CHINA
1979~1983 B. Sc., Nanjing University of Science and Technology, CHINA

Professional Activities

Vice-chairman of Electrical Fire Protection Committee, CFPA (2021~)
Vice-Presidents of Asia-Oceania Association for Fire Science and Technology (2007~2020)
Committee Member of the International Association for Fire Safety Science (2008~2017)
Committee Member of the National Science and Technology Award (2010~)
Vice-chairman of Chemical Safety Committee, CIESC (2017~)
Vice-chairman of Building Fire Protection Committee, CFPA (2008~2022)
Experts of the first national emergency response expert group for work safety (2015~)
Experts of the fifth national work safety expert group (2014~)
Academic Committee Member of University of Science and Technology of China (2009~)
Safety expert committee Anhui Province, Civil blasting group leader (2009~)
Member of Science and Technology Award Committee, Ministry of Public Security (2007~)
Member of Academic Committee of urban safety and disaster prevention, Urban Planning Society of China (2005~2015)
Evaluation expert in international scientific and technological cooperation program, Ministry of Science and Technology of China (2005~)
Executive director of Anhui Fire Protection Association (2005~)
Associate Editorial or Editorial Board of six International Journals (2010~)
Editorial Board of nine national Journals (2003~)
Academic Committee Member of China Fire Protection Association (2003~2020)

Honors and Awards

Fellow of The Combustion Institute (2023)

Model Research Worker Award, Anhui Province, China (2022)
Science and Technology Award, Second-class Award, Anhui Province (2022)
Moral Model of Teacher Award, Anhui Province, China (2021)
Lifetime Contribution Award of AOAFST (2021)
Science and Technology Progress Award, First-class Award, CAPS (2021)
Special government allowance of the State Council, The State Council of the P. R. China (2019)
Science and Technology Innovation Award, First-class Award, CFPA (2018)
Science and Technology Progress Award, First-class Award, China Highway and Transportation Society (2018)
Zhu Li Yuehua excellent teacher Award, Chinese Academy of Sciences (2017)
Excellent graduate student supervisor Award, Chinese Academy of Sciences (2017)
Zhu Li Yuehua excellent teacher Award, Chinese Academy of Sciences (2014)
Excellent graduate student supervisor Award, Chinese Academy of Sciences (2014)
Teaching Award of Anhui Province, First-class Award, Anhui Province (2010)
Beijing Science and Technology Award, Third-class Award, Beijing (2008)
Science and Technology Award for Young Scientist, Anhui Province (2006)
Safety Science and Technology Award of State Administration of Work Safety, Second-class Award (2006)
National Science and Technology Progress Award, Second-class Award, China (2006)
Outstanding Member of Hundred Talent Program, Chinese Academy of Sciences (2005)
Member of Hundred Talent Program, Chinese Academy of Sciences (2001)
National Science and Technology Progress Award, First-class Award, China (1993)

Professor Sun Jinhua has long been devoted to academic research and education in the area of fire science and fire protection. He has made substantial accomplishments in a number of fields in fire safety science and engineering, including fire risk assessment, performance-based fire protection design, building fire safety, industrial fire safety, fire safety in new energies. He led as a PI more than 20 important national research projects, such as the National "973 Program", key projects funded by National Natural Science Foundation of China (NSFC), the "11th Five-Year plan" and the "13th Five-Year Plan" national key R&D program, the sixth Framework Project of the EU International Cooperation Program in Science and Technology, general projects of NSFC, and "Outstanding Talents" project funded by the Chinese Academy of Sciences.

Prof. Sun has published more than 430 papers in peer-reviewed journals, including Progress in Energy and Combustion Science, Combustion and Flame, Renewable and Sustainable Energy Reviews, et al, which have been cited more than 15,000 times (Web of Science). Contributions have also been recorded in 11 academic books or book chapters and over 50 keynote or invited talks at national or international conferences. In addition, Prof. Sun has supervised near 60 PhD students.

Major Research Areas

1. Theories and methods of fire prevention for new energies
2. Methods for fire risk assessment and safety design of buildings and urban areas
3. Theory of fire dynamics, fire prevention and control for buildings
4. Industry fire dynamics and fire prevention

Selected Publications in 2023

1. **Wenxin Mei, Zhi Liu, Chengdong Wang, Chuang Wu, Yubin Liu, Pengjie Liu, Xudong Xia, Xiaobin Xue, Xile Han, Jinhua Sun, Gaozhi Xiao, Hwa-yaw Tam, Jacques Albert, Qingsong Wang, Tuan Guo, Operando monitoring of thermal runaway in commercial lithium-ion cells via advanced lab-on-fiber technologies, Nature communications, (2023) 14:5251**

Operando monitoring of complex physical and chemical activities inside rechargeable lithium-ion batteries during thermal runaway is critical to understanding thermal runaway mechanisms and giving early warning of safety-related failure. However, most existing sensors cannot survive during such extremely hazardous thermal runaway processes (temperature up to 500 °C accompanied by fire and explosion). To address this, we develop a compact and multifunctional optical fiber sensor (12 mm in length and 125 μm in diameter) capable of insertion into commercial 18650 cells to continuously monitor internal temperature and pressure effects during cell thermal run-away. We observe a stable and reproducible correlation between the cell thermal runaway and the optical response. The sensor's signal shows two internal pressure peaks corresponding to safety venting and initiation of thermal runaway. Further analysis reveals that a scalable solution for pre-dicting imminent thermal runaway is the detection of the abrupt turning range of the differential curves of cell temperature and pressure, which corresponds to an internal transformation between the cell reversible and irreversible reactions. By raising an alert even before safety venting, this new operando measurement tool can provide crucial capabilities in cell safety assessment and warning of thermal runaway.

2. **Zesen Wei, Chen Liang, Lihua Jiang, Mei Sun, Siyuan Cheng, Linjun Wang, Shiyao Chen, Zheng Fang, Yuxuan Li, Ningjie Zhang, Qingkui Peng, Xiangdong Meng, Wenhua Zhang, Jinhua Sun, Qingsong Wang, Probing the thermal degradation mechanism of polycrystalline and single-crystal Li(Ni0.8Co0.1Mn0.1)O2 cathodes from the perspective of oxygen vacancy diffusion, Energy Storage Materials, 56(2023) 495-505**

The Ni-rich cathode is one of the most promising materials for application in high-energy-density lithium-ion batteries. However, the inherent thermal instability of this material raises the risk of thermal runaway, which presents a significant obstacle to its eventual commercialization. At present, the in-depth mechanism of how grain structure affects the thermal stability of Ni-rich cathodes remains unclear. In this work, we study the thermal degradation behavior of polycrystalline and single-crystal NCM811 cathodes from multiple dimensions based on a series of state-of-the-art physicochemical characterization tools combined with theoretical calcula-tions, report different degradation pathways of polycrystalline and single-crystal cathodes, and investigate the enhancement mechanism of single-crystal structure on the thermal stability of cathodes from the atomic scale. The larger grain size and better integrity of single-crystal NCM811 particle effectively retard the oxygen vacancy formation and increase oxygen vacancy diffusion paths at high temperatures. As a result, the diffusion of oxygen vacancies is kinetically unfavorable during heating, which delays the degradation of its lattice structure and the release of oxygen. This work provides insight into the thermal failure mechanisms of Ni-rich cathode materials with different grain structures and offers an essential theoretical basis for designing future thermally stable cathode materials.

3. **Qiangling Duan, Huiqi Cao, Xiaoxi Li, Jinhua Sun, Effects of urea on the thermal decomposition behavior of ammonium nitrate: A reliable thermal safety performance enhancer, Process Safety and Environmental Protection, 171 (2023) 482-492**

To address the actual disaster of thermal decomposition and explosion of ammonium nitrate (AN), a commonly used raw material, urea was selected as an additive to study its effect on the thermal decomposition of AN through experimental and theoretical methods. The thermal decomposition kinetics, energy release, self-reaction properties of adiabatic environments, and escaping gaseous products have all been discussed. It was found that urea has an inhibitory effect on the crystalline transformation of AN stored at room temperature, which is beneficial to its thermal safety. The results showed that urea increased the activation energy of the thermal decomposition of AN, raised the temperature of the initial reaction and reduced heat generation. Furthermore, the action mechanism of urea is suggested to be heat absorption by its thermal decomposition and the escape of ammonia. Finally, the study carried out an engineering assessment of the thermal safety of AN under the action of urea and found that the addition of urea greatly enhanced the thermal safety performance of stored and transported AN. The comprehensive analysis concluded that a small dose of urea could be added to enhance the thermal stability of AN without affecting its normal function.

4. **Manman Zhang, Yu Wang, Mi Li, Fuhai Gou, Jinhua Sun, Experimental investigation of downward discrete flame spread of the thermoplastic material in exterior insulation walls: melt-flowing and dripping, Fire Safety Journal, 136(2023)103754**

Discrete flame spread, accompanied with melt-flowing and -dripping behaviors, significantly increases fire hazards of thermoplastic materials in exterior insulation walls. The movement of melt-burning combustible materials brings rigorous challenges to the current fire protection system but has not been sufficiently studied. Thus, two modes of bench-scale experiments, covering melt-flowing and melt-dripping, have been conducted to explore the basic knowledge and threshold of melting-dominant discrete flame spread. The typical thermoplastic material in the exterior thermal insulation system, expanded polystyrene foam (EPS), was selected as the research objective. For melt-flowing dominant flame propagation, a critical fuel coverage (f = 0.40–0.50) when a barrier prevented molten flows was determined experimentally, and a dimensionless analysis was conducted to clarify the downward flowing stages. For dripping-dominant flame propagation, a threshold diameter for ignition (13.3 mm) was obtained via comparing burning time and ignition time without the impact of dripping height. Then, the influence of dripping height on the critical ignition diameter was investigated by coupling with the established theoretical dripping acceleration. This work attempts to provide a reference for enhancing fire protection in building exterior walls.

New Investigations in Atmospheric Propagation & Microwave Biophysics

by André Vander Vorst, Member EUAS

Short Biography

André Vander Vorst was born in Brussels in 1935. At high school, he studied classical humanities, including Latin and Greek. He graduated in 1958 as an electrical and mechanical engineer at the UC Louvain (UCL), Belgium, from which he received his Doctoral degree in 1965. During his thesis he spent two times six weeks working at Philips Natuurkundig Laboratorium, Eindhoven, The Netherlands. As a research associate, he was at M.I.T 1964-1965 where he earned a M.Sc. degree in microwaves, and at Stanford University 1965-1966, both years in radioastronomy. Back in Belgium in 1966, he founded the Microwave Laboratory at UCL, which he headed for 35 years. His research interests were successively loaded waveguides and cavities, atmospheric propagation up to 300 GHz, opto-microwaves, humanitarian demining, and bio-microwaves. He has been teaching in four Belgian Universities on electromagnetics, transmission lines, and microwaves. He also taught analogue and hybrid computation, antennas, and microwave satellite communications. He supervised 27 doctoral theses and about 200 engineer's theses.

Prof. Vander Vorst has authored and co-authored seven books, a number of book chapters, and 400 papers in peer-reviewed journals and conference proceedings. His last book, RF/Microwave Interaction with Biological Tissues, with A. Rosen and Y. Kotsuka as co-authors was published in 2006 by Wiley, U.S.A. He recently co-authored papers on various websites on the 5G, the effect of electromagnetics on viral infections, and electro-hypersensitivity and how to cure it. He has written chapters on bioelectromagnetics in a collective book investigating electro-hypersensitivity and papers on the same subject.

Through his academic career at UCL, Prof. Vander Vorst has been Head of EE Department 1970-1971, Dean of Engineering 1972-1975, Vice-President of the Academic Council 1973-1975, and President of the Open School in Economic and Social Politics 1973-1987.

Over the last 60 years, Prof. Vander Vorst has been actively involved in developing the international microwave community. In 1967-2001 he was chairing Student Activities Committee and Educational Activities Committee and setting up Chapter Coordination Committee in I.E.E.E. Region 8. He was a corresponding member of the Organizing Committee of the first European Microwave Conference (EuMC) in London 1969, Chair EuMC Technical Program Committee in Brussels 1973, and Chair EuMC in Liège 1984. He has been a reviewer for every EuMC since 1969. He is a founder member of the European Microwave Association (EuMA) and has been EuMA Secretary General for 18 years. In the latter function he has set up and developed EuMA Headquarters. He is now appointed Secretary Emeritus and Data Protection Officer and is still active with EuMA.

Prof. Vander Vorst also served I.E.E.E. MTT Society, in which he has been active in 1985-2006. He is a Life fellow of the I.E.E.E. He obtained a number of awards including the Microwave Career Award 2004 from I.E.E.E MTT-S, the Distinguished Service Award 2016 from EuMA and the Propagation Award 2019 from the European Association for Antennas and Propagation (EurAAP).

He is an emeritus member of Belgian Academia of Letters and Science, a member of Academia Europaea, the Electromagnetics Academy, and the EU Academy of Sciences. He is an Honorary Member of Belgian National Committee or URSI and of a number of international committees. He has been a member of National Health Council in both Belgium and The Netherlands. He has been cited in a number of Who'sWho.

He loves music and has conducted choirs for more than 40 years.

He has five children, twelve grandchildren and four great-granddaughters.

From 1960 to 1964, André Vander Vorst investigated **fast switching of magnetic cores** for his doctoral thesis. As a research associate with a post-doctoral fellowship, he spent two years in the USA: 1964-1965 at M.I.T. and 1965-1966 at Stanford University in both Laboratories of Radio-astronomy. In 1966, back in Belgium he founded the Microwave Laboratory at the Université catholique de Louvain (UCL). Some typical publications are mentioned in what follows for each research topic mentioned.

He started research on propagation in lossless closed structures at X-band like loaded waveguides and cavities. The first doctoral thesis he supervised in the Laboratory was by F. Gardiol, 1966-1969, who analytically investigated the impact of a one-dimensional inhomogeneity on waveguide propagation [1].

Simultaneously, A. Vander Vorst started developing **numerical analysis for propagation** in diverse inhomogeneously loaded microwave transmission lines by means of variational principles [2]. He produced a numerical version of the variation-iteration method presented by Morse and Feshbach, *Methods of Theoretical Physics*, Part 1 and 2, McGraw-Hill, 1953. In 1969, he obtained the first numerical solution of a second-order partial derivative eigenvalue equation, describing the propagation in a rectangular waveguide loaded by inserts.

A number of doctoral students then investigated the impact of inhomogeneity on miscellaneous propagating structures, like microstrips, fin lines, and p-i-n transmission lines, as well as opto–induced effects on transmission lines [3]-[8].

This research ended up with propagation on lossy distributed structures at frequencies up to 100 GHz. In 2002, he co-authored a research book on variational principles and distributed circuits [9].

Atmospheric propagation has been a research interest of A. Vander Vorst from 1968 [10] until about 2000. In 1970, he set up two horizontal links at 11.6 and 35 GHz, respectively, operating for a five-year period [11]. This has been the subject of the first of his five consecutive COST projects on atmospheric propagation, covering both horizontal links and slant paths.

He was the Belgian participant to the Orbital Test Satellite (OTS) of the European Space Agency (ESA), 1978-1983. For this, he obtained significant funding from the Belgian State (equivalent to 5 million EUR at today's value) to obtain one transmitting-receiving fixed television station at 14 GHz (up, 2 kW) and 11 GHz (down), as well as two receiving stations at 11 GHz, one fixed and one mobile [12]-[14].

He has been the Belgian participant to the ESA Olympus experiment, 1988-1993, and obtained significant funding from the Belgian State and PTT Department, respectively, to set up two receiving stations at 12.5 and 30 GHz and 12.5 and 20 GHz in both polarisations at both frequencies, respectively. Measurements made at Louvain-la-Neuve included attenuation, depolarisation and scintillation at 12.5 and 30 GHz and radiometry in two polarisations at 12 and 35 GHz [15]. Fast measurements were available, every 34 ms, especially in view of investigating the time scale of the scintillation effects.

These experimental tools stimulated original atmospheric propagation investigations in theory, experiment, and simulation as well. With the OTS stations, the Laboratory has been one of the three research centres to experimentally point out the microwave scintillation phenomena, extensively investigated by several PhD students in their doctoral thesis and later.

Site-shielding, specifically by a knife-edge obstacle, has been investigated with measurements from 8 to 94 GHz [16]. The research then evaluated the bit-error rate prediction of atmospheric communications links [17]. It continued until the year 2000 with the evaluation of some special effects related to the structure of linearly tapered slot

antennas including the Vivaldi antenna, up to some tens of GHz [18].
A. Vander Vorst conducted research on atmospheric propagation of EM waves at frequencies up to 300 GHz [19]. He has been involved in EM wave propagation since 1960, start of his doctoral thesis, until the end of his active professional career.

Microwave biophysics has been another subject of interest of A. Vander Vorst. The project started at the end of the 70s by designing and implementing a system for eliminating bacteria in air by microwave heating, to proceed to open air medical surgeries. This system was patented and commercialized.

Experimental work has been going on with rabbits from 1987 through 1994, for a doctoral thesis on three experimental steps.
The first was devoted to developing a microwave acupuncture method by inserting a miniature cable into acupuncture points and exciting these by injecting microwaves in the cable, offering a quantitative method for measuring analgesia. The purpose was to excite the nervous system in some specific points for detecting an analgesic effect. Results were positive [20].

The second consisted of the development of a method to measure the effect of analgesia in the cervical centre of pain [Fig. 1]. This showed that by doing so the composition of the cervical liquid in the pain centre was modified similarly to what is obtained when ingesting analgesic products [21].

In the third step, a method was developed for measuring in the cervical centre of pain the effect of an electric impulse applied to a rabbit's foot in both the absence and presence of analgesia produced by microwave acupuncture. Simultaneously, the deformation of the impulse was measured on the nervous system and in particular the spinal cord, by inserting a microwave micro-antenna inside of the backbone [22], looking for a non-thermal microwave effect. The result was negative [23].

Fig. 1. Measuring pain threshold on a rabbit as a function of antalgic microwave acupuncture

A cooperation went on with colleagues of the UCL School of Medicine in the years 1993-1997 to evaluate the effect of magnetic induction produced by a coil implanted on a mouse for obtaining a muscular reinforcement. The result was positive [24].

Dielectric parameters and blood absorption have been measured from 2 to 110 GHz [25] and a review of microwave effects on nervous system and nervous fibre has been performed [26].

Research has then been more oriented toward biological effects and medical applications [27] and more specifically to **biological effects on living systems and especially human beings** [28]. Face heating at the occasion of a telephone conversation has been measured in direct view of a base station, on stairs and in the basement of a building, respectively, with the measurement of an increase of 0.7°C after 10 minutes in the basement [29].

Specific very low frequency magnetic field measurements have been made on spontaneous bioelectric activity of neurons [30] while dielectric absorption microwave power has been evaluated at the scale of nucleic acids [31].

Microwave exposure of rats has been prepared, performed and evaluated from 1998 through 2009, for another doctoral thesis. Rats were submitted to a microwave level corresponding to the calculation by WHO of the limit for the human being, taking into account however a factor 10 for difference of length between the human being and the rat. The exposure duration has been long: 2 hours per calendar day of 70% of the rat lifetime which was 30 months. There were four groups of 31 rats, including three groups exposed to three different microwave schemes, respectively, and one sham-exposed group, with in particular exposure to 970 MHz CW. Fifteen blood parameters were analysed 6 times on the 124 rats, yielding more than 10.000 biological data, together with behavioural effects and mortality. A combination of positive and negative results has been obtained on monocytes, behavioural effects, and mortality, respectively [32][33].

Planar antennas have been designed and evaluated in view of medical applications, from 2005 through 2013, being mainly the subject of a doctoral thesis. This necessitated the evaluation of a radiating structure, the operating frequencies, the influence of the substrate on the resonance frequencies of the antenna and their bandpass, the power necessary for medical applications, and mutual coupling between the elements [34].

A number of presentations have been made in medical symposia [35]. At the request of Wiley, a research book *RF/Microwave interaction with biological tissues* was published by Wiley U.S. in 2006, with A. Vander Vorst, A Rosen and Y. Kotsuka as co-authors, and with PhD students as a prime target [36]. During the last five years, A. Vander Vorst co-authored papers on various websites on 5G, on the effect of electromagnetics on viral infections, and on electro-hypersensitivity. He wrote chapters on bioelectromagnetics (em) and bioelectromagnetic interaction with the human body in a collective book investigating **electro-hypersensitivity** (EHS) [37]. He is a co-author of a review paper on the importance of molecular biomarkers and imaging in the study of EHS [38]. Over the last years, he co-authored about fifteen letters concerning em in hospitals on one hand [39] and on em interaction with the human body on the other [40].

Selected Publications

[1] Gardiol F., Vander Vorst A., "Wave propagation in rectangular waveguide loaded with an H-Plane dielectric slab", *IEEE Trans. Microwave Theory Tech.*, vol. MTT-17, January 1969, pp. 56-57

[2] Vander Vorst A., Govaerts R., "Application of a Variation-Iteration method to inhomogeneously loaded waveguides", *IEEE Trans. Microwave Theory Tech.*, vol. 19? March 1971, pp. 322-331

[3] Decreton M., Loute E., Vander Vorst A., Gardiol F., "Computer optimization of E-plane resonance isolators", *IEEE Trans. Microwave Theory Tech.*, vol. MTT-19, March 1971, pp. 322-331

[4] Cermak I., Getsinger W., Leake B., Vander Vorst A., Varon D. "The status of computer-oriented

microwave practices", *IEEE Trans. Microwave Theory Tech.*, vol. 22, March 1974, pp. 229-237 (*invited paper*)
[5] Kezai T., Vander Vorst A. "Modelling resonance in waveguide-to-microstrip junctions by unilateral fin line resonators", *IEEE Trans. Microwave Theory Tech.*, vol. 42, n° 2, February 1994, pp. 223-236
[6] Aksas R., Vander Vorst A., "Transverse conduction current and radiation pattern of an arbitrary shaped symmetrical patch antenna coupled with a director", *Microwave Optical Technology Lett.*, November 1994, vol. 7, n° 16, pp. 737-739
[7] Zhu Z., Vander Vorst A., "Microwave propagation in p-i-n transmission lines", *Microwave and Guided Waves Letters*, MTT-IEEE, vol. 7, n° 6, June 1997, pp. 159-161
[8] Serres M., Huynen I., Vander Vorst A., "Wideband photo-induced carriers at the end of an open-ended microstrip line", *IEEE J. Sel. Topics Quantum Electr.*, vol. 4, n° 6, November-December 1998, pp. 948-952
[9] Vander Vorst A., Huynen I., *Variational Principles and Distributed Circuits*, Research Studies Press, Baldock, United Kingdom, 2002, 318 p.
[10] Benoit A., Godfroid H., Mertens H., Vander Vorst A., "Study of the satellite/Earth station/domestic receiver chain in a satellite system for television distribution", *Proc. IEE*, November 1969, pp. 1797-1806
[11] Vander Vorst A., Gaudissart E., "Effects due to precipitation on horizontal links", *Proc. Symp. AGARD*, Gausdal, September 1972, pp. 14/1-6
[12] Vander Vorst A., "Cross-polarization on a terrestrial path", *Alta Frequenza*, English edition, vol. 48, no 4, April 1979, pp. 201-209
[13] Vanhoenacker D., Vander Vorst A., "Experimental evidence of a correlation between scintillations and radiometry at centimeter and millimeter wavelength", *IEEE Trans. Antennas Propagation*, vol. AP-33, January 1985, pp. 40-47
[14] Vander Vorst A., "Atmospheric and sea-surface effects from 30 to 300 GHz", *Revue HF*, vol. XIII, n° 3, 1985, pp. 67-75
[15] Vanhoenacker D., Vasseur H., Vander Vorst A., « Limitations de la largeur de bande dues aux phénomènes atmosphériques sur des liaisons spatiales de 10 à 300 GHz », *L'Onde Electrique*, vol. 72, mai-juin 1992, n° 3, pp. 35-38
[16] Vyncke C., Vander Vorst A., "A new approximate formula for site-shielding by a knife-edge obstacle, based on measurements from 8 to 94 GHz", *Microwave Optical Technology Lett.*, June 1995, vol. 9, n° 4, pp. 210-214
[17] Vander Vorst A., Vasseur H., Vyncke C., Amaya-Byrne C., Vanhoenacker-Janvier D., "From electromagnetics to system performance: a new method for the error rate prediction of atmospheric communications links", *IEEE J. Selected Areas in Communications*, Vol. 15, N° 4, May 1997, pp. 656-666
[18] Stockbroeckx B., Vander Vorst A., "Copolar and cross-polar radiation of Vivaldi antenna on dielectric substrate", *IEEE Trans. Antennas Propagation*, Vol. 48, n° 1, Jan. 2000, pp. 19-25
[19] Vander Vorst A., Vanhoenacker D., "Propagation limitations for transionospheric systems from 10 to 300 GHz", *AGARD*, Paris, Rome, Boston, LSP-172, June 1990, pp. 3.1-19 (*invited paper*)
[20] Teng J., Vanhoenacker D., Vander Vorst A., "Biological effects of microwaves in acupuncture", *Proc. Eur. Microwave Conf.*, London, September 1989, pp. 918-923
[21] Teng J., Yan H., Vanhoenacker D., Vander Vorst A., "Variations of pain threshold and norepinephrine release in rabbits due to microwave stimulation", *Proc. Microwave Theoty Tech. Symposium IEEE*, Boston, June 1991, pp. 801-804
[22] Teng J, Yan H., Vanhoenacker D., Vander Vorst A., "Inhibition of the nociceptive response of the parafascicular nucleus, due to microwave irradiation on spinal cord in rabbits", *Proc. Eur. Microwave Conf.*, Stuttgart, September 1991, pp. 1438-1443
[23] Teng J., Carton de Tournai D., Duhamel F., Vander Vorst A., "No nonthermal effect observed under microwave irradiation of spinal cord", *IEEE Trans. Microwave Theory Tech.*, Vol. 44, n° 10, October 1996, pp. 1942-1948
[24] Isac M., Marechal G., Vander Vorst A., Veraart C., Moens P., "Transformations in mouse soleus induced by chronic stimulations", *Journal of Muscle Research and Cell Mobility*, n° 15, August 1994, pp. 177-178
[25] Duhamel F., Huynen I., Vander Vorst A., "Measurements of complex permittivity of biological and organic liquids up to 110 GHz", *IEEE MTT-S Int. Microwave Symp.*, Denver, June 1997, Vol. I, pp. 107-110
[26] Vander Vorst A., Duhamel F., "1990-1995 Advances in investigating the interaction of microwave fields with the nervous system", *IEEE Trans. Microwave Theory Tech.*, Vol. 44, n° 10, October 1996, pp. 1898-1909
[27] Rosen A., Stuchly M., Vander Vorst A., "Applications of RF/Microwaves in medicine", *IEEE Trans. Microwave Theory Tech.*, 50th Anniversary Special Issue, vol. 50, no 7, Nov. 2002, pp. 963-974 (*invited paper*)

[28] Vander Vorst A., Stuchly M., "Impact of mobilophony", *Proc. Workshop II, Eur. Microwave Conf.*, Jerusalem, September 1997, pp. 97-123
[29] Taurisano M., Vander Vorst A., "Experimental thermographic analysis of thermal effects induced on a human head exposed to 900 MHz fields of mobile phones", *IEEE Trans. Microwave Theory Tech.,* Special Issue, vol. 48, no 11, Nov. 2000, pp. 2022-2032
[30] Azanza M., Pérez Bruzon R., Lederer D., Calvo A., del Moral L., Vander Vorst A., "Reversibility of the effects induced on the spontaneous bioelectric activity of neurons under exposure to 8.3 and 217.0 Hz low intensity magnetic fields" *Proc. 2nd Intl. Workshop Biol. Eff. Electrom. Fields*, Rhodes, octobre 2002, pp. 651-659
[31] Vanderstraeten J., Vander Vorst A., "Theoretical evaluation of dielectric absorption of microwave energy at the scale of nucleic acids", *Bioelectromagnetics*, 25 :380-389 (2004).
[32] Adang D., Campo B., Vander Vorst A., "Has a 970 MHz Pulsed Exposure an Effect on the Memory Related Behaviour of Rats?", *Eur. Conference Wireless Technologies 2006*, Manchester, Sept. 2006, Session ECWT08, pp. 135-138
[33] Adang D., Remacle C., Vander Vorst A., "Results of a Long-Term Low-Level Microwave Exposure of Rats", *IEEE Trans. Microwave Theory Tech.,* vol. 57, No. 10, Oct. 2009, pp. 2488-2497
[34] Halheit H., Vander Vorst A., Tedjini S., Touhami R., "Flexible Dual-Frequency Applicator for Local Hyperthermia", *Int. J. of Antennas and Propagation*, vol. 2012, Article ID 389214, 7 pages, Hindawi Publishing Corporation
[35] Vander Vorst A., "Effets des champs micro-ondes sur les organismes vivants", *Congrès Médecine environnementale*, AMSES, La Martinique, 10 novembre 2015, 47 pages (*invited paper*)
[36] Vander Vorst A., Rosen A., Kotsuka Y., *RF/Microwave Interaction with Biological Tissues*, Wiley USA, 2006, 300 p.
[37] Belpomme D., Cachard O., Huss J., Irigaray Ph., Lafforgue F., Ledoigt G., Le Ruz P., Vander Vorst, A. "Ce que sont en réalité les ondes électromagnétiques" with P. Leruz and "Comment les champs électromagnétiques interagissent avec notre corps" in *Le Livre Noir des Ondes*, Marco Pietteur, 2021, 416 pp., ISBN 978-2-87434-184
[38] Belpomme D. *et al*, Vander Vorst A., "The Critical Importance of Molecular Biomarkers and Imaging in the Study of Electrohypersensitivity. A Scientific Consensus International Report" *Int. J. Mol. Sci.*, 2021, *22*, 7321.
[39] Lintermans J., Vander Vorst A., "Effets des champs électromagnétiques en milieu hospitalier", *Neutone*, Vol. 26, 2021, no.1, p. 35-39
[40] Lintermans J., Vander Vorst A. "Vitamine E et dysfonctionnement de la barrière hémato-encéphalique chez les EHS", *LinkedInPost*, Aug. 13, 2021, *Mieux Prévenir*, Sept. 5, 2021

Static and Seismic Design of Bata Quay Wall

by Pedro Pinto, Member EUAS

Short Biography

***Education**: Licentiate in Civil Engineer (6 years course,1965-1971) (with honors); from 1971 to 1975 worked with Industry; Master of Engineering (1975 – 1977) (with high honors); 1977-1978 – Fulbright scholarship granted by USA with training periods in MIT (Boston, USA), United States Bureau of Reclamation (Denver), and University of California (Berkeley); Specialist in Geotechnique (Ph.D Degree) 1979 - 1983 (with high honors); from 1992 – Director of Research (Full Professor degree) (with high honors).*

ISSMGE Appointed ISSMGE Board member (2017-2022), and before Immediate Past President (2009-2013), President (2005-2009), Vice President for Europe (2001-2005) and Chairman of TC4 "Earthquake Geotechnical Engineer Committee" (1994-2000).

***Positions:** President of Scientific Committee of XVII ECSMGE (2024),*
- Member of the European Academy of Sciences
- Fellow of Portuguese Institute of Engineers
- Research Director of LNEC (currently retired)
- Full Professor of Geotechnical Engineering of University of Coimbra (currently retired),
- World Bank Consulting for Dams Safety (2013-2015),
- Invited Professor of Master Courses "Soil Mechanics" and "Engineering Geology" of New University of Lisbon (1983-1995),
- United Nations Consulting for Design and Instrumentation for Dams (1988-1992).
- Invited Guest Lecturer of University of California, USA (1992-1994).
- President of Portuguese Society for Geotechnique (1996- 2000).

***Professional Experience**: Pedro Sêco e Pinto is a Consulting Engineer and has participated in more than 450 major projects in Dams, Power plants, Bridges, Tunnels, Landslides and Quay Walls, in Portugal, Angola, Argelie, Brazil, Cabo Verde, China, Dominican Republic, Ecuador, Guine- Bissau, Guine Ecuatorial, India, Lebanon, Malawi, Morocco, Mozambique, Senegal, Syria, Tunisia, Uganda, Venezuela and Zambia, covering field and laboratory testing, dynamic analyses, earthquake engineering, numerical analyses, ground improvement, slopes, special foundations, instrumentation and safety evaluation.*

***Lectures**: He has presented more than 350 State-of-the Art Lectures and Special Lectures in 80 countries of the 5 Continents.*

***Awards**: Pedro Sêco e Pinto has received more than 50 international Awards including 3rd Victor de Mello Lecture, 3rd Braja Das Lecture, American Biographical Institute USA, "Special Volume for the Contributors of Earthquake Engineering, Nagadi Lecture by Indian Geotechnical Society, Széchy Lecture by Hungarian S M Society and Hungarian Academy of Sciences, Nonveiller Lecture by Croatia Geotechnical Society, Sukle Lecture by Slovenia Soil Mechanics Society, Chin Lecture by Huanzhou University (China), Qian Jia Huan Lecture by Hohai University (China) and Chin Fung Kee Memorial Lecture by Institute of Engineers of Malasia.*

***Journals**: Related his role with Editorial Boards and Reviewer he acted as:*
- Associate Editor of International Journal of Earthquake Engineering (since 2017)
- Editor in Chief of International Journal of Case Histories (2011-2017)
- Co-Editor of Geotechnical and Geological Engineering Journal, Springer Publisher (2005-2011)
- Member of Editorial Board of several Journals, namely: "Geotecnia", "Bulletin of Earthquake Engineering", "Acta de Geotecnia", "International Journal of Geotechnical Engineering" and SEAG Journal.

- Editor of Proceedings of 4 International Conferences.
***Author/Co-Author**: Pedro Sêco e Pinto is author or co-author of 500 Technical and Scientific Reports, more than 180 papers for national and international conferences and journals and has contributed for 13 books.*

Abstract

The static and seismic design of Bata Quay Wall composed by 30 caissons with size 16.95 m x 24.90 m and located in Guinea Equatorial is discussed.

Key Words: Quay Walls**,** Modelling, Analysis, Liquefaction

1. Introduction

The static and seismic design of Bata Quay Wall composed by 30 caissons with size 16.95 m x 24,90 m and located in Guinea Equatorial is discussed.

2. Bata Quay Wall Design

2.1 *Introduction*

The Bata quay wall located in Guinea Equatorial is composed by 30 caissons with size 16.95 m x 24,90 m and the caissons are founded in rockfill materials of 1/100 Kg with a thickness of 5/6 m, and the foundation soil will be reinforced by vibrocompaction to reach an allowable stress of 300 kPa (Figures. 1 and 2).

The caissons are divided into cells with size of 4.50 m x 3.50 m, filled by granular material (ballast).

The bottom level of the caisson is –10.55 m (ZH) and the caissons with a total height of 13.25 m, will give a work platform at level 2.70 m, for the construction of the superstructure.

After an evaluation of the results of the field tests and the laboratory tests, the geotechnical characteristics were defined.

The static design of quay wall has followed the Eurocode 7 and so ultimate limit states as well serviceability limit states were analysed.

The SLOPE W code was used to define the minimum safety factor for different scenarios of water level and so to analyse by pseudo-static methods different levels of seismic actions.

To verify serviceability limit states stress-strain analyses by SIGMA code were performed. In these analyses all the steps of construction phase were simulated.

Due to the low degree of compaction of foundations sandy materials and the risk of liquefaction, a treatment by vibroflotation was performed.

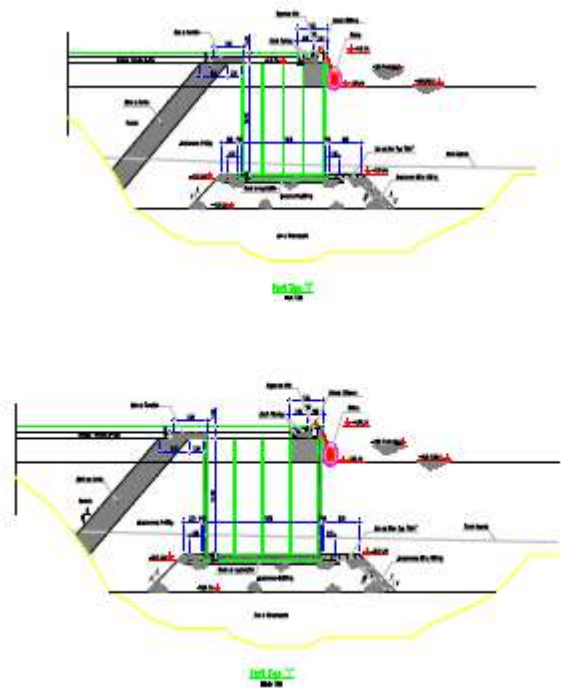


Figure 1. Quay wall profile

The caissons of the quay wall were monitored to compare the observed displacements with the predicted values by analyses

2.2 *Main Geological Characteristics*

In this section the main geological characteristics of each layer are presented, based on the information collected from borings (Etermar, 2006).

The boreholes lengths have varied between 13.57 m and 19.60 m and the SPT tests were performed 1.5 m apart.

Undisturbed samples were taken to perform triaxial tests (type CU-consolidated undrained) and oedometer tests.

In addition, some inspection trenches were opened in the north breakwater.

Alluvial materials are composed by:

i) Sandy materials with 7.5m of thick
ii) Silty materials with 4 to 5m thick.
iii) Clay with sands and gravel with 10 m thick.

2.3 *Geotechnical Characteristics*

After an evaluation of the results of the field tests and the laboratory tests, the following geotechnical characteristics were adopted:

i) Sandy materials

Cohesion c = 0

Friction angle $\phi = 32^{o}$
Elasticity modulus: 18 to 22 MPa
SPT values between 22 to 28 blows.
ii) Silty materials
Cohesion c= 10 kPa
Friction angle $\phi = 28^{o}$
Elasticity modulus: 8 to 16 MPa.
iii) Clay with sands and gravel
Cohesion c= 0
Friction angle $\phi = 28\text{-}32^{o}$
Elasticity modulus: 15 to 20 MPa.

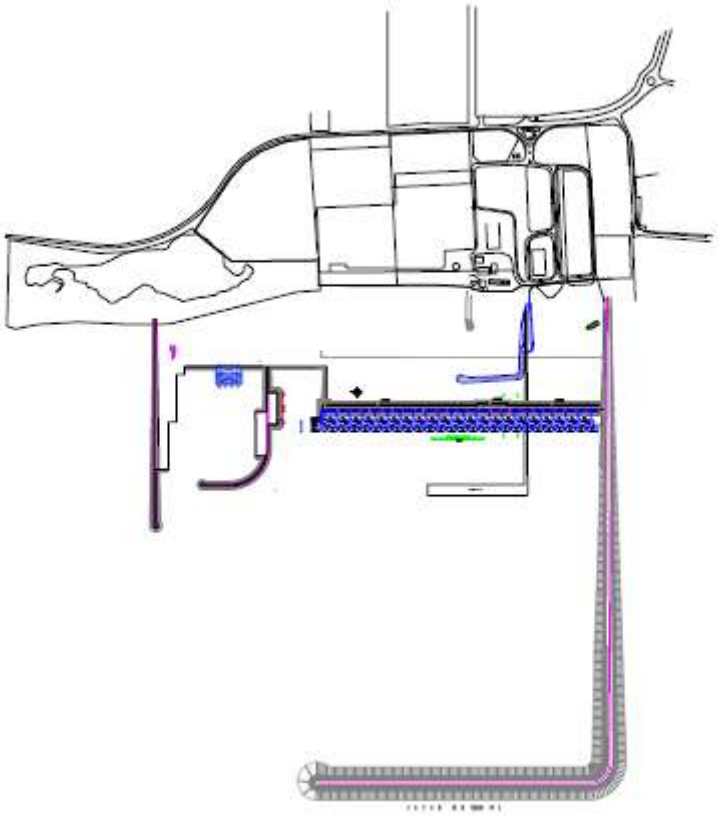


Figure 2. Quay wall plan

2.4 *Design Situations*

2.4.1 *Static Analysis*

The quay wall was designed taking into consideration limit states (Eurocode 7, 1997).

The following ultimate states (with severe consequences) can occur: (i) loss of overall stability; (ii) failure of a structural element such as the retaining wall, an anchorage, a micropile, etc; (iii) foundation failure; (v) unacceptable leakage through or beneath the wall; (v) rotational failure; (vi) movements of the retaining structure which may cause collapse of other structures; (vii) unacceptable change to the flow of groundwater; and

(viii) failure by sliding at the base of the wall.

The following serviceability limit states (with less severe consequences) can occur:
(i) movements of the retaining structure which may affect the appearance or efficient use of the building and other structures; and (ii) excessive vibrations.

2.4.2 *Seismic Analysis*

For the seismic action the definition of the horizontal seismic coefficient and of the vertical seismic coefficient was based in RSA (1983).

Considering EN 8 (1998 a, b) for the pseudo–static slope analyses the following design seismic inertia forces can be taken:

$F_H=0.5\alpha_{gr}\gamma_f SW/g$ for the horizontal direction (1)
$F_V = \pm 0.5\ F_H$ when the ratio α_{vg}/α_{gr} is greater than 0.6 (2)
$F_V = \pm 0.33\ F_H$ otherwise (3)

where α_{vg} is the applicable design ground acceleration in the vertical direction, α_{gr} is the reference peak ground acceleration for class A ground ratio, γ_f is the importance factor of the structure, S is the soil parameter and W is the weight of the sliding mass.

2.5 *Slope Stability Analyses*

The stability analysis was performed by GEOSLOPE code.

The physical, mechanical and pore pressures properties of the different materials are shown in Table 1.

For the pseudo-static analyses for the seismic coefficient values were considered Kc = 0.14 g and Kc = 0.186 g.

1st Analysis – In this analysis was considered a low sea level and the computed minimum safety factor was 1.589.
In Figure 3 is shown the mesh and the critical failure surface.

2nd Analysis – In this analysis was considered a high sea level and the computed minimum safety factor was 1.626.
In Figure 4 is shown the mesh and the critical failure surface

3rd Analysis – In this analysis was considered a low sea level and a horizontal seismic coefficient of 0.186 g and a vertical seismic coefficient of 0.33 of horizontal coefficient.
The minimum computed safety factor was 1.074.
In Figure 5 is shown the mesh and the critical failure surface.

Table 1. Material Characteristics

Type of material	Unit weigth (kN/ m3)	Cohesion (kPa)	Fiction angle(°)	Surface
Caisson	24	0	45	
Rockfill	23	0	38	1
Vibtrocompacted materials	20	0	32	1
Silty sands	19	0	28	1
Fill materials (lower layer)	18	0	22	1
Fill materials (upper layer)	19	0	25	1
Sandy materials	19	0	30	1

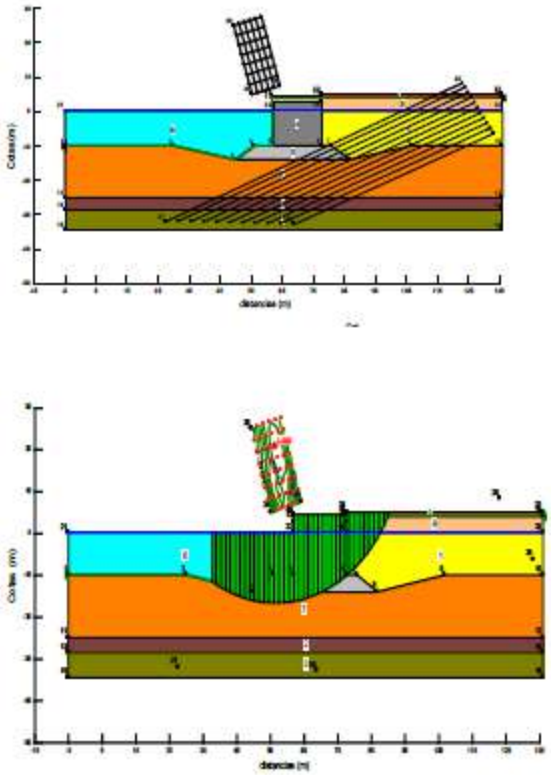


Figure 3. Mesh and critical failure surface

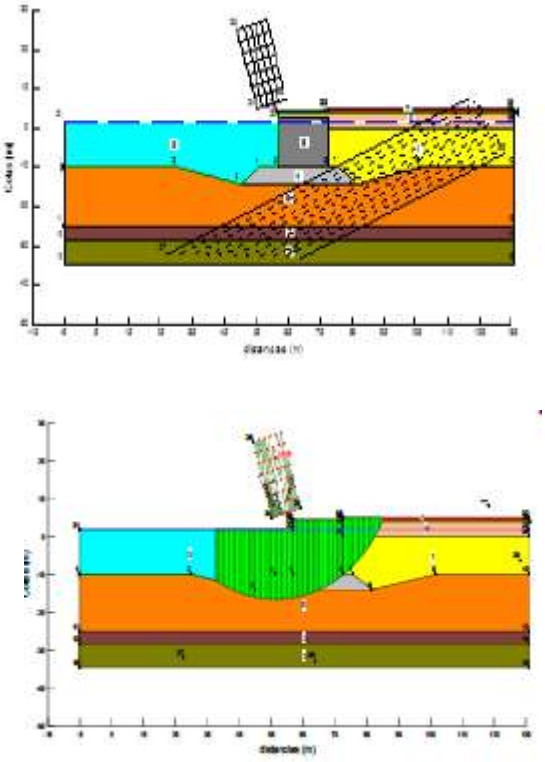


Figure. 4. Mesh and critical failure surface

4th Analysis – In this analysis was considered a low sea level and a horizontal seismic coefficient of 0.14 g and a vertical seismic coefficient of 0.33 of horizontal coefficient. The minimum computed safety factor was 1.161.
In Figure 6 is shown the mesh and the critical failure surface.
5th Analysis – In this analysis was considered a low sea level and a horizontal seismic coefficient of 50% of 0.186 g and a vertical seismic coefficient of 0.33 of horizontal coefficient. The minimum computed safety factor was 1.271.
In Figure 7 is shown the critical failure surface.

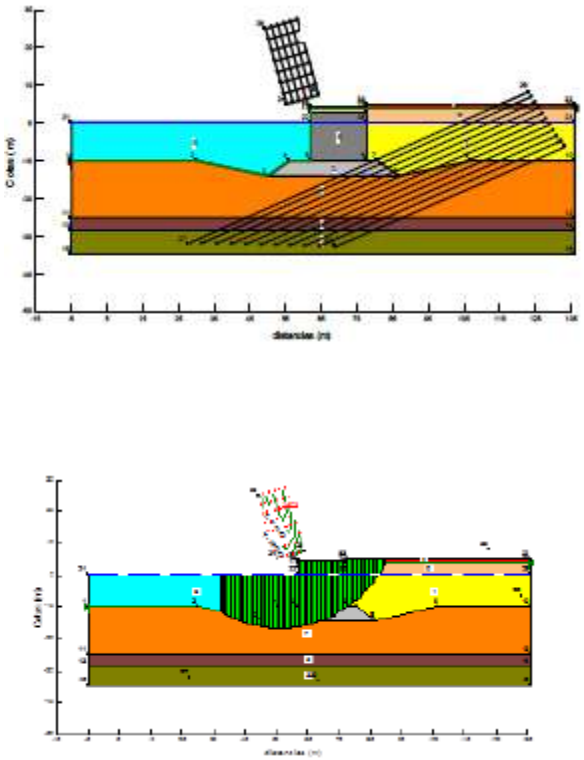


Figure 5. Mesh and critical failure surface

6th Analysis – In this analysis was considered a low sea level and a horizontal seismic coefficient of 50% of 0.14g and a vertical seismic coefficient of 0.33 of horizontal coefficient. The minimum computed safety factor was 1.335.
In Figure 8 is shown the mesh and the critical failure surface

7th Analysis – In this analysis was considered a high sea level and a horizontal seismic coefficient of 0.186 g and a vertical seismic coefficient of 0.33 of horizontal coefficient. The minimum computed safety factor was 1.074.
In Figure 9 is shown the mesh and the critical failure surface

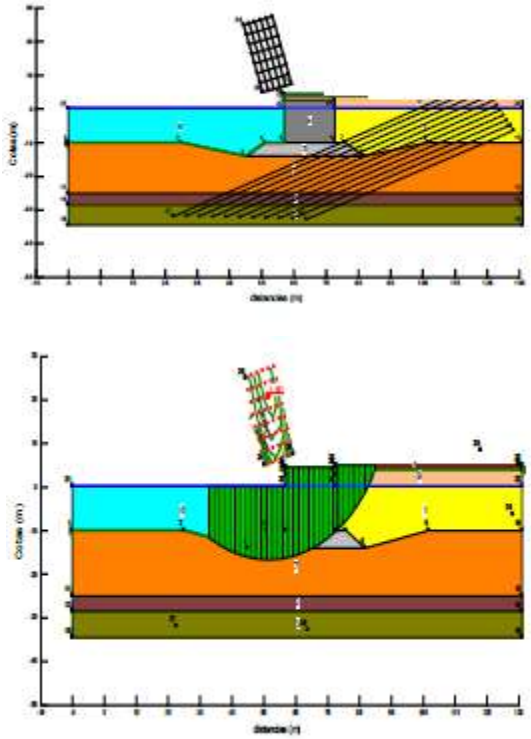


Figure 6. Mesh and critical failure surface

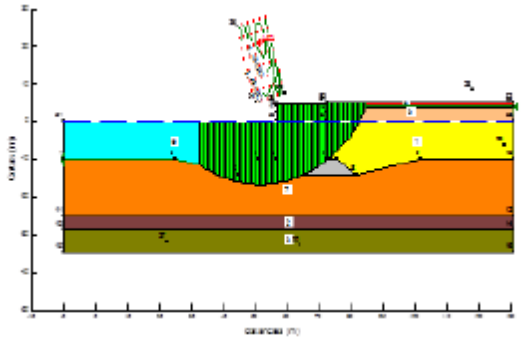
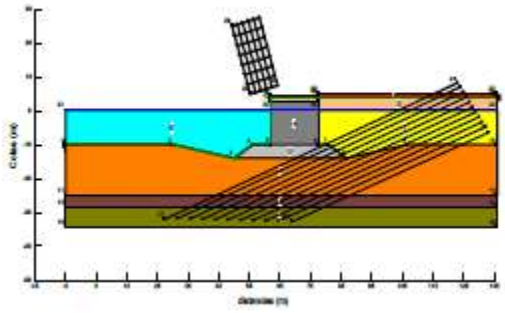


Figure 7. Critical failure surface



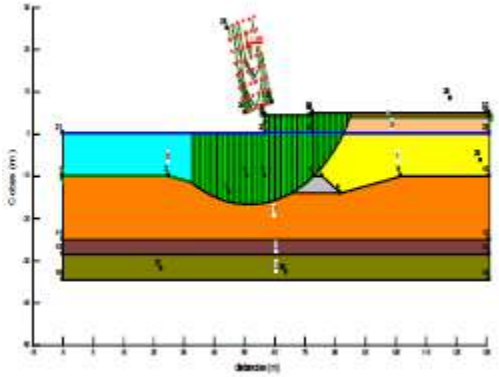


Figure. 8. Mesh and critical failure surface

3. Seismic Shear Stress

The seismic shear stress τ_e can be estimated from the simplified expression:

$\tau_e = 0{,}65\ \alpha_{gr}\gamma_f\ S\ \sigma_{vo}$ (7)

where α_{gr} is the design ground acceleration ratio, γ_f is the importance factor, S is the soil parameter and σ_{vo} is the total overburden pressure.

4. Conclusions

The following conclusions can be drawn:

i) Considering MCE (Maximum Credible Earthquake) = 186 gales (0.186g) and equation (7), a value $\tau/\sigma_0' = 0.242$ is obtained.

For OBE (Operating Design Earthquake) =140 gales (0.14g) a value $\tau/\sigma_0' = 0.182$ is obtained.

ii) The dredging level was -24.50 m (ZH) and the sands were placed above this level and subsequently vibrocompacted. The obtained SPT values for the sands, after vibrocompaction, were between 22 and 28 and after correction $N_1 = 20$ blows.

iii) Considering a value of $\tau/\sigma_0' = 0.242$ and a pourcentage of fines of < 5%, liquefaction can not occured.

iv) Considering a value of $\tau/\sigma_0' = 0.182$ and a pourcentage of fines of < 5%, liquefaction can not occured.

vi) The confining thin layers of soil materials with fines will exhibit a reasonable behavior during the occurrence of earthquakes.

vii) The results of SPT tests, after vibroflotation, have shown an increase of sand compacity.

References

EN 1997 Eurocode 7. Geotechnical design.

EN 1998a Eurocode 8 Structures in Seismic Regions-Design, Part 1 - Section 1 - General information.

EN 1998b Design Provisions for Earthquake Resistance of Structures - Part 5 Foundations, Retaining Structures and Geotechnical Aspects.

ETERMAR (2010) "Calcules de Stabilité et Contraintes –Deformations. Analyse du Potential de Liquefaction"». Septembre.

INA International Navigation Association. 2001. Seismic Design Guidelines for Port Structure. Publisher A. Balkema. 477 pp.

RSA 1983. "Portuguese safety and actions code for buildings and bridges" (in Portuguese).

Robust Inverse Q-Learning for Continuous-Time Linear Systems in Adversarial Environments

by Frank Lewis, Member EUAS

Short Biography

Dr. Frank L. Lewis was born in Würzburg, Germany, subsequently studying in Chile and Gordonstoun School in Scotland. He obtained the Bachelor's Degree in Physics/Electrical Engineering and the Master's of Electrical Engineering Degree at Rice University in 1971. He spent six years in the U.S. Navy, serving as Navigator aboard the frigate USS Trippe (FF-1075), and Executive Officer and Acting Commanding Officer aboard USS Salinan (ATF-161). In 1977 he received the Master's of Science in Aeronautical Engineering from the University of West Florida. In 1981 he obtained the Ph.D. degree at The Georgia Institute of Technology in Atlanta, where he was employed as a professor from 1981 to 1990. He is Moncrief-O'Donnell Endowed Chair Professor of Electrical Engineering at The University of Texas at Arlington.

Lewis is Ranked as number 19 in the world of all scientists in Electronics and Electrical Engineering by Research.com. Ranked number 5 in the world in the subfield of Industrial Engineering and Automation according to a Stanford University Research Study in 2021. Recognized as a Top 1% Highly Top Cited Researcher by Clarivate Web of Science every year since 2019. Fellow, National Academy of Inventors. Fellow of the IEEE, Fellow of IFAC, Fellow of the U.K. Institute of Measurement & Control, Fellow European Union Academy of Sciences, Fellow American Association for the Advancement of Sciences, Member of the New York Academy of Sciences. Registered Professional Engineer in the State of Texas and Chartered Engineer, U.K. Engineering Council. Published 500 Refereed Journal Papers. 80,800 google citations, h-index 123. Charter Member (2004) of the UTA Academy of Distinguished Scholars. UTA Academy of Distinguished Teachers 2012. IEEE Control Systems Society Distinguished Lecturer 2012-1014. Founding Member of the Board of Governors of the Mediterranean Control Association. Served as Visiting Professor at Democritus University in Greece, Hong Kong University of Science and Technology, Bristol University UK, Chinese University of Hong Kong, City University of Hong Kong, National University of Singapore, Nanyang Technological University Singapore.

Received IEEE Computational Intelligence Society Neural Networks Pioneer Award 2012, AIAA Intelligent Systems Award 2016, John Ragazzini Education Award 2018 from American Automatic Control Council. Received Fulbright Research Award 1988, American Society of Engineering Education F.E. Terman Award 1989, Int. Neural Network Soc. Gabor Award 2009, U.K. Inst Measurement & Control Honeywell Field Engineering Medal 2009, three Sigma Xi Research Awards, UTA Halliburton Engineering Research Award, UTA Distinguished Research Award, ARRI Patent Awards, various Best Paper Awards, IEEE Control Systems Society Best Chapter Award (as Founding Chairman of DFW Chapter), and National Sigma Xi Award for Outstanding Chapter (as President of UTA Chapter). Received Outstanding Service Award from the Dallas IEEE Section and selected as Engineer of the year by Ft. Worth IEEE Section. Listed in Ft. Worth Business Press Top 200 Leaders

in Manufacturing. Appointed to NAE Committee on Space Station in 1995 and IEEE Control Systems Society Board of Governors in 1996. Received the 2010 IEEE Region 5 Outstanding Engineering Educator Award and the 2010 UTA Graduate Dean's Excellence in Doctoral Mentoring Award. Texas Regents Outstanding Teaching Award 2013.
Current interests include autonomous systems, unmanned aerial vehicles, distributed cooperative control on graphs, reinforcement learning, nonlinear systems, intelligent control, process control, and neurobiological systems. Author of 7 U.S. patents, 472 journal papers, 52 chapters and encyclopedia articles, 420 refereed conference papers, and 20 books including Optimal Control, Optimal Estimation, Applied Optimal Control and Estimation, Aircraft Control and Simulation, Control of Robot Manipulators, Neural Network Control, High-Level Feedback Control with Neural Networks and the IEEE reprint volume Robot Control. Editor of Taylor & Francis Book Series on Automation & Control Engineering. Served as Editor for the flagship journal Automatica. Served/serves on many Editorial Boards including International Journal of Control, Neural Computing and Applications, Optimal Control & Methods, and Int. J. Intelligent Control Systems. Recipient of NSF Research Initiation Grant and continuously funded by NSF since 1982. He has received $12 million in funding from NSF, ARO, ONR, AFOSR and other government agencies, including significant DoD SBIR and industry funding. His SBIR program was instrumental in ARRI's receipt of the US SBA Tibbets Award in 1996.

Robust Inverse Q-Learning for Continuous-Time Linear Systems in Adversarial Environments

Frank L. Lewis et al

IEEE TRANSACTIONS ON CYBERNETICS, VOL. 52, NO. 12, DECEMBER 2022, 13083-13095.

Abstract

This article proposes robust inverse Q-learning algorithms for a learner to mimic an expert's states and control inputs in the imitation learning problem. These two gents have different adversarial disturbances. To do the imitation, the learner must reconstruct the unknown expert cost function. The learner only observes the expert's control inputs and uses inverse Q-learning algorithms to reconstruct the unknown expert cost function. The inverse Q-learning algorithms are robust in that they are independent of the system model and allow for the different cost function parameters and disturbances between two agents. We first propose an offline inverse Q-learning algorithm which consists of two iterative learning loops: 1) an inner Q-learning iteration loop and 2) an outer iteration loop based on inverse optimal control. Then, based on this offline algorithm, we further develop an online inverse Q-learning algorithm such that the learner mimics the expert behaviors online with the real-time observation of the expert control inputs. This online computational method has four functional approximators: a critic approximator, two actor approximators, and a state-reward neural network (NN). It simultaneously approximates the parameters of Q-function and the learner state reward online. Convergence and stability proofs are rigorously studied to guarantee the algorithm performance.

Anomaly Detection and Correction of Optimizing Autonomous Systems With Inverse Reinforcement Learning

Frank L. Lewis et al

IEEE TRANSACTIONS ON CYBERNETICS, VOL. 53, NO. 7, JULY 2023, 4555-4566.

Abstract

This article considers autonomous systems whosebehaviors seek to optimize an objective function. This goes beyond standard applications of condition-based maintenance, which seeks to detect faults or failures in nonoptimizing systems. Normal agents optimize a known accepted objective function, whereas abnormal or misbehaving agents may optimize a renegade objective that does not conform to the accepted one. We provide a unified framework for anomaly detection and correction in optimizing autonomous systems described by differential equations using inverse reinforcement learning (RL). We first define several types of anomalies and false alarms, including noise anomaly, objective function anomaly, intention (control gain) anomaly, abnormal behaviors, noise-anomaly false alarms, and objective false alarms. We then propose model-free inverse RL algorithms to reconstruct the objective functions and intentions for given system behaviors. The inverse RL procedure for anomaly detection and correction has the training phase, detection phase, and correction phase. First, inverse RL in the training phase infers the objective function and intention of the normal behavior system using offline stored data. Second, in the detection phase, inverse RL infers the objective function and intention for online observed test system behaviors using online observation data. They are then compared with that of the nominal system to identify anomalies. Third, correction is executed for the anomalous system to learn the normal objective and intention. Simulations and experiments on a quadrotor unmanned aerial vehicle (UAV) verify the proposed methods.

Inverse Reinforcement Learning for Adversarial Apprentice Games

Frank L. Lewis et al

IEEE TRANSACTIONS ON NEURAL NETWORKS AND LEARNING SYSTEMS, 09. 2021.

Abstract

This paper proposes new inverse reinforcement learning (RL) algorithms to solve our defined Adversarial Apprentice Games for nonlinear learner and expert systems. The games are solved by extracting the unknown cost function of an expert by a learner using demonstrated expert’s behaviors. We first develop a model-based

inverse RL algorithm that consists of two learning stages; an optimal control learning and a second learning based on inverse optimal control. This algorithm also clarifies the relations between inverse RL and inverse optimal control. Then, we propose a new model-free integral inverse RL algorithm to reconstruct the unknown expert cost function. The model-free algorithm only needs online demonstration of the expert and learner's trajectory data without knowing system dynamics of either the learner or the expert. These two algorithms are further implemented using neural networks (NNs). In Adversarial Apprentice Games, the learner and the expert are allowed to suffer from different adversarial attacks. A two-player zero-sum game is formulated for each of these two agents and is solved as a subproblem for the learner in inverse RL. Furthermore, it is shown that the cost functions that the learner learns to mimic the expert's behavior are stabilizing and not unique. Finally, simulations and comparisons show the effectiveness and the superiority of the proposed algorithms.

Reinforcement Learning Applications in Unmanned Vehicle Control: A Comprehensive Overview

Frank L. Lewis et al

Unmanned Systems, June, 2022

This paper briefly reviews the dynamics and the control architectures of unmanned vehicles; reinforcement learning in optimal control theory; and RL-based applications in unmanned vehicles. Nonlinearities and uncertainties in the dynamics of unmanned vehicles (e.g., aerial, underwater, and tailsitter vehicles) pose critical challenges to their control systems. Solving Hamilton-Jacobi-Bellman (HJB) equations to find optimal controllers becomes difficult in the presence of nonlinearities, uncertainties, and actuator faults. Therefore, reinforcement learning (RL)-based approaches are widely used in unmanned vehicle systems to solve the HJB equations. To this end, they learn the optimal solutions by using online data measured along the system trajectories. This approach is very practical in partially or totally model-free optimal control design and optimal fault-tolerant control design for unmanned vehicle systems.

Carbon Capture by the Macroalgae, Sarcodiasuae, using Aquaculture Wastewater and Green Energy in Subtropical Regions

by Peter H. Santschi, Member EUAS

Short Biography

Dr. Peter H. Santschi is a Regents Professor of Oceanography and Marine Sciences at the Texas A&M University, Galveston, TX, USA. He received his training in Geochemistry and Oceanography during his post-graduate work at L-DEO at Columbia University, N.Y., after graduating from the University of Bern, Switzerland, with a Ph.D. in Chemistry. Dr Santschi's research interests include Marine Chemistry, Environmental Chemistry and Environmental Radiochemistry; trace element interactions with natural organic matter; Tracer applications in natural water systems using stable and radioactive isotopes. Since 2000, he is associate editor of the journal Marine Chemistry. He is an author of well over 300 journal articles and 45 book chapters on these subjects, which, over the years, have received more than 15,000 citations. More on his research can be found at https://www.tamug.edu/mars/faculty-bios/PeterHSantschi.html and https://scholar.google.com/citations?user=ZKGyOTsAAAAJ&hl=en&oi=ao.

*His total of 400+ peer-reviewed publications, according to the ISI Web of Science (all databases as of August 3, 2020), attest to his productivity, while his citation record is a testimony of his impact. Santschi's record is thus not only of quantity alone but predominantly of quality. Metrics establishing scientific impact are difficult to come by, but if the citation count and other indexes (e.g., h-index from ISI, all databases) may serve as a measure of scientific impact, then his 400+ publications have been cited over 17,000 times, with an average citation per publication of over 42. Other indexes for his publications (ISI h-index = 71 and productivity m-index = $h/\Delta t$ = 1**.51** with Δt = 47 years since the 1st publication in 1974; g-index = 137; and Google Scholar h-index = 87 and i-10 index = 293, with well over 25,000 citations) are exceptional.*

Peter H. Santschi received ***numerous national and international awards****, e.g., he was elected Member of the European Union Academy of Sciences (EUAS) (2020), Geochemical Fellow of the Geochemical Society and the European Association of Geochemistry (2017); Fellow of the American Geophysical Union (2014), which are given annually to only 0.1% of the 60,000 members; received the Distinguished Achievement Awards in Graduate Student Mentoring (2013) from Texas A&M's Association of Former Students; Regents Professor of Texas A&M University (2009), and received the Association of Former Student Distinguished Achievement Award for Research from Texas A&M University (2004). These awards were not possible without many collaborative and/or supportive scientists.*

His international pre-eminence *is not only demonstrated by the prestigious awards that he received, but also by the fact that he was invited as a member of Academic Advisory or Review Panels, as well as a Visiting Professor at national and international Universities, e.g., at Lamont-Doherty Earth Observatory of Columbia University (1982-1988), University of Rhode Island, School of Oceanography (1986), Dept. of Geology and Dept. of Chemistry, University of Geneva, Geneva, Switzerland (1996), Dept. of Chemistry and Biochemistry, University of Bern, Bern, Switzerland (2002), Dept. of Chemistry, University of Geneva, Geneva, Switzerland (2003), Swiss Institute of Technology, ETH, Zurich, Switzerland (2003), National Taiwan University, Taipei, Taiwan (2003), and Hong Kong University of Science and Technology (2004), National Center for Oceanographic Research, NCOR (2008).*

Summary of Accomplishments in Environmental Science. *During his 45-plus year career in environmental science, Santschi has gained and communicated novel insights into some of the blueprints of the aquatic environment, spanning from rain water, rivers and lakes to groundwater, from surface to deep ocean. During his long research career, he, together with 40+ graduate students, post-doctoral fellows and scientists all*

over the world, was able to pioneer new concepts and approaches that were truly ***transformational****. The unifying theme of his research has been the* ***study of the self-cleansing capacity of natural aquatic systems****: in particular, the importance of natural organic matter compounds for particle, radionuclide, and trace element cycling in aquatic systems. The importance of natural organic matter was not obvious in aquatic chemistry, as for many decades, the dogma was that metal behavior is mostly controlled by inorganic ligand interactions. His research involves the main agents that can ameliorate impact (e.g., toxicity, mobility) of potential pollutants to aquatic biota, i.e., microbially produced macromolecular substances that occur in the colloidal phase. This phase is mostly composed of nano-sized exopolymeric substances, as well as terrestrially derived humic substances, both of which can, at times, greatly help to control the efficiency of the self-cleansing capacity of aquatic systems. Natural colloids in aquatic systems are thus, to a large extent, derived from biological production and degradation of natural particles. Therefore, Peter's main contributions and impacts in environmental geochemistry are on the role of macromolecular natural organic matter, trace metal, and radionuclide speciation, transport, and cycling.*

Dr. Santschi's ***seminal contributions*** *to science, more specifically to the field of environmental biogeochemistry and radiochemistry, have thus included major* ***transformational*** *breakthroughs, e.g., the Colloidal (or Brownian) Pumping Concept that led to paradigm shifts in aquatic science (see below), and sustained impact, with his most cited papers providing unifying chemical and physic-chemical concepts explain pollutant behavior in aquatic environments, including articles published from the 1980s, 1990s, and 2000s. This transformational "Colloidal or Brownian Pumping Model" was able to simulate observations of apparent particle concentration effects on both the widely observed particle-water distribution coefficients and the model kinetic constants of trace element and radionuclide uptake onto natural particles, given the observed colloidal fractions of trace metals and radionuclides. His work then stimulated many other researchers to build on these novel concepts. Over the years following this transformational work, he tackled the challenging question of macromolecular organic compounds that occur in the colloidal phase and act as carrier molecules for specific trace elements and radionuclides. Due to the numerous difficulties in finding such compounds at relevant but trace levels in the midst of thousands of other compounds, selective separation and purification chemistry had to be thoroughly tested, before state-of-the-art instrumentation can be applied.*

Abstracts of Recent Publications 2023

1. Weerakkody, W.S., Ling, K., Hsieh, H.-H., Abedneko, V.G., Shyu, J.-F., Lee, T.-M., Shih, Y.-Y., Ranatunga, K., Santschi, P.H., Hung, C.-C. 2023. Carbon capture by the macroalgae, *Sarcodiasuae*, using aquaculture wastewater and green energy in subtropical regions. STOTEN, 855 (2023) 158850.

Abstract: Rapid growth in the aquaculture industry and corresponding increases in nutrient and organic carbon levels in coastal regions can lead to eutrophica7on and increased greenhouse gas emissions. Macroalgae are the organisms primarily responsible for the capture of CO2 and removal of nutrients from coastal waters. In the current study, we developed a novel wastewater treatment system in which the red macroalga, Sarcordia suae, is usedto captureCO2 under thermosta7c condi7ons in subtropical regions. In 2020 (without temperature control), the carbon capture rate (CCR) of Sarcordia suae varied considerably with the season: winter/spring (2.1–3.9 g-C m−2 d−1) and summer (0.09 g-C m−2 d−1). In 2021, solar powered cooling reduced summer seawater temperatures from 31 to 33 °C to 23–25 °C with a corresponding increase in the mean CCR: winter/spring (2–7 g-C m−2 d−1) and summer (1.33 g-C m−2 d−1). The proposed aquaculture wastewater system proved highly efficient in removing nitrogen (20.7 mg-N g−1 DW d−1, DW = dry weight) and phosphorus (4.4 mg-P g−1 DW d−1). Furthermore, the high density of Sarcodia (1.10 ± 0.03 g cm−3) would permit the harves7ng and subsequent dumping of

Sarcodia in deep off-shore waters. This study demonstrated a low-cost land-based seaweed cul7va7on system for capturing CO2 and excess nutrients from aquaculture wastewater year-round under temperature- controlled environments in subtropical regions.

2. Lin, T.-Y., Chen, C.-L., Shih, Y.-T., Hsieh, H.-H., Huang, W.-J., Santschi, P.H. Hung, C.-C. 2023. A smallholders' mariculture device for rearing seafood: environmentally friendly, and providing improved quality. Sustainability, 15, 110.3390/su15010862.

Abstract: The aquaculture industry in Taiwan grosses more than USD 1.1 billion annually; however, it also generates considerable waste discharge (causing eutrophica7on in estuarine and coastal waters) and heavy groundwater withdrawals (causing land subsidence in coastal areas). Many aquaculture facili7es using earth ponds are affected by benthic algae, resul7ng in an earthy odor, and fixed-cage farms are difficult to relocate during cold weather events. In this study, we tested small-scale (~15 ton) mobile cage tanks for the nearshore rearing of white shrimp and grouper in the Yung-An district of Kaohsiung, Taiwan. At the conclusion of the mariculture experiment, the content of free amino acids in shrimp and groupers reared in our mobile tanks surpassed that in animals reared locally in tradi7onal earthy ponds. In a blind taste test involving 42 volunteers, groupers reared in mobile cage tanks were deemed more palatable than those raised in ponds. Our results demonstrate that small-scale mobile cage tanks are a feasible approach to the sustainable rearing of high-quality shrimp or fish. Note that wastewater from the mobile tanks is easily diluted by seawater, thereby reducing the likelihood of eutrophica7on in coastal regions. The proposed system could also be used for recrea7onal fishing ac7vi7es to increase income for smallholders of fishermen and/or aquaculture farmers.

3. Grandbois, R.H., Santschi, P.H., Xu, C., Mitchell, J.M., Kaplan, D.I., Yeager, C.M. 2023. Iodide uptake by forest soils is principally related to the ac1vity of extracellular oxidases. Fron1ers in Chemistry, Radioiodine Detec1on and Management, Front. Chem. 11:1105641.

Abstract: 129I is a nuclear fission decay product of concern because of its long half-life (16 Ma) and propensity to bioaccumulate. Microorganisms impact iodine mobility in soil systems by promo7ng iodina7on (covalent binding) of soil organic mader through processes that are not fully understood. Here, we examined iodide uptake by soils collected at two depths (0–10 and 10–20 cm) from 5 deciduous and coniferous forests in Japan and the United States. Autoclaved soils, and soils amended with an enzyme inhibitor (sodium azide) or an an7bacterial agent (bronopol), bound significantly less 125I tracer (93%, 81%, 61% decrease, respec7vely) than the untreated control soils, confirming a microbial role in soil iodide uptake. Correla7on analyses iden7fied the strongest significant correla7on

between 125I uptake and three explanatory variables, ac7nobacteria soil biomass (p = 6.04E-04, 1.35E-02 for Kendall-Tau and regression analysis, respec7vely), soil nitrogen content (p = 4.86E-04, 4.24E-03), and soil oxidase enzyme ac7vity at pH 7.0 using the substrate L-DOPA (p = 2.83E-03, 4.33E-04) and at pH 5.5 using the BTS (p = 5.09E-03, 3.14E-03). Together, the results suggest that extracellular oxidases, primarily of bacterial origin, are the primary catalyst for soil iodina7on in aerobic, surface soils of deciduous and coniferous forests, and that soil N content may be indica7ve of the availability of binding sites for reac7ve iodine species.

4. Lin, P., Xu, C., Kaplan, D.I., Yeager, C.M., Xing, W., Nichols, R., Santschi, P.H. 2023. Presence of organic maSer and its characteriza1on in cemen11ous materials: Implica1ons for radionuclide immobiliza1on, J. Env. Radioac1vity, 263 (2023) 107183.

Abstract: Grout materials are commonly used to immobilize low-level radioac7ve waste. Organic moie7es can be uninten7onally present in common ingredients used to make these grout waste forms, which may result in the forma7on of organo-radionuclide species. These species can posi7vely or nega7vely affect the immobiliza7on efficiency. However, the presence of organic carbon compounds is rarely considered in models or characterized chemically. Here, we quan7fy the organic pool of grout formula7ons with and without slag, as well as the individual dry ingredients used to make the grout samples (ordinary Portland cement (OPC), slag and fly ash), including total organic carbon (TOC) and black carbon, followed by aroma7city evalua7on and molecular characteriza7on via Electro Spray Ioniza7on Fourier-Transform Ion Cyclotron Resonance Mass Spectrometry (ESI-FTICRMS). All dry grout ingredients contained significant amounts of organic carbon, ranging from 550 mg/ kg to 6250 mg/kg for the TOC pool, with an averaged abundance of 2933 ± _2537 mg/kg, of which 60 ± _29% was composed of black carbon. The significant abundance of a black carbon pool implies the presence of the aroma7c-like compounds, which was further iden7fied by both phosphate buffer-assisted aroma7city evalua7on (e.g., >1000 mg-C/kg as aroma7c-like carbon in the OPC) and dichloromethane (DCM) extrac7on with ESI-FTICRMS analysis. Besides aroma7c-like compounds, other organic moie7es were also detected in the OPC, such as carboxyl-containing alipha7c molecules. While the organic compound only consists of minor frac7ons of the grout materials inves7gated, our observa7ons of the presence of various radionuclide-binding organic moie7es suggests the poten7al forma7on of organo-radionuclides, such as radioiodine, which might be present at lower molar concentra7ons than TOC. Evalua7ng the role of organic carbon complexa7on in controlling the disposed radionuclides, especially for those radionuclides with strong associa7on with organic carbon, has important implica7ons for the long-term immobiliza7on of radioac7ve waste in grout systems.

5. Schultz, G.E., Jr.; Santschi, P.H. 2023. Effect of the Added Acyl Homoserine Lactones on Separated Free-Living Marine Bacteria as a Model of Quorum Sensing. J. Mar. Sci. Eng. 2023, 11, 1258.

Abstract: Quorum sensing is a communica7on system by which bacteria use signal molecules to induce a physiological response. In natural marine environments, quorum sensing is suspected to occur in regions with high cell densi7es. Free-living bacteria, however, are largely believed to exist at concentra7ons too low to make use of a density-dependent quorum-sensing system. Due to socalled 'free-living' bacteria inhabi7ng marine gels composed of exopolymeric substances occurring in an opera7onally defined colloidal frac7on, it is possible that quorum-sensing molecules would also occur in this frac7on. In this study, possible signaling molecules were collected from marine water, separated, and concentrated as some organic mader. Their iden7fica7on with an Agrobacterium tumefaciens assay indicated the presence of AHLs. In fall 2002 and spring 2003, free-living (single cells) frac7on of marine bacterioplankton was sampled and separated. Various AHLs were added to these disperse popula7ons (109 cells/L). The studied bacterial communi7es responded with change in the thymidine incorpora7on. The results are discussed as existence of ac7ve reac7on of marine free-living bacteria to signaling molecules even in sparse inhabi7ng marine gels. That there is a bacterial response to signaling molecules in so sparse popula7ons is of great significance for marine and environmental sciences.

Numerical Modelling in Biomedical & Sustainable Engineering: Activity and Progress

by Eddie Ng Yin-Kwee, Member EUAS

Short Biography

Dr. Eddie obtained Ph.D. at Cambridge Univ. with a Cambridge Commonwealth Scholarship.
He is elected as:
Fellow (inaugural) for National Academy of Technology (USA);
Academician for European Academy of Sciences and Arts (EU-Austria);
Fellow (Life) of the American Society of Mechanical Engineers (USA);
Fellow of Institute of Engineering and Technology (United Kingdom);
Fellow of International Engineering and Technology Institute (Hong Kong),
Distinguished Fellow for Institute of Data Science and Artificial Intelligence, (China), and,
Academician for Academy of Pedagogy and Learning, (USA).
Eddie received 2022 Alumni Highly Commended Award from the VC of Newcastle upon Tyne University, UK for his contributions to the society and achievements as academia.
He published more than 542 papers in SCI-IF int. journal (430); int. conf. proceedings (150), textbook chapters (>105) and others (32) over the 28 years. Co-edited 14 books on "Cardiac Pumping and Perfusion Engineering" by WSP (2007); "Imaging and Modelling of Human Eye" by Artech (2008); "Distributed Diagnosis and Home Healthcare, v.1" by ASP (2009); "Performance Evaluation in Breast Imaging, Tumor Detection & Analysis" by ASP (2010); "Distributed Diagnosis and Home Healthcare, v.3" by ASP (2011); "Computational Analysis of Human eye with Applications" by WSP (2011); "Human Eye Imaging and Modeling" by CRC (2011); "Multimodality Breast Imaging" by SPIE (2013); "Image Analysis and Modeling in Ophthalmology"; "Ophthalmology Imaging and Applications" by CRC (2013, 2014); "Bio-inspired Surfaces and Applications" by WSP (2016); "Application of Infrared to Biomedical Sciences" by Springer (2017) and "Computation and Mathematical Methods in Cardiovascular Physiology" by WSP (2019). Also, co-authored a textbook: "Compressor Instability with Integral Methods" by Springer (2007).
Since 1992, he works as Faculty in the School of Mechanical & Aerospace Engineering in Nanyang Technological University, Singapore.
He is included in the Stanford list of the World's top 2% Scientists since 2019 (ranked 83 out of 64,425 as 0.001% in the field of Biomedical Engineering). The ranking method is calculated by removing the self-citation of the literature.
His Score in researchgate.net is one of the highest in our school (> 44.82 or higher than 97.5% of all ResearchGate members' scores).
He is also ranked # 5 (Worldwide) in Google Scholar (h-index: 68) under Biomedical category [see http://scholar.google.com.sg/citations?user=9QW1LYAAAAAJ].

RESEARCH INTERESTS

• Numerical modeling in biomedical engineering (including AI in healthcare and thermal-fluids engineering such as Computational Fluid Dynamics (CFD) & Heat Transfer-CHT).
• Infrared physics & technology with its application to clinical diagnosis of health abnormalities.

Ongoing update of Ng's roles in Infrared physics & technology with PINN

Eddie and team developed a novel Physics-Informed Neural Network (PINN) method for fast forward simulation of heat transfer through cancerous breast models [1]. The proposed PINN method combines deep learning and physical principles to predict the temperature distributions in breast tissues and identify potential abnormal regions indicating the presence of tumours. The PINN model is normally trained by physics in terms of the residuals of the heat transfer equation, as well as boundary conditions with and without datasets of surface thermal imaging data concerning cancerous breast tissues, which can be used for future inverse thermal modelling to calculate tumour sizes and locations. The model is validated by comparing its predictions with those obtained by traditional Finite Element Analysis (FEA) for various cases. The comparison validates the PINN model as an accurate and fast method for thermal modelling and breast cancer diagnostic tool as the PINN simulation is found to be around 12x faster than its FEM counterpart. The utilization of deep learning and physical principles in a diagnostic tool provides a non-invasive and safer alternative for breast self-examination compared to traditional methods such as mammography. These findings hold promise for the ongoing development of a new portable AI (Artificial Intelligence) tool for the early detection of breast cancer in breast self-examination [2] as promoted by WHO, which is crucial for reducing mortality rates of breast cancer in the world.

Next, the early detection of malignant nodules and timely diagnosis of thyroid abnormalities play a crucial role in improving medical treatment outcomes and minimizing disease progression. Thermography has emerged as an affordable and non-radiation method for detecting thyroid issues, reducing the risks associated with unnecessary invasive biopsies. By extracting radiomics features from thermal images of the thyroid, valuable information about the underlying tissue characteristics can be obtained, offering numerous advantages in the field of medical imaging [3]. In this study, radiomics features were extracted from thermal images of the thyroid, and unsupervised feature selection techniques including Principal Component Analysis (PCA), Independent Component Analysis (ICA), and variance thresholding were employed to reduce the dimensionality of the feature set [3]. It is important to acknowledge that the field of radiomics analysis in thermography thyroid images is still emerging, and further research is required to validate the clinical usefulness of these features. Nevertheless, radiomics analysis

holds significant potential to enhance the assessment of thermography thyroid images and provide valuable insights into thyroid function and pathology.

Ongoing update of Ng's interests in Energy Sustainability

Drag-dominant tidal turbine energy holds tremendous clean energy potential but faces significant hurdles as unsuitability of the actuator disc model due to the varying swept blockage area, unaccounted bypass flow downstream interaction, and rotor parasitic drag, whereas blade element momentum theory is computably effective for majorly 3-blade lift-dominated aerofoil. We validated a novel method to find the optimal tip speed ratio (TSR) of any turbine with a cost-effective and user-friendly moment balancing algorithm to support robust tidal energy development [4]. Performance analysis CFD study of Pinwheel and Savonius tidal turbines in a Biffis canal hydrodynamic system was carried out.
My team also extend a novel technique to calculate the optimal turbine TSR with a cost-effective and user-friendly moment balancing algorithm [5]. A reliable dynamic TSR matrix was developed with varying rotational speeds and fluid velocities, unlike previous works simulated at a fixed fluid velocity. Thrust and idle moments are introduced as functions of inlet fluid velocity and rotational speed, respectively. The quadratic relationships are verified through regression analysis, and net moment equations are established [5]. Rotational speed was a reliable predictor for Pinwheel's idle moment, while inlet velocity was a reliable predictor for thrust moment for both models. The optimal (Cp, TSR) values for Pinwheel and Savonius turbines were (0.223, 2.37) and (0.63, 0.29), respectively, within an acceptable error range for experimental validation. Our study aims to improve prevailing industry practices by enhancing an engineer's understanding of optimal blade design by adjusting the rotor speed to suit the inlet flow case compared to 'trial and error' with cost-intensive simulations.

Next, with Vertical Axis Wind Turbines (VAWTs) showing promising capabilities in the recent years, lately there has been an increase in research towards the performance enhancements of said VAWTs, respectively. Our work emphasizes on the conceptual design optimization of a Contra-Rotating VAWT (CR-VAWT) using Taguchi method and CFD [6]. Accordingly, the optimal combination of design parameters were obtained for the optimal CR-VAWT, and comparisons between the optimal CRVAWT and a Conventional VAWT (C-VAWT) indicated that the CR-VAWT showed better performance in terms of power characteristics throughout the range of TSR tested and additionally indicating a 14% increase at the optimal TSR, which confirm that upon proper selection of design parameters, CR-VAWTs can show better performance than the C-VAWT.

As wind energy continues to be a crucial part of sustainable power generation, the need for precise and efficient modelling of wind turbines, especially under yawed conditions, becomes increasingly significant. Addressing this, my team introduces a machine learning (ML)-based symbolic regression approach for

elucidating wake dynamics [7]. Utilizing WindSE's actuator line method (ALM) and Large Eddy Simulation (LES), we model an NREL 5-MW wind turbine under yaw conditions ranging from no yaw to 40 degrees. Leveraging a hold-out validation strategy, the model achieves robust hyper-parameter optimization, resulting in high predictive accuracy. While the model demonstrates remarkable precision in predicting wake deflection and velocity deficit at both the wake center and hub height, it shows a slight deviation at low downstream distances, which is less critical to our focus on large wind farm design. Nonetheless, our approach sets the stage for advancements in academic research and practical applications in the wind energy sector by providing an accurate and computationally efficient tool for wind farm optimization [7]. This study establishes a new standard, filling a significant gap in the literature on the application of machine learning-based wake models for wind turbine yaw wake prediction.

Finally, the flow structure of the vortex cooling is asymmetrical compared to the traditional gas turbine leading edge cooling, such as the impingement cooling and the axial flow cooling. My team study [8] involves the mainstream flow field and the rotational effects based on the profile of the General-Electric (GE-E3) blade to reveal the mechanism of the asymmetrical flow structure effects. Results show that the nozzle position presents different influences under low and higher rotational speeds. As for the mainstream flow, rotation makes the stagnation line move from the pressure surface side to the suction surface side, which changes the coolant film attachment on the blade leading edge surface. The position of nozzles, however, indicates limited influence on the coolant film flow. As for the internal channel vortex flow characteristics, the coolant injected from the nozzles forms a high-velocity region near the target wall, which brings about enhancing convective heat transfer [8].

References

[1] O Mukhmetov, Y Zhao, A Mashekovaa, V Zarikas, EYK Ng, N. Aidossov, "Physics-informed Neural Network for the Prediction of Temperature Distributions in Cancerous Breasts as a Portable AI-based Diagnostic Tool", Computer Methods and Programs in Biomedicine, Vol. 242, pp. 107834 (24 pages), (2023).

[2] N Aidossov,.. EY.K. Ng, et al, "Evaluation of Integrated CNN, Transfer Learning and BN with Thermography for Breast Cancer Detection", Applied Sciences, (2023), Vol. 13: 600, (21 pages).

[3] Etehadtavakol, M., Sirati-Amsheh, M., Ng, E.Y.K. (2023). "Radiomics Feature Selection from Thyroid Thermal Images to Improve Thyroid Nodules Interpretations". In: Kakileti, S.T., *et al*. (eds) Artificial Intelligence Over Infrared Images for Medical Applications (AIIIMA 2023). Lecture Notes in Computer Science, vol 14298. Springer.

[4] Y Zhang, E.Y.K. Ng, M Shivansh, "The Biffis canal hydrodynamic system performance study of drag-dominant tidal turbine using moment balancing method", Sustainability, Vol. 15(19), (2023), pp. 14187, (24 pages).

[5] Y Zhang, M Shivansh, E.Y.K. Ng, "CFD Validation of Moment Balancing Method on Drag-dominant Tidal Turbines (DDTTS), Processes, Vol. 11, (2023), pp. 1895, (17 pages).

[6] J. Radhakrishnan,… EYK Ng et al, “Design Optimization of a Contra-Rotating VAWT: A Comprehensive Study using Taguchi Method and CFD”, Energy Conversion and Management, Vol. 298 pp. 117766 (13 pages), (2023).
[7] Gajendran, M.K.; Kabir, I.F.S.A.; Vadivelu, S.; Ng, E.Y.K., Machine Learning-Based Approach to Wind Turbine Wake Prediction under Yawed Conditions. J. Mar. Sci. Eng. (2023), 11(11), pp. 2111 (21 pages). Special Issue "Advances in Offshore Wind".
[8] Wang, J., Ng, EYK., et al. “Study on Rotational Effects of Modern Turbine Blade on Coolant Injecting Nozzle Position with Film Cooling and Vortex Composite Performance”. Frontiers in Heat and Mass Transfer, (2023), 21(1), 1–31.

Bioaccumulation and Biomagnification of Heavy Metals in Marine Micro-Predators

by Roberto Danovaro, Member EUAS

Short Biography

Roberto Danovaro was born in Genoa (degrees in 1988). PhD in Environmental Sciences at the University of Pisa in 1993. Full Professor in 2001 at the Polytechnic University of Marche. Director of the Department of Marine Sciences (2004 to 2010), Director of the Department of Life and Environmental Sciences (2011 to 2014) at the Polytechnic University of Marche. Pro-Rector (Delegated to the Research) at the Polytechnic University of Marche (2010-2013). President of the Scientific Council of WWF Italy, Steering Board Member of OECD (Fostering Innovation in Ocean Economy). Member of the Scientific Council of several research institutions and panels (IUCN, UNEP, EU), Editor in Chief of international journals and coordinator of several EU and international programs. President of the Italian Society of Ecology (2011-2013), and of the Italian Society of Limnology and Oceanography (2008-2011). President of the European Federation of Scientific Technological Societies (2008-2012). Member of the EU Academy of Sciences. RD received several Awards, including the World Prize BMC Biology (London, 2010), the Award of French Society of Oceanography (2011), and the ENI Award "Protection of the Environment" (2013). Nominated in 2013 by the Italian Ministry of Education University and Research (MIUR), President of the Stazione Zoologica Anton Dohrn (National Institute of Marine Biology Ecology and Biotechnology). In the 2018 was renewed as President of the SZN (2018-2022). (RD Scientometric data: H index - 100; articles on ISI journals with IF >500; citations>37.000 – Google Scholar, December 2023)

Selected Publications 2023

Bioaccumulation and biomagnification of heavy metals in marine micro-predators

Roberto Danovaro, *Adele Cocozza di Montanara, Cinzia Corinaldesi, Antonio Dell'Anno, Silvia Illuminati, Trevor J. Willis & Cristina Gambi.* ***Communications Biology*** *6: 1206 (2023)*

Nematodes represent >3/5 of the abundance of the world's metazoans and usually account for nearly 90% of the total benthic fauna, playing a key ecological role in the benthic ecosystem functioning on a global scale. These small metazoans include a relevant number of microscopic predators and, in turn, are the most abundant preys of macro-megafauna and fish juveniles thus playing a key role in marine food

webs. Here, using two independent approaches, we test the bioaccumulation in marine nematodes of several heavy metals present in contaminated sediments. We report here that nematodes, despite their short life cycle and small size, bioaccumulate significantly heavy metals. Bioaccumulation increases from deposit feeders and microalgal grazers to predators of microbes and other tiny metazoans. These results suggest that nematodes also contribute to their biomagnification along the food webs and can contribute to increase the transfer of contaminants from the sediments to larger organisms.

Integrating ocean observations across body-size classes to deliver benthic invertebrate abundance and distribution information

Henry A. Ruhl, Brian J. Bett, Jeroen Ingels, Adrian Martin, Andrew R. Gates, Andrew Yool, Noëlie M.A. Benoist, Ward Appeltans, Kerry L. Howell, ***Roberto Danovaro****.* ***Limnology and Oceanography Letters*** *8: 692-706 (2023).*

Invertebrate animals living at the seafloor make up a prominent component of life globally, spanning 10 orders of magnitude in body size over 71% of Earth's surface. However, integrating information across sizes and sampling methodologies has limited our understanding of the influence of natural variation, climate change and human activity. Here, we outline maturing practices that can underpin both the feasibility and impact of establishing Benthic Invertebrate Abundance and Distribution as a Global Ocean Observing System—Essential Ocean Variable, including: (1) quantifying individual body size, (2) identifying the well-quantified portions of sampled body-size spectra, (3) taking advantage of (semi-)automated information processing, (4) application of metadata standards such as Darwin Core, and (5) making data available through internationally recognized access points. These practices enable broader-scale analysis supporting research and sustainable development, such as assessments of indicator taxa, biodiversity, biomass, and the modeling of carbon stocks and flows that are contiguous over time and space.

Deep-sea impacts of climate interventions

Lisa A. Levin, Joan M. Alfaro-Lucas, Ana Colaço, Erik E. Cordes, Neil Craik, ***Roberto Danovaro****, Henk-Jan Hoving, Jeroen Ingels, Nélia C. Mestre, Sarah Seabrook, Andrew R. Thurber, Chris Vivian, and Moriaki Yasuhara.* ***Science*** *379(6636): 978-981 (2023).*

Scientists, industry, and policy-makers have turned increasing attention toward the ocean as a source of climate change mitigation solutions. Efforts to develop ocean-based climate interventions (OBCIs) to remove and sequester carbon dioxide (CO2), manage solar radiation, or produce renewable energy have accelerated. Questions have been raised about OBCI costs, governance, impacts, and effectiveness at scale, but limited attention has been given to ocean biogeochemistry

and ecosystems and particularly to impacts on deep-sea ecosystems (>200-m water depth), an ocean region that is understudied but fundamental for Earth's healthy function. The deep sea, with low energy supply; typically cold, stable conditions; and a low density of organisms with reduced metabolism, requires specific attention. Here we discuss OBCIs that could affect deep-ocean ecosystems and their services, identify governance challenges, and highlight the need for an integrated research framework to help centralize consideration of deep-sea impacts in mitigation planning. Science and governance gaps have featured broadly in past discussions of ocean vulnerabilities to anthropogenic pressures including overfishing, biodiversity loss, plastic pollution, climate change, acidification, and deoxygenation. Threats to the deep sea have emerged from oil spills, destructive bottom fisheries, and seabed mining. Many of these stands to be compounded or exacerbated by OBCIs. In addition, the massive deposition or transfer of particles, organic matter (OM), and CO2 into the deep ocean from OBCIs present new biogeochemical and ecosystem threats and governance challenges, particularly in international waters.

Microbiome assisted restoration of degraded marine habitats: a new nature-based solution?

Corinaldesi Cinzia, Bianchelli Silvia, Candela Marco, Dell'Anno Antonio, Gambi Cristina, Rastelli Eugenio, Varrella Stefano, ***Danovaro Roberto****. Frontiers in Marine Science 10: 1227560 (2023)*

Microorganisms interact with all biological components in a variety of ways. They contribute to increase the efficiency of marine food webs and facilitate the adaptation of multicellular organisms to climate change and other human induced impacts. Increasing evidence suggests that microbiomes are essential for the health of marine species, for maintaining productive marine ecosystems, and thus for the sustainable functioning of the global biosphere. Marine microbiomes are typically species- or habitat-specific and are susceptible to environmental and human-driven changes. The microbiota of seagrasses, macroalgae, mangroves or tropical corals benefits their hosts by increasing their fitness, contributing to the removal of toxic compounds, conferring protection against pathogens, and/or supporting nutrient requirements. Alterations of the microbiomes might have negative consequences on species' health, survival, and overall ecosystem functioning. Despite the key ecological role of microbiomes in all ecosystems, their potential for the restoration of degraded habitats is still largely unexplored. Here we present a literature survey of the existing information on the microbiota associated with habitat-forming species and suggest that the resilience/recovery of damaged marine habitats can depend largely on the changes in the microbiota. Nature-based solutions relying on microbiome analyses (also through omics approaches) enable health monitoring of transplanted organisms/metacommunities and potential identification/production of probiotics/bio-promoters to stabilize unhealthy conditions of transplants. In the context of international strategies concerning ecological restoration, the use of the scientific knowledge acquired on the marine microbiome deserves to be exploited to

assist both traditional and innovative restoration approaches. The success of habitat restoration may depend on our ability to maintain, along with the restored species and habitats, a functional microbiota.

Novel insights on the Bacterial and Archaeal diversity of the Panarea Shallow-Water Hydrothermal vent field

Erika Arcadi, Emanuela Buschi, Eugenio Rastelli, Michael Tangherlini, Pasquale De Luca, Valentina Esposito, Rosario Calogero, Franco Andaloro, Teresa Romeo, ***Roberto Danovaro****.* ***Microorganisms*** *11(10): 2464 (2023).*

Current knowledge of the microbial diversity of shallow-water hydrothermal vents is still limited. Recent evidence suggests that these peculiar and heterogeneous systems might host highly diversified microbial assemblages with novel or poorly characterized lineages. In the present work, we used 16S rRNA gene metabarcoding to provide novel insights into the diversity of the bacterial and archaeal assemblages in seawater and sediments of three shallow-water hydrothermal systems of Panarea Island (Tyrrhenian Sea). The three areas were characterized by hot, cold, or intermediate temperatures and related venting activities. Microbial biodiversity in seawater largely differed from the benthic one, both in α-diversity (i.e., richness of amplicon sequence variants—ASVs) and in prokaryotic assemblage composition. Furthermore, at the class level, the pelagic prokaryotic assemblages were very similar among sites, whereas the benthic microbial assemblages differed markedly, reflecting the distinct features of the hydrothermal activities at the three sites we investigated. Our results show that ongoing high-temperature emissions can influence prokaryotic α-diversity at the seafloor, increasing turnover (β-)diversity, and that the intermediate-temperature-venting spot that experienced a violent gas explosion 20 years ago now displays the highest benthic prokaryotic diversity. Overall, our results suggest that hydrothermal vent dynamics around Panarea Island can contribute to an increase in the local heterogeneity of physical–chemical conditions, especially at the seafloor, in turn boosting the overall microbial (γ-)diversity of this peculiar hydrothermal system.

Positive effects of two decades of passive ecological restoration in a historically polluted marine site

Emanuela Fanelli, Antonio Dell'Anno, Ettore Nepote, Marco Lo Martire, Luigi Musco, Silvia Bianchelli, Cristina Gambi, Pierpaolo Falco, Francesco Memmola, Alessandro Coluccelli, Martina Meola, Stefano Varrella, ***Roberto Danovaro****, Cinzia Corinaldesi.* ***Frontiers in Marine Science*** *10: 1199654 (2023).*

The Mediterranean Sea is one of the most exploited regions of the world's oceans. Here industrial activities have determined either acute or long-term impacts on coastal marine ecosystems. In this study, we investigated macrofauna distribution and diversity, and food-web functioning in a coastal area of the Mediterranean Sea facing an industrial chemical plant abandoned in the '90s to assess benthic

ecosystem health. This area has been identified as a Site of National Interest (SNI) since 2002 and has been closed to any human activity awaiting to be remediated according to national laws. Our results indicate that, two decades after the SNI declaration (a decade after the plant decommissioning), there is no longer any sign of the impact of historical contaminations on macrofauna and benthic food web functioning. Overall, all the thirty-six sites showed high/good ecological quality according to the score assigned by AMBI and M-AMBI indexes, reflecting the absence of chronic impacts. Our findings reveal, for the first time, the positive effects of passive restoration (i.e., unassisted, or spontaneous recovery following cessation of anthropogenic impacts) on historically impacted coastal ecosystems since their health conditions, in terms of both abiotic (environmental variables and contaminant concentration) and biotic (macrofauna diversity and community composition, and benthic food-web structure) factors, were indistinguishable from surrounding non-impacted areas. These findings also suggest that other effective area-based conservation measures (OECMs) could be useful not only for biodiversity conservation of vulnerable and priority habitats in larger ocean sectors but also to promote the passive recovery of historically contaminated ecosystems.

Estimating preferences for Mediterranean deep-sea ecosystem services: A discrete choice experiment

Lorenzo Carlesi, Emilia Cubero Dudinskaya, ***Roberto Danovaro****, Gianfranco D'Onghia, Serena Mandolesi, Simona Naspetti, Raffaele Zanoli.* ***Marine Policy*** *151: 105593 (2023).*

The deep sea represents Earth's largest (but least explored) biome. It is increasingly affected by anthropogenic stressors and climate change, which threaten the provision of essential ecosystem services. The monetary value of these benefits has rarely been assessed. High biodiversity is hosted in the deep sea and, more generally, in the oceans. This paper uses a hypothetical choice experiment to investigate Italian households' preferences for deep-sea ecosystem services. The data show wide heterogeneity of the preferences for preserving the Mediterranean deep sea. Many respondents indicate that they would refuse to pay to support the protection of biodiversity and scientific research in this remote and unfamiliar environment. Overall, global warming was of little concern for most respondents, who would not be willing to pay to limit the increase in global temperatures. High income and formal education positively influenced the willingness of the respondents to donate to Non-Governmental Organization's initiatives to support the Mediterranean deep sea. Deep-water corals appear more 'charismatic' to respondents than submarine canyons among deep-sea habitats.

Self-Cleaning Sensors Based on Thermoresponsive Polymeric Film Modified Screen-Printed Platinum Electrodes

by Pankaj Vadgama, Member EUAS

Short Biography

CURRENT APPOINTMENTS

2000- Director IRC in Biomedical Materials, Queen Mary University of London
2000 - Professor of Clinical Biochemistry, Queen Mary University of London
2000 - 15 Honorary consultant Chemical Pathologist Barts Health NHS Trust
2003 - 15 Head of NHS Clinical Service (Appointed NHS Consultant 1983)
2015- Visiting Professor Southern Medical University Guangzhou, China
2017 - Visiting Professor University of Grenoble Alps

ACADEMIC QUALIFICATIONS

1971 MB, BS Newcastle University
1976 BSc Chemistry (1st Class Hon) Newcastle University
1977 Member (later Fellow) Royal College of Pathologists
1984 PhD Newcastle University
1994 Fellow Royal Society of Chemistry
2001 Fellow Institute of Materials Minerals and Mining
2002 Fellow Institute of Physics
2006 Fellow Royal Society of Medicine
2008 Chartered Scientist (Institute of Materials, Minerals and Mining)
2010 Fellow Royal Society of Biology

ACADEMIC APPOINTMENTS

1977-1980 MRC Training Fellow Newcastle University
1983-1988 Director Biosensor Research Group Newcastle University
1988-2000 Professor of Clinical Biochemistry, Manchester University
1998-2000 Professor of Biomedical Materials, Manchester University
1991-1997 Head of Department of Medicine, Manchester University (Salford)
1993-1996 Postgraduate Dean, Faculty of Medicine, Manchester University
1996-1998 Research Dean, Faculty of Medicine, Manchester University
1998-2000 Head of Division of Biomedical Engineering, Manchester University

Editorial Board Positions

Editorial Board: Physiological Measurement, Medical Engineering and Physics, Bioanalytical Reviews, Functional Biomaterials, Medical Devices and Sensors, 3D Printed Systems and Materials, Journal of Biochemistry and Molecular Biology Research, Chinese Chemical Letters. Guest Editor for Analytical and Bioanalytical Chemistry: (i) Thin film characterisation (ii) Membrane based sensors. Sub-Editor Biomaterials Series (RSC). Editor for (i) Bioelectrochemistry for the Encyclopedia of Interfacial Chemistry, Surface Science and Electrochemistry (ii) Bioinstrumentation and Bioinformatics for the Encyclopedia of Biomedical Engineering (Elsevier).

National/International Committees

Member EPSRC (Engineering and Physical Science Research Council): Materials Strategic Advisory Team (SAT) (2004/5/7/8); Healthcare (2005). Member, Institute of Materials Minerals and Mining Smart Materials Committee, Nanotechnology Committee, Biomedical Applications Division and External Advisory Committee. National Measurement Systems (NMS) Grants Committees for Materials and Modelling (2002 – 15) and Innovation R&D (2012-15); NPL(National Physical Laboratory)/LGC (Laboratory of the Government Chermist) projects. Past EPSRC grants panel memberships (includes as chair of some panels) from 1986: Materials, Structural Materials,

Chemistry, Multidisciplinary (Engineering), Health Care, Analytical Science, Mechanical and Medical Engineering, Follow-on Funding, DTCs (Doctoral Training Centres), Master's Training Packages, Sensors' Policy Group, SMART Technologies, Basic Sciences, Life Science Interface, Engineering Fellowships (Senior/Advanced). Nanotechnology Strategy Working Group (co-author, section on nanomedicine) (2005). ROPA (Realising our Potential) Panels EPSRC, MRC (Medical Research Council) (1995-96). MRC Joint Research Equipment Initiative Panel (JREI, 1996-7). Royal Society of Chemistry, Industrially-Sponsored Award in Electroanalytical Chemistry (1997, 2000). Member of Organisation and Delivery of Healthcare Task Force (Foresight Healthcare, 1999-2000). Member Academy of Medical Sciences/Foresight Working Group on the Detection and Identification of Infectious Disease (2004). Member Institution of Electrical Engineers Professional Group S9 (Biomedical Engineering, 1990-93). Chair (i) R&D (ii) Point of Care Testing committees, Division of Pathology Barts Health NHS Trust (2002-2011). Member BBSRC Strategic Research Studentships Panel 2004, LINK Program Medical Technologies and Molecular Sensors (1994-2001), Foresight LINK awards (2001). European Space Agency Advisory Panel on bioassay under microgravity (2000). Various EU FP IV & V Panels: Biotechnology, Biomedical and Health Research, Cell Factory, Growth, Standards, Measurements and Testing (1993-2000). Chair DTI Building up Biomaterials (BuB) Materials Healthcare Advisory Group (2001-2003). Member UK delegations (x3) to Japan (Biomaterials) and Singapore (x1) (Materials). Roadmap Champion for Diagnostics for human health, RSC (2010). Member Manchester Commonwealth Games 2002 Scientific Congress Committee.

RAE (Research Assessment Exercise, UK) Panel member Materials (2008). External Assessor Faculty of Engineering, University of Coimbra, Portugal (2013), Founder member biennial international conference series: Biomaterials Interfaces (2007-). Chair RSC Chemistry in Medicine Panel (2010). Chair, Steering Committee EPSRC IRColl Interdisciplinary Research Collaboration) in Bionanotechnology, University of Oxford (2003-5), Member 4th Generation Light Source (4GLS) Advisory Group, Daresbury. Member, international task force on environmental carcinogens (Halifax Project, 2014). Advisor, UK Biobank Project (2004). Member Special Inquiry into Regenerative Medicine Research at UCL.

RAE Advisor University of Manchester, REF Advisor University of Central Lancashire. Academic promotions advisor (Rutgers, Cranfield, Ulster, Manchester, Leeds, Flanders). Advisor, Engineering – Materials Faculty research quality, Limerick (2011). Cranfield University Senate committee panel member on Biomedicine MScs (2013). External advisor on the reorganization of the Chemistry Department, University of Surrey (2001). Scrutineer for Fellowship/Membership applications to the Institute of Materials Minerals and Mining. External assessor for staff appointments, PhD applications for Nazarbayev University (2014). Advisor to University of Ege (Turkey) on summer school biotechnology rolling Programme. International advisory member (vice-chair) of Uganda based research training foundation; advice on training needs and external funding, eg secured for geological sciences MScs. Co-Chair UK – China Biomaterials Partnership (2006-9). Global Initiative of Academic Networks (GIAN, India)) lecture course at University of Tezpur (2016). Host to Commonwealth Fellows India (Tezpur, 2015; Aligarh Muslim University, 2003), PhD Fellow (Government of Pakistan, 2017). NMS research project advisor, LGC (2005-07).

Chair UK Foresight Panel on Biomaterials and member of Materials, Smart Materials panel (2004) (co-author, strategy documents). Member, DTI Innovation and Growth Team (2006), Member UK Standards Group on ISO TC 229; nanotechnology nomenclature (2006 -). Chair of ISO Working Group on Nanomedicine and member Working Group on Nanobiotechnology (2006 – 2010). Member BSI Committees on Nanotechnology, Botechnology and Cell Therapies.

Member DFG Review Panel for German Excellence Initiative: Materials 2005,2007). Member Finland Research Council panel on Bioscience and Engineering (2008). Grants reviewing national funding councils: Australia, Quatar, Hong Kong, Portugal, Austria, Netherlands, Italy, Ukraine, Kazakhstan, Netherlands, Romania.

COLLABORATIONS

-EPSRC Program grant on elite athlete monitoring (ESPRIT) with Loughborough University Imperial College and UK Sport (£600k) (2011-15)

-DoH Dual function nano-silver incorporated polymers for medical device antimicrobial coatings – 2 projects (total £263 k) (2010 – 2014) Rainbow Medical Ltd

-EU Marie Curie exchange with five China Universities: Microsystems and Bioanalysis (£78k) (2010 – 14)

-Industrial CASE PhD Studentship on polymer bioadhesives with UEA, TWI (2012 -16)

-EU Marie Curie exchange with three China Universities Advanced biomaterials for generative medicine (£39k) (2010 – 15)

-UKIERI collaboration with Central Electronics Engineering Research Institute, India on Micro/nanofluidics for diagnostics (£65k) (2014 -16).

-TSB/BBSRC grant on Blood brain barrier model for drug permeability and toxicity testing with Kirkstall Ltd and Leeds University. (£52k) (2014-15)

- DoH Anti-bacterial 'Fill & Flush' Urinary Catheter Development (£61k) (2017 -19)

- Newton Institutional Links Grant (Egypt) Renewable Energy Driven Hybrid Desalination System for Remote Areas (£115, 647) (2016 – 18)

- EPSRC grant Multi-parametric optical sensing for monitoring haemodynamic shock awarded to City University (£656,799) (2018-21) (CoI)

INDUSTRIAL

Diagnostics company (Camstech Ltd) established 2015, funded by CERN-STFC Business Support, North Wales Photonics Launch Pad, Innovate UK Investment Accelerator (£1.3M funding to date). 25 patent applications filed with ICI/University of Manchester (1983-2000). Board member Oxford Scientific Consultants Ltd. Consultant SmartZyme Ltd, Israel.

WEB COMMUNICATION

Six public videos, including two for school children for the Royal Society of Chemistry

CHEMICAL PATHOLOGY CONSULTANT

HOPE HOSPITAL, SALFORD (1988 – 2000)

Head of Department, oversaw the work of large teaching hospital department: 350,000 test requests p.a. (1.6 million tests), 30% GP service. Specialist assays: steroids and hormones, drugs of abuse, porphyrins, catcholamines. Management through the Senior
Staff Committee (new methodology, analytical methods, organization, tendering, capital replacement). Preparation for laboratory accreditation and service rationalisation with Trafford Clinical Biochemistry). Weekly teaching round with medical trainee. Participation in the biochemistry on call rota.
Staff complement: 2.5 Consultants, 7 Grade B Biochemists, 2 Grade A Trainees, 2 Specialist Registrars, 25 MLSOs, MLAs.

BARTS NHS TRUST, LONDON (2000 – 2017)

Head of Department, 0.5M test requests p.a. (5M tests with 2007 amalgamation of Whips Cross and Newham General Hospital srvices).
Staff committee chair, ITU clinical liaison, chair Hospital POCT committee.
Member London Deanery Speciality Training Committee, Chemical Pathology. RCPath Speciality Adviser North East London (2005) for Clinical Biochemistry.
Staff Complement at Royal London base hospital: 2 Consultants, 5 Grade B Biochemists, 3 Grade A Trainees, 1 Specialist Registrar, 30 MLSOs, MLAs.

THE DOCTORS LABORATORY (TDL) (2007 -)

Advisory Chemical Pathologist to Blackheath Hospital and London Independent Hospital (to 2021). Advice on clinical diagnostic test: selection, phoning limits and derived parameters as member of TDL Harmonisation Working Group. Sub-editor: Sonic Laboratory Handbook (2021).

Yang, L and Lopes, I C and Vadgama, P. ***Self-Cleaning Sensors Based on Thermoresponsive Polymeric Film Modified Screen-Printed Platinum Electrodes.*** **Chemical Engineering Journal 474, 2023, 145932, 2023**

Abstract

Electrochemical sensors have progressively become important tools for monitoring the concentration of complex substances in biological media. However, surface fouling and biological contamination from bio-colloids have not been effectively resolved. In this study, a self-cleaning electrochemical sensor was constructed where a thermoresponsive outer polymer layer was equipped to repel the absorbent proteins. Enhanced hydrophilic P(NIPAAm-co-NVP) copolymers bearing N-isopropylacrylamide (NIPAAm) and N-vinyl pyrrolidone (NVP) were synthesized by free radical polymerization, and the resulting thermoresponsive polymeric films were drop coated on screen-printed platinum electrodes (SPPEs) followed by thermal annealing. Grafting density, surface wettability, surface microstructure and amperometric response, respectively, were evaluated for the modified SPPEs. Self-cleaning behavior after albumin adsorption was assessed by cyclic voltammetry (CV) and scanning electron microscopy (SEM) using various set temperatures respectively. The results showed the lower critical solution temperature (LCST) varied from 25°C to 40°C for P(NIPAAm-co-NVP) copolymers with the NVP content ranging from 0 to 47.62%. It indicated that NVP enhanced film hydrophilicity and could raise the LCST to above physiological data. It was concluded that films without NVP or with low NVP content resisted protein adsorption over lower temperatures, whilst with higher NVP content outstanding self-cleaning ability was also seen at physiological temperature. This opens the way to realize smart thermally addressable sensors able to solve the existing problem of biological surface contamination in sensor systems, and provides a strong model basis and technical capability for achieving novel, low drift electrochemical sensors.

Type VI Secretion Systems of Pathogenic and Commensal Bacteria Mediate Niche Occupancy in the Gut

by B. Brett Finlay, Member EUAS

Short Biography

Dr. B. Brett Finlay is a Professor in the Michael Smith Laboratories, and the Departments of Biochemistry and Molecular Biology, and Microbiology and Immunology at the University of British Columbia. He obtained a B.Sc. (Honors) in Biochemistry at the University of Alberta, where he also did his Ph.D. (1986) in Biochemistry under Dr. William Paranchych, studying F-like plasmid conjugation. His post-doctoral studies were performed with Dr. Stanley Falkow at the Department of Medical Microbiology and Immunology at Stanford University School of Medicine, where he studied Salmonella invasion into host cells. In 1989, he joined UBC as an Assistant Professor in the Biotechnology Laboratory. Dr. Finlay's research interests are focussed on host-microbe interactions, at the molecular level. By combining cell biology with microbiology, he has been at the forefront of the field called Cellular Microbiology, making several fundamental discoveries in this area, and publishing over 525 papers (h index=140). His laboratory studies several pathogenic bacteria, including Salmonella and pathogenic E. coli, and more recently microbiota. He is well recognized internationally for his work, and has won several prestigious awards including the E.W.R. Steacie Prize, the CSM Fisher Scientific Award, CSM Roche Award, a MRC Scientist, five Howard Hughes International Research Scholar Awards, a CIHR Distinguished Investigator, BC Biotech Innovation Award, the Michael Smith Health Research Prize, the IDSA Squibb award, the Jacob Biely Prize, the prestigious Canadian Killam Health Sciences Prize, the Flavelle Medal of the Royal Society, the Queen Elizabeth II Diamond Jubilee Medal, the Prix Galien, is a Fellow of the Royal Society of Canada and the Canadian Academy of Health Sciences, is a Member of the German National Academy of Sciences, the European Union Academy of Sciences, the American Academy of Microbiology, Chair d'État, Collège de France and is the UBC Peter Wall Distinguished Professor. He is an Officer of the Order of Canada and Order of British Columbia, and inducted into the Canadian Medical Hall of Fame. He is a cofounder of Inimex Pharmaceuticals, Inc. and Microbiome Insights, scientific cofounder of Vedanta Pharmaceuticals and CommenSe, Director of the SARS Accelerated Vaccine Initiative, and Founding Director and Senior Fellow of CIFAR's Microbes and Humans. He is also the co-author of the books Let Them Eat Dirt and The Whole Body Microbiome.

Selected Papers 2023

Serapio-Palacios A, Woodward SE, Vogt SL, Deng W, Creus-Cuadros A, Huus KE, Cirstea M, Gerrie M, Barcik W, Yu H, Finlay BB. Type VI secretion systems of pathogenic and commensal bacteria mediate niche occupancy in the gut. Cell Rep. 2022 Apr 26;39(4):110731. doi: 10.1016/j.celrep.2022.110731.

The type VI secretion system (T6SS) is a contractile nanomachine widely distributed among pathogenic and commensal Gram-negative bacteria. The T6SS is used for inter-bacterial competition to directly kill competing species; however, its importance during bacterial infection *in vivo* remains poorly understood. We report that the murine pathogen *Citrobacter rodentium*, used as a model for human pathogenic *Escherichia coli*, harbours two functional T6SSs. *C. rodentium* employs its T6SS-1 to colonize the murine gastrointestinal tract by targeting commensal *Enterobacteriaceae*. We identify VgrG1 as a *C. rodentium* T6SS antibacterial effector, which exhibits toxicity in *E. coli*. Conversely, commensal prey species *E. coli* Mt1B1 employs two T6SSs of its own to counter *C. rodentium* colonization. Collectively, these data demonstrate that the T6SS is a potent weapon during bacterial competition, and is used by both invading pathogens and resident microbiota to fight for a niche in the hostile gut environment.

Bauer KC, Littlejohn PT, Ayala V, Creus-Cuadros A, Finlay BB. Nonalcoholic Fatty Liver Disease and the Gut-Liver Axis: Exploring an Undernutrition Perspective. Gastronenterology. 2022 Jun;162(7):1858-1875.e2. doi: 10.1053/j.gastro.2022.01.058.

Nonalcoholic fatty liver disease (NAFLD) is a chronic condition affecting one quarter of the global population. Although primarily linked to obesity and metabolic syndrome, undernutrition and the altered (dysbiotic) gut microbiome influence NAFLD progression. Both undernutrition and NAFLD prevalence are predicted to considerably increase, but how the undernourished gut microbiome contributes to hepatic pathophysiology remains far less studied. Here, we present undernutrition conditions with fatty liver features, including kwashiorkor and micronutrient deficiency. We then review the gut microbiota-liver axis, highlighting key pathways linked to NAFLD progression within both overnutrition and undernutrition. To conclude, we identify challenges and collaborative possibilities of emerging multiomic research addressing the pathology and treatment of undernourished NAFLD.

Woodward SE, Vogt SL, Peña-Díaz J, Melnyk RA, Cirstea M, Serapio-Palacios A, Neufeld LMP, Huus KE, Wang MA, Haney CH, Finlay BB. Gastric acid and escape to systemic circulation represent major bottlenecks to host infection by Citrobacter rodentium. ISME J. 2023 Jan;17(1):36-46. doi: 10.1038/s41396-022-01321-9.

The gastrointestinal (GI) environment plays a critical role in shaping enteric infections. Host environmental factors create bottlenecks, restrictive events that reduce the genetic diversity of invading bacterial populations. However, the identity and impact of bottleneck events on bacterial infection are largely unknown. We used Citrobacter rodentium infection of mice, a model of human pathogenic Escherichia coli infections, to examine bacterial population dynamics and quantify bottlenecks to host colonization. Using Sequence Tag-based Analysis of Microbial Populations (STAMP) we characterized the founding population size (Nb') and relatedness of C. rodentium populations at relevant tissue sites during early- and peak-infection. We demonstrate that the GI environment severely restricts the colonizing population, with an average Nb' of only 12-43 lineages (of 2,000+ inoculated) identified regardless of time or biogeographic location. Passage through gastric acid and escape to the systemic circulation were identified as major bottlenecks during C. rodentium colonization. Manipulating such events by increasing gastric pH dramatically increased intestinal Nb'. Importantly, removal of the stomach acid barrier had downstream consequences on host systemic colonization, morbidity, and mortality. These findings highlight the capability of the host GI environment to limit early pathogen colonization, controlling the population of initial founders with consequences for downstream infection outcomes.

Multiple micronutrient deficiencies in early life cause multi-kingdom alterations in the gut microbiome and intrinsic antibiotic resistance genes in mice. Littlejohn PT, Metcalfe-Roach A, Cardenas Poire E, Holani R, Bar-Yoseph H, Fan YM, Woodward SE, Finlay BB.Nat Microbiol. 2023 Dec;8(12):2392-2405. doi: 10.1038/s41564-023-01519-3. Epub 2023 Nov 16.PMID: 37973864

Globally, ~340 million children suffer from multiple micronutrient deficiencies, accompanied by high pathogenic burden and death due to multidrug-resistant bacteria. The microbiome is a reservoir of antimicrobial resistance (AMR), but the implications of undernutrition on the resistome is unclear. Here we used a postnatal mouse model that is deficient in multiple

micronutrients (that is, zinc, folate, iron, vitamin A and vitamin B12 deficient) and shotgun metagenomic sequencing of faecal samples to characterize gut microbiome structure and functional potential, and the resistome. Enterobacteriaceae were enriched in micronutrient-deficient mice compared with mice fed an isocaloric experimental control diet. The mycobiome and virome were also altered with multiple micronutrient deficiencies including increased fungal pathogens such as Candida dubliniensis and bacteriophages. Despite being antibiotic naïve, micronutrient deficiency was associated with increased enrichment of genes and gene networks encoded by pathogenic bacteria that are directly or indirectly associated with intrinsic antibiotic resistance. Bacterial oxidative stress was associated with intrinsic antibiotic resistance in these mice. This analysis reveals multi-kingdom alterations in the gut microbiome as a result of co-occurring multiple micronutrient deficiencies and the implications for antibiotic resistance.

Development of Porous Nanomaterials for Energy and Environmental Applications

by Yoshio Bando, Member EUAS

Short Biography

Prof. Yoshio Bando has been leading the communities of nanomaterials and electron microscopy for many years. Holding a PhD degree from Osaka University, he joined the National Institute for Research in Inorganic Materials (NIRIM) in 1975. In 2001, NIRIM was merged with the National Research Institute for Metals to form the National Institute for Materials Science (NIMS), and he was appointed as Director of the Advanced Beam Analysis Group, followed by being appointed Director-General of International Center for Young Scientist. He became a NIMS Fellow in 2004. From 2008 to March 2017, he was responsible for the operation of MANA with the appointed position of Chief Operating Officer (COO). In addition, he was adjunct professor at the University of Tokyo (2009-2012) and guest professor of Waseda University (2008-2016). After retirement of NIMS in 2017, he has been appointed as Distinguished Professor at the University of Wollongong (UOW) from 2017 to 2021, Australia. He was also Professor at Institute for Molecular Plus, Tianjin University China from 2018 to 2021. He is now an Emeritus Fellow of NIMS and Honorary Professors at UOW, Australia. He is also Distinguished Scientist at King Saud University (KSU), Saudi Arabia. He has received many prestigious awards and fellowships, including the "Sacred Treasure" given from the Japanese Emperor in 2017, The 3rd Thomson Reuters Research Front Award in 2012, The Tsukuba Prize in 2005, Academician, The Commendation Award by the Minister of State for Science and Technology in 1998, The Academic Award of the Ceramic Society of Japan in 1997, The Seto Award of Electron Microscopy Society of Japan in 1994 and others. He was appointed as adjunct member of the Science Council of Japan in 2006. He is also a Fellow of the American Ceramic Society and the Royal Society of Chemistry. He served as Editor-in-Chief of Journal of Electron Microscopy and Editorial Board Members of "Nano Energy", "Small", "Nanotechnology", "Nanotechnology", "Nanomaterials" and others. He has been selected as ISI Highly Cited Researcher in Materials Science in 2012, 2014, 2015, 2016 2017, 2018, 2019, 2020, 2021,2022 and 2023. To date, he has authored about 913 original/review research papers that have been cited more than 67,765 times with h-index of 137 (Web of Science in 2023). He has registered 43 foreign patents and 70

Japanese patents..

Research Activities

1.Synergistic mesoporous bimetallic gold-silver nanoparticles: Synthesis, structure, and superior electrocatalytic activity[1)]

Mesoporous bimetallic nanoparticles have gained immense interest due to their unique properties and applications in various fields. In this study, we report a novel and straightforward one-pot chemical reduction method for the synthesis of mesoporous AuAg nanoparticles, featuring a substantial mesopore size (>10 nm) and a well-defined structure. The synthetic route involves employing L-cysteine as a ligand to form thiolate-metal(I) complexes and co-reduction of metal precursors around sacrificial templates of polymeric micelles. The resulting nanoparticles exhibit remarkable uniformity in size and possess a well-ordered mesoporous structure. Structural analyses confirm the formation of an alloy system containing Au and Ag without any distinct phases. By adjusting the initial precursor composition, precise control over the Au:Ag ratios in the final products is achievable. The electrocatalytic activity of mesoporous AuAg nanoparticles in the electrooxidation of small molecules surpasses that of mesoporous Au nanoparticles, owing to the synergistic effect arising from both the alterations in the electronic structure and the benefits offered by the porous architecture. This synthetic approach provides a promising avenue for developing efficient and cost-effective mesoporous Au-based nanoparticles for adverse range of applications.

2. A Self-Floating Robust Polyaniline-Wood Composite Fabricated by One-Step In-Situ Polymerization for High-Performance Solar Steam Generation[2)]

Owing to their cost-effectiveness and renewability, wood based solar steam generators (WSSG) have gained prominence in the field of desalination and water purification. However, conventional bi-layered WSSG is limited by the high energy consumption of fabrication and low strength of the bonding interface, which makes them unsuitable for long-

term applications. Here, a unique bi-layered structural composite with polyaniline (PANI) nanorods uniformly incorporated into a 3D mesoporous matrix of natural wood was fabricated via a one-step in-situ polymerization strategy. The PANI decorated wood (PANI-wood) shows ultrahigh sunlight absorptance (³98.9%) over a broad wavelength range (2002500 nm) due to the conjugation of coralloid PANI nanorods and wood. Moreover, numerous aligned wood microchannels enable constant and rapid water transport at the air-water interface under the pressure of capillary forces. The highly stable PANI-wood composite
shows high potential as an ideal solar steam generator with a high evaporation rate of 1.62 kgm2 h¹1, which is significantly higher than those of other previously reported wood based bi-layered composites. Moreover, PANI-wood exhibits long-term floating and is chemically stable, making it a potential candidate for low-energy photothermal interfacial sewage purification2).

References

1. Asep Sugih Nugraha, Minsu Han, Aditya Ashok, Yunqing Kang, Jeonghun Kim, Saad M. Alshehri, Tansir Ahamad, Yoshio Bando, Yusuke Yamauchi, “Synergistic mesoporous bimetallic gold-silver nanoparticles: Synthesis, structure, and superior electrocatalytic activity”, Nano Energy 116 (2023) 108770.

2. Taotao Meng, Zhengtong Li, Luzhen Wang, Kangjie Shi, Xiangting Bu, Saad M. Alshehri,Yoshio Bando, Yusuke Yamauchi, Dagang Li, and Xingtao Xu, “A self-floating robust Polyaniline-wood composite fabricated by one-step in-situ polymerization for high-performance solar steam generation”, Bull. Chem. Soc. Jpn., 96 (2023) 20230145.

DNA Methylation Changes Provide Insights into Prostate Cancer Precursor Lesions

by William Nelson, Member EUAS

Short Biography

Dr. Nelson is the Marion I. Knott Professor and Director of the Department of Oncology, Director of the Sidney Kimmel Comprehensive Cancer Center, and Professor of Medicine, Pharmacology, Pathology, Radiation Oncology, Urology, and Environmental Health Sciences at Johns Hopkins. He received his undergraduate degree in Chemistry at Yale University, and earned doctoral degrees in Pharmacology and in Medicine at the Hopkins School of Medicine. He then completed Internship and Residency training in Internal Medicine and a Fellowship in Medical Oncology at the Johns Hopkins Hospital. .

Dr. Nelson's research has focused on epigenetic aspects of prostatic carcinogenesis. He has now authored 337 articles and book chapters, attracting >41,000 citations with an h-index of 108, conducted 123 podcast interviews, and provided expert opinions for >300 additional podcasts. He also has secured 13 issued patents from the US Patent and Trade Office. He currently serves on the Board of the V Foundation, as a Scientific Co-Chair for Stand Up 2 Cancer, as Chair of the Board for Break Through Cancer, on the Scientific Advisory Board for the Prostate Cancer Foundation, and as Executive Editor of Cancer Today.

DNA Methylation Changes are Drivers of Prostatic Carcinogenesis

For some 80 years after Charles Huggins described the first molecularly targeted treatment for prostate cancer, the reduction of circulating male sex steroid hormones to attenuate androgen signaling in prostate cancer cells, the disease itself was thought to be caused by excessive androgen exposure[1,2]. This misconception persisted despite the recognition that testosterone and dihydrotestosterone levels fall steadily with age as prostate cancer incidence and mortality rise[3]. Furthermore, male sex steroid hormone levels do not differ between Black men and non-Hispanic White men despite in the United States (US) despite a 1.78-fold higher prostate cancer incidence and a 2.2-fold

higher prostate cancer mortality mortality for prostate cancer than non-Hispanic White men[4]. The identification of somatic translocations between androgen receptor genes, such as *TMPRSS2*, and ETS family oncogenes in many prostate cancer cases hints that far from promoting prostatic carcinogenesis, the propensity for androgen signaling to drive terminal differentiation of prostate epithelial cells may comprise a significant barrier to neoplastic transformation[5].

Instead, prostate cancers appear to arise in a chronically inflamed microenvironment within the prostate gland somehow triggered by diet and lifestyle practices common in most developed countries across the world[6,7]. Yet, the nearly ubiquitous presence of asymptomatically inflammation in prostates from aging men from these regions has complicated attempts to formally test causal associations between prostate inflammation and prostate cancer[4]. Perhaps the best population data in support of this hypothesis comes from analyses of study cohorts where men underwent 'end-of-study' prostate biopsies as part of the placebo arms of the Prostate Cancer Prevention Trial (PCPT) and the ensuing Selenium and Vitamin E Cancer Prevention Trial (SELECT)[11,12]. For men in PCPT, prostate cancer was detected more commonly when prostate inflammation was also present, with an odds ratio of 1.78 for all prostate cancer and 2.24 for high-grade prostate cancer[13]. And for men on the placebo arm of PCPT who later participated in SELECT, the chance of detecting prostate cancer some 5.9 years later at the end-of-study SELECT biopsy was increased as much as 1.6-fold, depending on the amount of inflammation seen on the prior end-of-study PCPT biopsy[14].

The recognition that an inflamed milieu within the prostate can spawn specific lesions termed proliferative inflammatory atrophy (PIA) has opened the door for more mechanistic queries on the contributions of inflammation to prostatic carcinogenesis. PIA lesions, now suspected to embody the earliest precursors to full-blown, invasive, prostate cancer, contain damaged and regenerating epithelial cells showing molecular signs of stress in place of androgen-regulated differentiation to a secretory phenotype[8]. The evidence that PIA can give rise to prostatic intraepithelial neoplasia (PIN) and prostatic carcinoma includes: *(i)* the direct proximity of many PIA lesions to PIN and to prostatic carcinoma, *(ii)* some sharing of molecular alterations between some PIA lesions, PIN, and prostatic carcinomas, and *(iii)* the propensity for PIA lesions to arise in advance of PIN and prostatic carcinoma in exposure-driven rodent models of prostatic carcinogenesis[9-11]. The tight association of PIA to prostate inflammation is reflected in the propensity for cells within PIA lesions to produce inflammatory cytokines IL-1, IL-6, and IL-8[7,16]. Inflammatory cytokine exposure itself may be sufficient to cause PIA: mice genetically-engineered to produce IL-1 in the prostate generate PIA lesions[17].

Among all of the molecular alterations catalogued for human prostate

cancers, the most common early changes appear to be MYC activation, telomere shortening, increased DNA methylation at critical genes such as *GSPT1*, and rearrangements involving ETS family transcription factors[18]. Hypermethylation at the *GSTP1* promoter causing loss of GSTP1 expression has attracted particular interest because while it is not present in normal prostate cells, it is the most frequent genome defect yet reported in prostate cancer cells, present in >90% of cases, and appears to be the earliest to arise, detected in some 6.3% of PIA lesions[19,20].

In full-blown invasive prostate cancers, the ~kb CpG island which surrounds the *GSTP1* promoter tends to be very densely populated with $^{5\text{-me}}$CpG dinucleotides[21]. Yet in a study reported this year, detailed bisulfite sequencing analyses of the distribution of $^{5\text{-me}}$CpG dinucleotides within the CpG island region of *GSTP1* in DNA recovered from PIA, PIN, and prostatic carcinoma lesions revealed an increasing density of $^{5\text{-me}}$CpG accompanying prostatic carcinogenesis, from PIA to PIN to prostatic carcinoma[22]. Thus for the first time for any human cancer, the findings provided a glimpse into earliest epigenetic events accompanying neoplastic transformation. Of interest, previous model studies where *GSTP1* promoter sequences were transfected into culture prostate cancer cells had suggested that 'seeding' of rare $^{5\text{-me}}$CpGs led to spreading of DNA methylation changes, and to an increased $^{5\text{-me}}$CpG density, if transcription had been silenced[23]. The new findings of sparse $^{5\text{-me}}$CpG density in prostate cancer precursor lesions support this model, and present a critical etiologic question: what are the molecular mechanisms by which inflammatory stressors drive $^{5\text{-me}}$CpG 'seeding' and loss of transcription at the *GSTP1* promoter and elsewhere within the genomes of PIA cells?

As is the case for prostate cancer, chronic or recurrent inflammation in response to significant environmental exposures propels the pathogenesis of most epithelial cancers. Somehow, these carcinogenic insults lead to changes in DNA methylation in all the resultant cancers, exerting profound effects on the portfolio of genes available for regulated expression. Abnormal DNA methylation changes have already emerged as a therapeutic target for established cancers. Moving forward, these epigenetic defects could provide an avenue for cancer prevention. Ultimately, if the molecular details regarding the placement *de novo* of DNA methylation changes at the *GSTP1* promoter can be determined, new tactics to prevent such molecular alterations could be discovered with the potential of preventing prostate cancer, and many other significant human cancers threatening morbidity and mortality throughout the world.

References

1. Huggins C, Hodges CV. Studies on prostatic cancer. *Cancer Res.* 1941; 1:293-297
2. Nelson WG. Commentary on Huggins and Hodges "Studies on prostate cancer". *Cancer Res.* 2016; 76:186-187.
3. Rohrman S *et al.* Serum estrogen, but not testosterone levels differ between black and white men in a nationally representative sample of Americans. *J Clin Endocrinol & Metabol.* 2007; 92: 2519-2525.
4. Nelson WG *et al.* Health inequity drives disease biology to create disparities in prostate cancer outcomes. *J Clin Invest.* 2022; 132:e155031.
5. Haffner MC *et al.* Transcription-induced DNA double strand breaks: both oncogenic force and potential therapeutic target? *Clin Cancer Res.* 2011; 17:3858-3864.
6. Nelson WG *et al.* Prostate cancer. *New Engl J Med.* 2003;349:366-381.
7. De Marzo AM *et al.* Inflammation in prostate carcinogenesis. *Nat Rev Cancer.* 2007;7:256-269.
8. De Marzo AM *et al.* Proliferative inflammatory atrophy of the prostate; implications for prostatic carcinogenesis. *Am J Pathol.* 1999; 155:1985-1992.
9. Putzi MJ, De Marzo AM. Morphologic transitions between proliferative inflammatory atrophy and high-grade prostatic intraepithelial neoplasia. *Urology* 2000; 56:828-832.
10. Bethel CR *et al.* Decreased NKX3.1 protein expression in focal prostatic atrophy, prostatic intraepithelial neoplasia, and adenocarcinoma: association with Gleason score and chromosome 8p deletion. *Cancer Res.* 2006; 66:10683-10690.
11. Gurel B *et al.* Nuclear MYC protein overexpression is an early alteration in human prostate carcinogenesis. *Mod Pathol,* 2008; 21:1156-1167.
12. Thompson *IM et al.* The influence of finasteride on the development of prostate cancer. *New Engl J Med.* 2003; 349:215-224.
13. Lippman SM *et al.* Effect of selenium and vitamin E on risk of prostate cancer and other cancers: the Selenium and Vitamin E Cancer Prevention Trial (SELECT). *JAMA.* 2009; 301:39-51.
14. Gurel B *et al.* Chronic inflammation in benign prostate tissue is associated with high-grade prostate cancer in the placebo arm of the prostate cancer prevention trial. *Cancer Epidemiol Biomarkers Prev.* 2014; 23:847-856.
15. Platz EA *et al.* A prospective study of chronic inflammation in benign prostate tissue and risk of prostate cancer: linked PCPT and SELECT cohorts. *Cancer Epidemiol Biomarkers Prev.* 2017; 26:1549-1557.
16. Maynard JP *et al.* IL8 expression is associated with prostate cancer aggressiveness and androgen receptor loss in primary and metastatic prostate cancer. *Mol Cancer Res.* 2020; 18:153-165.
17. Ashok A *et al.* Consequences of interleukin 1b-triggered chronic inflammation in the mouse prostate gland: altered infiltration mimics human proliferative inflammatory atrophy. *Prostate.* 2019; 79:732-745.
18. Haffner MC *et al.* Genomic and phenotypic heterogeneity in prostate cancer. *Nat Rev Urol.* 2021; 18:79-92.
19. Nelson WG *et al.* Epigenetic alterations in human prostate cancers. *Endocrinology.* 2009; 150:3991-4002.
20. Nakayama M *et al.* Hypermethylation of the human glutathione S-transferase-pi gene (GSTP1) CpG island in a subset of proliferative inflammatory atrophy lesions but not in normal or hyperplastic epithelium of the prostate: a detailed study using laser capture microdissection. *Am J Pathol.* 2003; 163:923-933.
21. Lin X *et al.* GSTP1 CpG island hypermethylation is responsible for the absence of GSTP1 expression in human prostate cancer cells. *Am J Pathol.* 2001; 159:1815-1826.
22. Gupta H *et al.* Progressive spreading of DNA methylation in the GSTP1 promoter CpG island across transitions from precursors to invasive prostate cancer. *Cancer Prev Res.* 2023; 16:449-460.
23. Song JZ *et al.* Hypermethylation trigger of the glutathione S-transferase gene (GSTP1) in prostate cancer cells. *Oncogene* 2002; 21:1048-1061.

New Progress on Structural Safety and Control

by Hong-Nan Li, Member EUAS

Short Biography

Dr. Hong-Nan Li received his bachelor, master and PhD degrees from China in 1982, 1987 and 1990, respectively. He had conducted his postdoctoral research at Virginia Polytechnic Institute and State University from 1992-1994. He has been a Distinguished Professor of School of Civil Engineering at Dalian University of Technology (DUT), China since Sept. 2001. He is the founding director of the Research Center for Structural Health Monitoring and Control at DUT.

He is a Fellow of American Society of Civil Engineers (ASCE). His research interests are primarily in safety and security of civil infrastructure systems, focusing on development of innovative and interdisciplinary science and technology for sensors, health monitoring, damage assessment, structural control and disaster prevention. He is the author/co-author of 8 books and more than 400 refereed journal papers including more than 300 international journals. He is also an inventor or co-inventor of 67 invention patents and 8 computer software certificates. He has delivered over 80 keynote and invited lecture at international conferences and universities in different countries.

He ever edited the first standard in the area of SHM in China "Design Standard for Structural Health Monitoring Systems (CECS 333: 2012)" and other 15 standards. His related achievements have been applied to more than 70 major infrastructures, such as the Zhoushan Transmission Tower (The World's the Tallest Transmission Tower), Dalian gymnasium (The World's Largest Span Suspended Dome Structure), the long span suspension dome structure NB35-2 (Ultra Large Offshore Oil Platform), Shenyang Boguan bridge (Complicated Long-Span Arch Bridge), Dalian World Trade Center. He received various prizes in recognition of his innovative achievements in research, such as played a leading role in the 2015 National Technology Invention Award, 2010 & 2007 National Science and Technology Progress Awards, and more than 10 provincial Science & Technology awards in China. He was also awarded as the "Outstanding Technical Contribution Award" by ASCE Aerospace Division (2014)

With a long-term commitment to serving society, He is currently the Editor-in-Chief of Structural Monitoring and Maintenance, An international Journal, Associate Editor of Journal of Aerospace Engineering-ASCE and an editorial board member of more than 30 other journals. He also has held many extensive academic and professional leadership positions related to: vice chair of the Advanced Materials and Structures committee & vice chair Dynamics and Controls Committee, American Society of Civil Engineers (ASCE); vice chair of China Panel, International Association for Structural Control and Monitoring (IASHM); council member of The International Society for Structural Health Monitoring of Intelligent Infrastructure (ISHMII), etc.

Dr. Li promoted the education of undergraduate students and graduate students in Civil Engineering. He has supervised more than 56 Ph.D. students and 70 Master students. Some thesis from his students were awarded for the provincial excellent theses.

New Progress on Research Activities

1. Development of an explicit time integral algorithm based on optimal integration parameters updating

The integral algorithm is an important mean to solve the discrete time equations of structural dynamics in earthquake engineering. In this paper, a new model-based explicit integration algorithm, featured by updating the integral parameters based on optimization, is newly developed for a more accurate and efficient solution of structural dynamic problems. Numerical properties of the new integration algorithm are investigated in details using the amplification matrix method for a linear elastic single degree-of-freedom system. Meanwhile, a series of typical numerical examples are analyzed and compared with other representative conventional algorithms to further supplement analysis results and illustrate the improved performance of the new algorithm. The following key conclusions can be drawn:

(1) The acquisition of the optimal integral parameters is related to the optimization method and the number of generations. A more accurate solution of the optimal parameters will be obtained when using an optimistic method with powerful capacity in global optimization. Besides, considering the burden of computation, it is necessary to select an optimization algorithm with a simple form and satisfactory convergence.

(2) The new algorithm is consistent and possess the second-order accuracy when $1/2\ \alpha 2 = \alpha 1\ \beta$, $\beta = 2/(-1/6\ \Omega\hat{}2 + 2/3\ \xi\hat{}2\ \Omega + \xi\Omega + 1)$ and $\alpha 2 = 2 - (2\xi\Omega\hat{}(-1) + \xi\Omega + 2/3\ \xi\hat{}2\ \Omega\hat{}2)\beta$; otherwise, it will have the first-order accuracy. This property of the proposed method is identical to the Newmark algorithms.

(3) The new algorithm is a complete explicit integral algorithm with unconditional stability. It shows negligible numerical damping for the low order modes and visible numerical damping for the high order modes. Nevertheless, its amplitude decay exhibits a significant increasing trend when $\Omega > 1$.

(4) When the new algorithm is introduced to the nonlinear systems, the stability of the algorithm can still be guaranteed by the constraint conditions with sacrifice of its accuracy in both stiffness hardening and softening systems.

(5) The new algorithm has equivalent performance for the MDOF system compared to the SDOF system. It also shows superior accuracy in the application of structural dynamic response analysis under the ground motion excitations.

In comparison with other algorithms, the new algorithm has the most promising

advantages of controllable accuracy and numerical characteristics that can be adjusted by changing the objective functions and constraint conditions according to the specific requirements. Besides, the proposed method promotes to be more accurate in the pseudo-dynamic or real-time substructure tests, since its optimization goal is to minimize the error.

2. Optimal vibration control design of antenna mast on super-tall buildings against multi-hazards of earthquake and wind

Antenna mast structures are usually set on the top of modern super-tall buildings to meet the requirements of communication and aesthetics, and such buildings are highly sensitive to horizontal loads that can greatly increase the acceleration and displacement responses during their life-cycles owing to the inherent high flexibility and low damping. As a result, the antenna masts with small mass and stiffness may suffer serious whiplash effect under the earthquake or wind excitations. In this paper, a multi-hazard protective system with hybrid isolated and energy-dissipated devices of isolation bearing, viscous damper, and mild steel damper is presented for the typical inserted antenna mast structures on super-tall buildings. To determine the optimum parameters of the hybrid system that maximize the structural control efficiency under a single hazard of earthquake or wind load, as well as the coupled conditions of these two hazards, an optimization method based on the genetic algorithm is developed for the presented hybrid control system to resist various hazard scenarios. Objective functions are further proposed to penalize the relative accelerations and displacements at the top of the antenna mast structure. Taking a super-tall TV tower as an example, the OpenSeesPy platform is employed to establish the finite element (FE) model. The numerical results show that the optimization scheme for the hybrid energy-dissipated antenna mast system under a single hazard is not suitable for the other hazard condition, while the optimized results for the multi-hazard condition can give consideration to the effects of both earthquake and wind. Moreover, the sensitive analysis is performed to investigate the effect of each parameter of the hybrid system on the objective functions. It can be concluded that the proposed hybrid system performs well under earthquake, wind and coupled multi-hazard, which is of practical significance for the vibration control of antenna masts on super-tall buildings.

3. Wind-resistant performance and failure modes for “Deep Sea No. 1” energy station in LS17-2 gas field during jacking

closure

Currently, the construction process of large offshore platforms worldwide involves building the topside and hull separately and then having them integrated. The jacking closure scheme by overlapped support tower bearing the topside is a new integration method, which has great advantage over other traditional methods in vertical bearing capacity. But its weak bearing capacity to lateral forces like wind load limits the jacking height. Moreover, few engineering examples and academic researches also cause insufficient understanding on it. Therefore, this paper, based on the first deep-water semi-submersible platform with the10,000-ton oil storage worldwide, i.e. “Deep Sea No. 1” energy station, aims to evaluate the wind-resistant performance during the jacking closure process. Firstly, the background and the jacking closing scheme of this project are introduced in detail. Secondly, the finite element model (FEM) of the jacking system is established according to the overlapped characteristics of jacking towers and the corresponding failure modes. Then, the wind-induced vibration response is simulated, and the static pushover is conducted to evaluate the ultimate bearing capacity and its influencing factors. The failure criteria are checked using ANSYS parameter design language. It is found that “the occurrence of tensile stress on the contact surface” is the first and main failure mode of the structure. Additionally, the results also reveal that the strand cables can not only improve the ultimate bearing capacity of the structure but also change its weak direction. However, the improvement is gradually weakened with the increase of jacking height. In contrast, the contribution of the bracing pipes to the structural bearing capacity is always significant. Some significant conclusions can be drawn from the numerical results:

(1) The wind-induced vibration coefficient of jacking towers is almost constant with the increase of height, while the wind-induced vibration coefficient of corner points in the topside is noticeably larger than that of the center point, which indicates that the torsion effect has a great influence. Therefore, in the static pushover calculation, the wind-induced vibration coefficient of jacking towers can be directly averaged without considering the influence of height, while that of the topside should take into account the amplification influence of the torsion effect on the dynamic response and adopt different values at different loading points.

(2) The wind-induced vibration coefficient varies with the progress of jacking construction, i.e. different jacking system models have different wind-induced vibration coefficients. In addition, different wind directions correspond to different weaker jacking towers. So in the static pushover analysis, not only different

jacking-up stages should be considered, but also the influence of wind direction should be adequately considered.

(3) “The occurrence of tensile stress on the contact surface”, “yield failure under vertical pressure”, and “shear failure under lateral load” of the jacking beam are taken as the failure control criteria of all FEMs. Additionally, the failure criteria were checked using the ANSYS parameter design language. The results show that “the occurrence of tensile stress on the contact surface” is the first and main failure mode of the structure. So, “the occurrence of tensile stress on the contact surface” can be taken as the control criterion of structural failure.

(4) The strand cables can not only improve the ultimate bearing capacity of the structure but also change its weak direction. These also have the flexibility advantage of being monitored in real time. However, its effect of improving the bearing capacity is gradually weakened with the increase of the jacking height. In contrast, the contribution of the bracing pipes to the increase in the bearing capacity of the structure is always significant. Therefore, the characteristics of the two can be used to develop a more reasonable closure plan before construction, additionally, the strand cables can be monitored in real-time during the construction process to deal with emergencies and ensure the safety of the structure.

Roadmap for Interactive Granular Computing (IGrC) in the Era of AI in the Connected World

by Andrzej Skowron, Member EUAS

Short Biography

Andrzej Skowron, *ECCAI (EurAI), AAIA and IRSS Fellow, Member of Academia Europaea (MAE), Member EU Academy of Sciences, Web Intelligence Academy Founding Fellow (WIA), Advisory Board member of Web Intelligence Consortium, received the Ph. D. and D. Sci. (habilitation) from the University of Warsaw in Poland. In 1991 he received the Scientific Title of Professor. He is Full Professor in the Systems Research Institute, Polish Academy of Sciences. He is Emeritus Professor in Faculty of Mathematics, Computer Science and Mechanics at the University of Warsaw. Andrzej Skowron is the (co)author of more than 400 scientific publications and editor of many books, special issues of journals and volumes of conference proceedings. His areas of expertise include reasoning with incomplete information, approximate reasoning, soft computing methods and applications, rough sets, rough mereology, (interactive) granular computing, intelligent systems, (adaptive) complex systems, perception based computing, machine learning. He was the supervisor of 22 PhD Theses. In the period 1995-2009 he was the Editor-in-Chief of Fundamenta Informaticae journal. He is on Editorial Boards of many others international journals. Andrzej Skowron was the President of the International Rough Set Society (1996-2000). He has delivered numerous invited talks at international conferences including a plenary talk at the 16th IFIP World Computer Congress (Beijing, 2000), a keynote talk at the 8th Joint Conference on Information Sciences (JCIS 2005) (encompassing 12 individual conferences and workshops) (USA, 2005), an invited talk at the 2006 IEEE/WIC/ACM International Conference on Intelligent Agent Technology (IAT 2006) and on Web Intelligence (WI 2006) (Hong Kong, 2006), and a plenary talk at the 2nd World Congress on Biologically Inspired Computing (Japan, 2010). He was serving as (co-)program chair or PC member of more than 200 international conferences. He was involved in numerous research and commercial projects including dialog-based search engine (Nutech), fraud detection for Bank of America (Nutech), logistic project for General Motors (Nutech), algorithmic trading (Adgam), control of UAV (Linköping University), and medical decision support (e.g., in Polish-American Pediatric Clinic in Cracow). Andrzej Skowron was on the ICI Thomson Reuters/ Clarivate Analytics lists of the most cited researchers in Computer Science (globally) in 2012, 2016, 2017. H-index=66 (Google Scholar).*

Abstract

This article is a continuation of Andrzej Skowron's articles published, in particular in EU ACADEMY ANNUAL REPORTS 2019-2022 and focuses on works related to Interactive Granular Computing (IGrC). More details about IGrC can be found in papers related to

IGrC on the site https://dblp.org/pid/s/AndrzejSkowron.html, and in the recent invited lectures of the author. In this report we concentrate on the roadmap for IGrC in WI = AI in the connected world (https://wi-consortium.org/wiacademy.php). In particular, we present a short discussion on perspectives of IGrC in further development foundations of Intelligent Systems (IS's) dealing with complex phenomena, adaptive rough sets and fuzzy sets as well as cognitive computing. For more details the reader is referred, e.g., to [2,18].

Comments on IGrC model for building foundations for IS's dealing with complex phenomena.

IGrC is attempting to model computational building blocks for cognition (see http://people.seas.harvard.edu/~valiant/researchinterests.htm) using dynamic complex granules (c-granules) generated along interactive granular computations. One should note, that many of such computational building blocks are not pure mathematical objects, e.g., they can be specified in natural language by complex vague concepts or they may contain both abstract and physical objects when aspects of perception and action are both considered in modelling of granules.

There is a huge literature about Granular Computing (GrC). However, it is emphasised in [13]:

The current studies of decision-making with GrC lack a theoretical foundation and normative research paradigm.

The IGrC model is the computing model which we selected as the basis for developing theoretical foundations for the design and analysis of Intelligent Systems (IS's) dealing with complex phenomena in the physical world. According to opinions of many researchers in this case classical mathematical modeling is not satisfactory. For example, according to Frederick Brooks [1]:

Mathematics and the physical sciences made great strides for three centuries by constructing simplified models of complex phenomena, deriving, properties from the models, and verifying those properties experimentally. This worked because the complexities ignored in the models were not the essential properties of the phenomena. It does not work when the complexities are the essence.

Hence, one cannot expect that humans are able to derive the high quality models of the vague concepts related to complex phenomena using traditional mathematical modeling. It is also worthwhile to mention here the current discussion on Turing test [14]:

The Turing test, as originally conceived, focused on language and reasoning; problems of perception and action were conspicuously absent. The proposed tests will provide an opportunity to bring four important areas of AI research (language, reasoning, perception, and action) back into sync after each has regrettably diverged into a fairly independent area of research.

According to the above opinions and many other evidences from different areas [18], construction of models for complex vague concepts related to complex phenomena in the physical world should be grounded on an unconventional computing model able to deal with abstract and physical objects. This is necessary for modelling interactions of IS's with the physical world in perception by IS's of different situations in this world. We propose to base processes of construction of models for such concepts on IGrC. In [2] we discuss how application of the IGrC model may enhance the performance of a medical decision support platform.

Adaptive fuzzy sets based on IGrC

Fuzzy sets are defined by fuzzy membership functions of the form $f: X \rightarrow [0,1]$, where X is a given universe of objects and [0,1] is the unit interval of reals [19-20]. Such objects are purely mathematical (abstract). Problems related to the question how such functions are modelled for complex vague concepts are outside of the mathematical theory of fuzzy sets [20]. For IS's dealing with complex phenomena the traditional approach closed in the abstract space is not satisfactory because IS's should be able to construct membership functions as the result of perceiving situations in the physical world. From the experience of many researchers (see, e.g., the cited above opinion by Frederick Brooks) we cannot expect that it will be possible to derive the high quality models of the vague concepts related to complex phenomena using traditional mathematical modeling. Fuzzy membership functions for complex vague concepts are examples of such models. In discovery of such models one should consider the necessity of inducing the definition of the set X (e.g., based on value vectors of some relevant attributes, time series or structural representation of results of perception) and next models of fuzzy membership functions based on X. One should also take into account the necessity of adaptation of induced models according to perceived changes in the physical world. We propose to base approximation of such membership functions on IGrC. In a sense, we are following the discussion on necessity to modify the Turing test by putting into sync in IGrC not only issues of language and reasoning but also perception and action [13].

Adaptive rough sets based on IGrC

One of the most important object of the rough set theory is the indiscernibility relation [15-18]. On the basis of the indiscernibility relation (relative to a given set of attributes A) are constructed the lower approximation $LOW(A,X)$ and the upper approximation $UPP(A,X)$ of subsets X of a given universe U of objects. The set of borderline cases of X (relative to A), called the boundary region of X is defined by the set theoretical difference $UPP(A,X) \setminus LOW(A,X)$. However, this is contrary to opinion of philosophers claiming that the collection of borderline cases is not definable in set theory [8]. However, one should take into account that defining the approximations of a considered concept we take into account only a sample U of objects and some attributes A as well as exemplary cases from U *for* and *against* of the approximated concep. If these items are changing the boundary region is 'moving'. However, the issues of how this dynamical process of 'moving' is defined was not investigated in detail in the rough set theory so far. Using IGrC it is possible to use c-granules with control responsible for modifying accordingly these items. One should take into account that this dynamic process is influenced by interactions of c-granules with the real physical world what causes that the dynamics of perceived situations cannot be defined precisely [18].

Toward developing of fuzzy cognitive computer based on IGrC

Human-inspired computing is defined as the intelligence computing model enlightened by human brain intelligence and biological processes. We propose to take (networks of) c-granules, the basic components of IGrC, as the basic ingredients of such a model. They seem to be the relevant in modelling basic and higher order granular neurons. They have a

richer structure then traditional artificial neurons and they seem to be more suitable as objects for designing of cognitive computers based on IGrC than the traditional artificial neurons. For example, on different levels of hierarchical modelling may be used c-granules with different languages for expressing perceived properties. Certainly, here arises a challenge related to discovery of such languages. In the future, we will investigate dynamical structures related to granulation of c-granules (e.g., into networks of c-granules) and their degranulation processes aiming at searching for the relevant c-granules understood as computational building blocks for cognition, using the Valiant formulation (see http://people.seas.harvard.edu/~valiant/ researchinterests.htm). These computational building blocks can be used, e.g., to approximate complex vague concepts triggering realization of transformations' specifications (e.g., in the form actions or plans) by control of c-granules. For modeling of cognitive computer, evolving societies of networks of c-granules will be used following experience (e.g., in the developing of its distributed control) widely discussed in the literature (see, e.g., [4-6,8,10-12). Further cooperation with neuroscientists [6] may substantially enhance the development of strategies for modeling such dynamical structures. Also issues of multiscaling reasoning inspired by biological processes are of the great importance. Here, it is worthwhile to cite the following statement from [3]:

> *One of the fascinating goals of natural computing is to understand, in terms of information processing, the functioning of a living cell. An important step in this direction is understanding of interactions between biochemical reactions.* […] *the functioning of a living cell is determined by interactions of a huge number of biochemical reactions that take place in living cells.*

References

[1] Brooks, Jr., F.P.: The Mythical Man-Month: Essays on Software Engineering, Anniversary Edition. Addison-Wesley (1995)
[2] Soma Dutta, S., Skowron, A., Sosnowski, Ł.: Medical decision support in the light of interactive granular computing: Lessons from the Ovufriend project. International Journal of Approximate Reasoning 165, 1–13 (2024).
[3] Ehrenfeucht, A., Rozenberg, G.: Reaction systems: A model of computation inspired by biochemistry. In: Gao, Y., Lu, H., Seki, S., Yu, S. (eds.), Developments in Language Theory, Springer Berlin, Heidelberg, pp. 1–3 (2010).
[4] Gerrish, S.: How Smart Machines Think. MIT Press, Cambridge, MA (2018)
[5] Gershenson, C.: Design and Control of Self-organizing Systems, PhD Thesis. Vrije Universiteit, Brussel (2007), https://web-archive.southampton.ac.uk/cogprints.org/5442/1/thesis.pdf
[6] Gershenson, C.: Guiding the self-organization of cyber-physical systems. Frontiers Robotics AI 7, 1–13 (2020).
[7] Gazzaniga, M., Ivry, R.B., Mangun, G. R.: Cognitive Neuroscience: The Biology of the Mind. W. W. Norton & Company, New York, NY (2019)
[8] Hurwitz, J., Kaufman, M., Bowles, A.: Cognitive Computing and Big Data Analytics. Wiley & Sons, Inc., Indianapolis (2015)
[9] Keefe, R.: Theories of Vagueness. Cambridge Studies in Philosophy, Cambridge, UK (2000)
[10] Mendel, J.M.: The perceptual computer: an architecture for computing with words. In: Proceedings of Modeling with Words, Workshop in Proceedings of FUZZ-IEEE, Melbourne, Australia, pp. 35–38 (2010)
[11] Minsky, M.: Society of Mind. Simon & Schuster, New York, NY (1985)

[12] Minsky, M.: The Emotion Machine. Commonsense Thinking, Artificial Intelligence, and the Future of the Human Mind. Simon & Schuster, New York, NY (2006)
[13] Qin, J., Martínez, L., Pedrycz, W., Ma, X., Liang, Y.: An overview of granular computing in decision-making: Extensions, applications, and challenges. Information Fusion 98, 101833 (2023).
[14] Ortitz Jr., C.L.: Why we need a physically embodied Turing test and what it might look like. AI Magazine 37, 55–62 (2016)
[15] Pawlak, Z.: Rough sets. International Journal of Computer and Information Sciences 11, 341–356 (1982).
[16] Pawlak, Z.: Rough Sets: Theoretical Aspects of Reasoning about Data, System Theory, Knowledge Engineering and Problem Solving, vol. 9. Kluwer Academic Publishers, Dordrecht, The Netherlands (1991).
[17] Pawlak, Z., Skowron, A.: Rudiments of rough sets. Information Sciences 177(1), 3–27 (2007).
[18] Skowron, A., Ślęzak, D.: Rough sets in interactive granular computing: Toward foundations for intelligent systems interacting with human experts and complex phenomena. In: Campagner, A., O.U., Xia, S., Ślęzak, D., Wąs, J., Yao, J.T. (eds.) Rough Sets. IJCRS 2023. Lecture Notes in Computer Science, vol. 14481, pp. 1–23 (2024).
[19] Wu, H.C.: Mathematical Foundation of Fuzzy Sets. John Wiley & Sons (2023).
[20] Zadeh, L.A.: Fuzzy sets. Information and Control 8, 338–353 (1965)

Recent Developments in Ion-Solid Interactions

by William J. Weber, Member EUAS

Short Biography

Professor Emeritus, Department of Materials Science and Engineering, The University of Tennessee - Knoxville

Prof. William J. Weber received his PhD in Nuclear Engineering from the University of Wisconsin - Madison, USA. He joined Pacific Northwest National Laboratory (PNNL) in 1977 as a research scientist and was appointed Laboratory Fellow in 1997. During 1983, he was a visiting scientist at the Institute for Transuranium Elements in Karlsruhe, Germany, He is currently Professor Emeritus in the Department of Materials Science and Engineering at the University of Tennessee. He retired as Professor and Director of the Ion Beam Materials Laboratory in January 2023. From 2010 through 2020, he was the Governor's Chair Professor for Radiation Effects in Materials at the University of Tennessee, with a joint appointment at Oak Ridge National Laboratory. His research has encompassed the fundamental aspects of radiation-solid interactions, radiation effects in materials, ion beam modification and analysis of materials, and defects and defect processes in materials. Much of his current research emphasizes the coupling of electronic and atomic energy dissipation processes and their role on radiation effects, defect evolution, formation of novel nanostructures, creation of new functionalities, and the response of materials to extreme environments. He is a member of the EU Academy of Sciences (2016), Fellow of the American Ceramic Society (2000), Fellow of the American Association for the Advancement of Science (2006), Fellow of the Materials Research Society (2008), Fellow of the American Physical Society (2010) and Fellow of the Ion Beam Society of India (2016). He is the recipient of the MRS Woody White Service Award from the Materials Research Society (2023); the Radiation Effects in Insulators Award from the International Committee on Radiation Effects in Insulators (2023), the James I. Mueller Award from the American Ceramic Society (2020); Lee Hsun Lecture Award (2015); the Outstanding Young Alumni Award (1983) and the Distinguished Alumni Award (2009) from the University of Wisconsin - Oshkosh; the PNNL Laboratory Director's Award for Individual Lifetime Achievement in Science & Technology (2009); the PNNL Laboratory Director's Award for Scientific and Engineering Excellence (1995); the PNNL Chester L. Cooper Mentor of the Year Award (2005); and the U.S. Department of Energy's Materials Science Award for Research with Significant Implication for DOE Related Technologies (1995). He has published more than 602journal articles, 118 peer-reviewed conference papers, and 14 book chapters. Based on the Web of Science, his publications have over 27,700 citations, with an h-index of 82; based on Scopus, his publications have over 29,700 citations, with an h-index of 83; based on Goggle Scholar, his publications have over 37,300 citations, with an h-index of 92.

The interaction of energetic ions with a solid is well known to result in inelastic energy loss to electrons and elastic energy loss to atomic nuclei in the solid. However, the coupled effects of these energy loss pathways and the critical role of energy dissipation processes on defect production and the evolution of defects, nanostructures and phase transformations under far from equilibrium conditions in materials are complex and not well understood. Particularly challenging are the dynamics of energy transfer processes to electrons and the exchange of energy between electrons and the atomic nuclei via electron-phonon coupling. In general, the electrons along the ion path undergo a high degree of excitation and electron–electron scattering, and they subsequently transfer much of their energy, via electron–phonon coupling, to atoms in the same region, causing a highly-localized thermal spike. Following thermalization of the electrons and recombination of electrons and holes, a high density of localized electronic defects (trapped electrons, holes and excitons) may remain. This partitioning of energy deposition and energy dissipation on the electronic and atomic structures are important to the control of ion beam modification methods to create defects and nanoscale structures that tailor materials properties or create new functionalities, as well as the development of radiation-tolerant materials and devices. Predicting and modeling such complex processes, which are temporally and spatially coupled, are grand challenges that demand fundamental understanding of materials processes at the level of electrons and atoms over several orders of magnitude in time scale, from femtoseconds to nanoseconds.

The effects of thermochemical treatments on the (He-Cd) laser-excited emission spectra of $SrTiO_3$ have been compared with results obtained under ion-beam irradiation. Emission bands centered at 2.4 eV and 2.8 eV, which appear under laser excitation, exhibit intensities dependent upon previous thermal treatments in oxidizing (O_2) or reducing atmosphere (H_2). The emission band centered at 2.8 eV is clearly enhanced in samples exposed to a reducing atmosphere. By comparing with the ion-beam-induced luminescence data, it is clear that the laser-excitation experiments can be rationalized within a framework developed from ion-beam excitation studies. In particular, the band at 2.8 eV, sometimes attributed to oxygen vacancies, does not exhibit any correlation with the concentration of oxygen vacancies but it does behave as expected for optical transitions from conduction-band (CB) states to the ground state level of the self-trapped exciton center. The band at 2.0 eV reported in ion-beam irradiated $SrTiO_3$, and attributed to oxygen vacancies, is not observed in laser-excited crystals. As a consequence of this analysis, a consistent scheme of electronic energy levels and optical transitions can now be reliably offered for $SrTiO_3$.

Oxide perovskites exhibit fascinating properties that identify them as key materials for the next generation of multifunctional devices, and ion-beam modification can be used to tune their functionality. While it is well-established that atomic-level defects are created by elastic (nuclear) energy transfer, S_n, from charged particles to atomic nuclei, the effects of inelastic (electronic) energy loss, S_e, to target electrons is more complicated. High-energy ions with S_e values above a threshold of 5.90 keV/nm interact synergistically with a pre-existing fractional disorder level of 0.3 in $KTaO_3$ to form amorphous nanotracks along the ion trajectories at 300 K. To further investigate this phenomenon, the interactions of energetic ions with defective $KTaO_3$ have been studied by irradiating pre-damaged single crystal $KTaO_3$ with 5 MeV C, 7 MeV Si and 12 MeV O ions at 300 K. For a pre-damaged fractional disorder level of 0.3 and an inelastic electronic energy loss, $S_e \geq 4.65$ keV/nm (7 MeV Si ions), the results show that the synergistic interaction of electronic energy loss with defects enables amorphous ion track creation. At lower values of S_e (5 MeV C and 12 MeV O), minor increases in disorder are observed initially over a region of depth for an ion fluence of 10 ions/nm^2, which may be due to dissolution of pre-existing interstitial or

amorphous clusters; however, with further increase in ion fluence, a transition from irradiation-induced disorder production to ionization-induced damage recovery processes is observed, which has not previously reported in $KTaO_3$.

Systematic investigations of electronic energy loss (S_e) effects on pre-existing defects in crystalline silicon (Si) are crucial to provide reliance on the use of ionizing irradiation to anneal pre-existing defects, which can promote the successful implementation of this technology in the fabrication of Si-based devices. Consequently, the effects of S_e on nonequilibrium defect evolution in pre-damaged Si single crystals at 300 K have been investigated using intermediate-energy ions (12 MeV O and Si ions) that interact with the pre-damaged surface layers of Si mainly by ionization, except at the end of their range where the nuclear energy loss (S_n) is no longer negligible. Under these irradiation conditions, experimental results and molecular dynamics simulations have revealed that pre-existing defect disorder in Si can be almost fully annealed by subsequent irradiation with intermediate-energy incident ions with S_e values as low as 1.5 to 3.0 keV/nm. Selective annealing of pre-existing defect levels in Si at room temperature provides a new and effective strategy to mediate the transient enhanced diffusion of dopants in Si. This approach is more desirable than the regular thermal annealing, which is not compatible with the processing requirements that fall below the typical thermal requirements.

The initial luminescence yields from amorphous silica under ion irradiation have been studied at temperatures between 30-100 K, using swift ions of different masses and energies (3 MeV H, 3.5 MeV He, 19 MeV Si and 19 MeV Cl), with the aim of understanding the pathways and mechanisms leading from the initial generation of free carriers and self-trapped excitons (STEs) to the production of two stable defect structures in irradiated silica, non-bridging oxygen hole centers (NBOHCs) and oxygen deficient centers (ODCs). The kinetic behavior of three emission bands centered at 1.9 eV (assigned to NBOHCs), 2.1 eV (assigned to the intrinsic decay of STEs), and 2.7 eV (assigned to ODCs) reveal the physical origin of these emissions under intense electronic excitation. The creation of NBOHCs is governed by a purely electronic mechanism. The kinetics curve of the NBOHC band shows two main contributions: an instantaneous (beam-on) contribution, followed by a slower process that is fluence and temperature dependent and correlated with the concentration of STEs. The beam-on contribution is proportional to deposited ionization energy. The growth of the ODC band is linear in fluence up to around 2×10^{12} cm^{-2}. The growth rate is independent of temperature but proportional to the number of irradiation-induced oxygen vacancies per ion, demonstrating that the 2.7 eV emission is associated with ODCs created in an excited state. The intensity of the 2.1 eV emission band has been found to systematically vary with ion mass, energy and irradiation temperature. A model has been developed to explain observed ion and temperature dependences of the 2.1 eV luminescence emission of silica under high electronic excitation from swift ions. The model provides quantitatively agreement with the experimental data and deeper insight into the complex and rapid process of STE formation, migration, and recombination in silica exposed to swift ions. At the lowest temperatures measured, STEs are immobile, and their yield is governed primarily by the competition between Auger recombination and STE formation. For heavy ions (Si and Cl), the inelastic thermal spike also appears to suppress STE formation at the center of the ion track. One of the remarkable predictions of the model is the formation of a STE halo around the track core. At higher temperatures, the luminescence yield is largely controlled by STE hopping. A surviving STE can diffuse either to the center of the defective track core, where it is likely to be quenched through non-radiative recombination process, or outwards towards other

defects in the glass network. The results are consistent with an activation energy for STE migration of around 0.12 eV.

Systematic investigations of the effects of temperature on irradiation damage evolution in ion-irradiated Ni-based concentrated solid-solution alloys (CSAs) are critical to providing performance reliance for their use in nuclear applications. In an effort to understand the relative ranking of the temperature-dependent irradiation resistance among equiatomic NiFe, NiCoCr, and NiCoFeCr alloys, previous experimental and theoretical data have been compared with new ion channeling results from ion-irradiated NiCoFeCr at 500 K. Furthermore, the new results have been compared with independent theoretical calculations and relevant TEM results, which reveal that the lower migration energies of vacancies in NiCoCr, as compared with those in NiFe and NiCoFeCr, are the reason that NiCoCr does not exhibit higher irradiation resistance than NiFe under ion irradiation above 300 K.

Improved understanding and predictive models of materials performance are essential for societal needs in energy conservation and production, a clean environment, and national security. Understanding the response of materials to energy deposition is important for nuclear research and reactor applications, defect engineering, device fabrication, ion-beam processing and modification, space exploration, and high-energy accelerators. Ion beams have been employed to to study the irradiation resistance of concentrated solid-solution alloys (CSAs) and high-entropy alloys (HEAs), particularly radiation damage, ion-induced defect configurations and their concentrations, and phase stability. Over the past few years, significant modeling efforts and experimental characterization of irradiated CSAs and HEAs have revealed that improved radiation performance is attributed to inefficient formation of defect clusters from displacement cascades events and suppressed growth under prolonged irradiation. Chemical disorder leads to significant modification of scattering mechanisms and decreases in the effectiveness of energy dissipation via both electronic and atomic subsystems that control energy transport through electrons and phonons. The chemical disorder does not monotonically increase with more alloying elements but can be tuned by specific alloying elements and the corresponding concentrations. Although chemical disorder may be tuned to enhance radiation performance, knowledge of the interplay behind energy dissipation and defect evolution is still limited. Ion irradiation will continue to be utilized for radiation effects studies in order to develop fundamental understanding of radiation damage processes beyond simplified displacement events, especially in simulating neutron environments. Despite the historical achievements and new advancements in alloy development, the links to bridge the fundamental understandings of materials and numerous applications requiring various properties are still missing. To bridge the gap between neutrons and ions for radiation effect studies, research needs to fundamentally address the intertwined aspects of recoil spectrum, dose rates, configurations and distribution of defects, as well as the temporal and spatial coupling of the collision and energy dissipation processes.

Select Publications Related to This Research

1. M. L. Crespillo, J. T. Graham, F. Agulló-López, Y. Zhang, and W. J. Weber, Effect of thermochemical treatments on laser-induced luminescence spectra from strontium titanate: comparison with swift ion-beam irradiation experiments, *The European Physical Journal D* **75**: 314 (2021).

2. G. Velisa, E. Zarkadoula, D. Iancu, M. D. Mihai, C. Grygiel, I. Monnet, B. Kombaiah, Y. Zhang and W. J. Weber, Near-surface modification of defective $KTaO_3$ by ionizing ion irradiation, *J. Physics D: Applied Physics* **54**: 375302 (2021).
3. D. Iancu, E. Zarkadoula, M. D. Mihai, C. Burducea, I. Burducea, M. Straticiuc, Y. Zhang, W. J. Weber, and G. Velisa, Revealing two-stage phase transition process in defective $KTaO_3$ under inelastic interactions, *Scripta Materialia* **222**: 115032 (2023).
4. M. D. Mihai, D. Iancu, E. Zarkadoula, R. A. Florin, Y. Tong, Y. Zhang, W. J. Weber, and G. Velișa, Athermal annealing of pre-existing defects in crystalline silicon, *Acta Materialia* **261**: 119379 (2023).
5. J. T. Graham, M. L. Crespillo, F. Agulló-López, and W. J. Weber, Light emission of self-trapped excitons from ion tracks in silica glass: Interplay between Auger recombination, exciton formation, thermal dissociation, and hopping, *Acta Materialia* **229**: 117829 (2022).
6. M. L. Crespillo, J. T. Graham, W. J. Weber, and F. Agulló-López, Defect generation mechanisms in silica under intense electronic excitation by ion beams below 100 K: Interplay between radiative emissions, *Acta Materialia* **255**: 119097 (2023).
7. Y. Zhang, C. Silva, T. G. Lach, M. A. Tunes, Y. Zhou, L. Nuckols, W. L. Boldman, P. D. Rack, S. E. Donnelly, L. Jiang, L. Wang, and W. J. Weber, Role of electronic energy loss on defect production and interface stability: Comparison between ceramic materials and high-entropy alloys, *Current Opinion in Solid State & Materials Science* **26**: 101001 (2022).
8. G. Velisa, F. Granberg, E. Levo, Y. Zhou, Z. Fan, H. Bei, F. Tuomisto, K. Nordlund, F. Djurabekova, W.J. Weber, and Y. Zhang, Recent progress on understanding the temperature-dependent irradiation resistance ranking among NiFe, NiCoCr and NiCoFeCr alloys: A review, *J. Materials Research* **38**: 1510-1526 (2023).
9. Y. Zhang, L. Wang, and W. J. Weber, Charged Particles: Unique Tools to Study Irradiation Resistance of Concentrated Solid Solution Alloys, *J. Materials Science & Technology* **140**: 260-276 (2023)

Genetics of Cancer Development

by Webster K. Cavenee, Member EUAS

Short Biography

Education And Experience:

Director Emeritus, Ludwig Institute for Cancer Research (2020-present)
Distinguished Professor Emeritus, UCSD (2020-present)
Director, Strategic Alliances-CNS, Ludwig Institute for Cancer Research (2015-2020)
Distinguished Professor, UCSD (2015-2020)
Director, Ludwig Institute for Cancer Research- San Diego Branch) (1991-2015)
Distinguished Professor, UCSD (1991-2015)
Director, Ludwig Institute for Cancer Research-Montreal Branch (1986-1991)
Associate/Full Professor, Medicine, Neurology, Pathology, Human Genet., McGill Univ.
Assistant/Associate Professor, Microbiol. & Mol. Genet., Univ. Cincinnati (1983-1986)
Associate, Howard Hughes Medical Institute, Univ. Utah Medical School (1981-1986)
Visiting Research Scientis, Massachusetts Institute of Technology (1979-1981)
Postdoctoral Fellow, The Jackson Laboratory (1977-1979)
NIH Predoctoral Fellow (Ph.D., Honors), Microbiology, Univ. of Kansas (1973-1977)
Undergraduate (B.Sc.), Biology, Kansas State Univ. (1969-1973

Selected Honors and Awards:

Anna Fuller Fund Postdoctoral Fellowship (1978-17979)
National Research Service Award, NCI, NIH (1979-1982)
Basil O'Connor Award, March of Dimes Birth Defects Foundation (1983)
Rhoads Prize, American Association for Cancer Research (1988)
General Motors Cancer Research Foundation, Award New York (1990)
Farber Prize, American Association of Neurological Surgeons (1994)
DSc. (Honoris Causis), Univ.Cincinnati (2002(
Anthony DippleAward, European Association for Cancer Research, Granada, Spain. (2002)
Raymond Bourgine Award, Paris, France (2002)
Albert Szent Gyorgyi Award, National Foundation for Cancer Research, New York (2007)
Distinguished Achievement Medal, Ohio State University, Columbus, OH (2008)
Elected Fellow, American Assoc. Advancement Science (2008)
Honorary Professor, Tianjin Medical University, China (2010)
AACR Margaret Foti Award, San Diego, CA (2014)
Friendship Award, The People's Republic of China, Beijing, China (2016)
Feldman Founder's Award, National Brain Tumor Society, Boston, MA (2016)
Lifetime Achievement Award, Society for Neuro-oncology, San Francisco (2017)
Helen Keller Award in Vision Research, Honolulu, HI (2018)
Weinman Award in Cancer Research, Honolulu, HI (2018)
D. K. Ludwig Medal, New York, NY (2019)
M.D. (Honoris Causis), Heidelberg University (2023
Helis Medical Foundation Lifetime Achievement Award, Houston, TX (2023)

Elected Fellowship in Professional Societies:

American Association for Cancer Research Academy (elected Fellow 2015)
International Union Against Cancer (elected Fellow, 1994).

American Society of Clinical Investigation (elected Honorary Member, 1995).
American Academy of Microbiology (elected Fellow, 1997).
National Academy of Sciences (elected Member, 1997).
Joint Section on Tumors, American Association of Neurological Surgeons and Congress of Neurological Surgeons (elected Honorary Member, 2002).
National Academy of Medicine (elected Member, 2007)
American Association for the Advancement of Science (elected Fellow, 2008)
Leopoldina German Academy of Sciences (elected Member, 2012)
AACR Academy (elected Fellow, 2013)
Chinese Academy of Engineering (elected Member, 2017)
EU Academy of Sciences (elected Member, 2023)
Academic Service:
Founding Council, Human Genome Organization (1988-1992
Board of Scientific Counselors, Division of Cancer Etiology, NCI (1989-1994)
Board of Directors, American Association for Cancer Research (1994-1997)
Board of Directors, Damon Runyon-Walter Winchell Cancer Research Fund (1995-2001)
President, American Association for Cancer Research (1998)
Chair, Executive Committee, World Alliance of Cancer Research Organizations (2002-2004)
Scientific Advisory Board, Cancer Institute, National Univ. Singapore 2004-2007)
Scientific Advisory Board, Institute for Personalized Medicine, Barcelona, Spain (2009-2019)
Scientific Advisory Board, Molecular Biology Center, Heidelberg (2010-2019)
Scientific Advisory Board, International Precision Cancer Institute, Tianjin, China (2017-2019)
Chair, Scientific Advisory Board, DKFZ Heidelberg, Germany (2010-2020)
Chair, Scientific Advisory Board, National Cancer Centre Singapore (2013-)
Chair, Scientific Advisory Board, Cure Brain Cancer Foundation, Sydney, Australia (2014-)
Board of Directors, Global Coalition for Adaptive Research (2014-)
Chair, Scientific Advisory Board, National Found. for Cancer Res., Bethesda, Maryland (2015-)
Scientific Advisory Board, AC Camargo Cancer Center, Sao Paulo, Brazil (2016-)
Board of Directors, Asian Fund for Cancer Research, Hong Kong (2020)
Academic Advisory Committee, Chinese Academy of Medical Sciences, Beijing (2022-)

Dr. Cavenee is an internationally recognized cancer geneticist and biologist. His contributions include decades of influential basic and translational research into the genetics of cancer predisposition and progression. This is evidenced by more than 400 publications, more than 120 awarded honors and nearly 1000 invited lectures. His accomplishments can be distributed among 4 major areas.

The first is how and **why some human individuals are predisposed to develop cancer** with high probability. While familial occurrence of some forms of many human cancers appeared to be heritable, not all cells of an affected tissue were transformed. Dr. Cavenee made the first discoveries that demonstrated that this was due to the heritable mutation being predisposing with the transforming event being somatic. This was the first genetic evidence for the existence of tumor suppressor genes. He also demonstrated that identifying these lesions could provide accurate predictions of cancer development before cancer was physically detectable. This was one of the most influential discoveries in cancer research and his coined term “loss of heterozygosity” has been cited more than 30,000 times. Among his seminal discoveries in the area of human tumor predisposition are: A) direct genetic proof that tumor suppressor gene mutations could cause predisposition to cancer; B) that such genes could be important for the etiology of more than one cancer; C) that molecular genetics could provide the first accurate premorbid predictions of cancer development in humans; D) that mitotic recombination existed in humans and could be used to map human tumor suppressor genes; and E) that these genes were the underlying targets in virtually every human solid cancer, both sporadic and inherited. It led to

hundreds of other investigators testing and validating the approach for other forms of cancer in thousands of publications.

Secondly, the impact of Dr. Cavenee's ongoing research into **the mechanistic underpinnings of cancer progression** has been equally impactful. He developed and employed various genetic mapping strategies to identify several of the underlying lesions in human brain tumors, their temporal occurrence and their effects on pathophysiology. Many of these were confirmed through the efforts of the TCGA and several are now being used as targets for therapeutic design. Among the most significant of his accomplishments in this area are: A) that high stage astrocytomas shared genetic defects with lower stage tumors, in addition to their own unique aberrations, providing a genetic explanation for tumor evolution; B) this evolution was causal of the loss of inhibition of angiogenesis and that angiogenesis through VEGF was essential for brain tumor growth; C) that low stage astrocytomas have DNA methylation patterns that are shared among other tumor types as well as unique to them and so could represent novel diagnostic markers and gene discovery tools; D) that a common recurrent cytogenetic and molecular alteration in CNS tumors was due to targeted inactivation of the PTEN gene and that this gene was responsible for growth regulation in a manner that was dependent on its lipid phosphatase activity and sensitive to the extracellular micro-environment.

The third area of Dr. Cavenee's accomplishment entail **therapeutic approaches with targeted agents and tumor resistance** to them. His efforts to define the mechanistic underpinnings of tumor progression led to the discovery of a mutated form of the EGF receptor that is common in the late stage of brain tumor progression. It has many particular influences on tumor behavior: it is constitutively active and growth enhancing for brain tumor cells; it is maintained on the surface of cells due to a lack of engagement with the internalization machinery; it causes these cells to become resistant to some DNA-damaging drugs and, to be differentially sensitive to a particular tyrosine kinase inhibitor. These latter results led to his preclinical studies showing that brain tumor cells with the mutated receptor could be specifically killed using a combination of drug and kinase inhibitor or monoclonal antibody that now form the basis for ongoing Phase1/2 clinical trials. Dr. Cavenee's efforts to elucidate the molecular details of the activities of this receptor and to therapeutically target it have led him to uncover mechanisms by which tumor cells escape from targeted pathway inhibition. These include: interactions between oncogenic and tumor suppressive pathways, post-translational modification of interacting family members to mimic their inactivation but in a transient and rapid response, activation of previously unsuspected metabolic pathways to bypass the need for the receptor, hyperactivation of apoptosis protective pathways to render the inhibition of receptor signaling inconsequential, the influence of heterogeneous tumor cell populations within and among themselves, and the ability of tumor cells to lose the receptor through chromosomal gymnastics by which it can minimize and hide the target when drug is present and reactivate increased receptors when drug is removed. All of these mechanisms have been demonstrated in patients and their discovery is causing a re-examination of the dosing schedules and other design elements of clinical trials designed to test the efficacy of targeted therapeutic agents.

Fourth and finally, Dr. Cavenee serves as a Founder and Member of the Board of Directors for the **groundbreaking clinical trial for malignant brain tumors** called GBM-AGILE. This trial is a novel design, international, platform trial with Bayesian

adaption. The adaptive trial design concept provides a unique and innovative approach to learn from every patient entering the trial. Using a Bayesian design and incorporating biomarkers to divide GBM into subclasses, GBM AGILE will more rapidly and efficiently test single agents and their combination. Beyond increasing the numbers of agents and the speed of the screening process, effective therapies can move quickly and more cost-effectively to "graduate" from GBM AGILE – and move seamlessly on to a confirmatory phase 3 registration trial through cohort expansion. The adaptive design also addresses one of the other major barriers in identifying effective drugs for GBM and many other human cancers – the lack of validated biomarkers. Since GBM AGILE is a standing trial that will learn from every patient, and as the trial proceeds it will be possible to qualify and validate biomarkers. The master protocol for GBM AGILE has been developed and approved by the US FDA. This trial includes several countries (Canada, Australia, Israel, the EU to date) with a global team. This is perhaps a first example of "crowdsourcing knowledge", a model that may be of great value as we strive to break down silos and build knowledge bases to ensure that precision medicine is available to all patients. The impact of this trial will be enormous. In fact, the Head of the US Food and Drug Administration said publicly that it will change the design for all clinical trials going forward.

Conversion of ALD CuO Thin Films into Transparent Conductive p-type CuI Thin Films

by Markku Leskelä, Member EUAS

Short Biography

Markku Leskelä *(born 1950) received both M.Sc. (1974) and PhD (1980) degrees from Helsinki University of Technology. During 1979-1986 he worked at University of Oulu and Helsinki University of Technology as associate professor or acting professor, in 1986-1990 at University of Turku as professor and in 1990-2018 at University of Helsinki as professor of inorganic chemistry. He made sabbatical visits in 1983 (University of Utrecht), 1987-1988 (University of Florida) and in 1999 (University of Paris VI). During 2004-2009 he served as Academy professor. Since 2019 he has worked as emeritus professor at University of Helsinki.*

*His research interests cover luminescent materials, catalytic activation of small molecules with metal compounds, and development of chemistry for Atomic Layer Deposition of thin films – the latter topic being dominating during last five years. He has worked as vice-director (2002-2007) and director (2012-2017) in two centers of excellence funded by Academy of Finland. He has published about 735 original and 65 review papers which have been cited more than 37 000 times (h-index 90; Web of Science). He holds more than 40 patents. He was nominated in 2004 as ISI Highly Cited Author in materials science. He has received several honors and awards: Magnus Ehrnrooth Foundation Award in Chemistry (2002), SVR I (2005), A.I. Virtanen award (2011), American Vacuum Society ALD innovation award (2012), Honorary award of Finnish Academy of Sciences and Letters (2014), Honorary member (2014) and honorary chairman (2019) of Finnish Chemical Society, Honorary doctor (University of Tartu 2016). He is a member of four academies of sciences. He has and has had several positions of trust in universities (for example board of trustees of University of Helsinki 2010-2017), scientific societies, academies and foundations. He has been the president of the Finnish Academy of Technical Sciences 2019-2022 and the chairman of The Council of Finnish Academies (*CoFA*) 2021-2022.*

A. Weiß, J. Goldmann, S. Kettunen, G. Popov, T. Iivonen, M. Mattinen, P. Jalkanen, T. Hatanpää, M. Leskelä, M. Ritala & M. Kemell: Conversion of ALD CuO Thin Films into Transparent Conductive p-type CuI Thin Films. Adv. Mater. Interface 10 (2023) 2201860 (8 pp.)

Copper iodide (CuI) is a high-performance p-type transparent semiconductor that can be used in numerous applications, such as transistors, diodes, and solar cells. However, the lack of conformal and scalable methods to deposit CuI thin films limits its establishment in applications that involve complex-shaped and/or large substrate areas. In this work, atomic layer deposition (ALD) is employed to enable scalable and conformal thin film deposition. A two-step approach relying on ALD of CuO and its subsequent conversion to CuI via exposure to HI vapor at room temperature is demonstrated. The resulting CuI films are phase-pure, uniform, and of high purity. Furthermore, CuI films on several substrates such

as Si, amorphous Al_2O_3, n-type TiO_2, and γ-$CsPbI_3$ perovskite are prepared. With the resulting n-TiO_2/p-CuI structure, the easy and straightforward fabrication of a diode structure as a proof-of-concept device is demonstrated. Moreover, the successful deposition of CuI on γ-$CsPbI_3$ proves the compatibility of the process for using CuI as the hole transport layer in perovskite solar cell applications in the nip-configuration. It is believed that the ALD-based approach described in this work will offer a viable alternative for depositing transparent conductive p-type CuI thin films in applications that involve complex high aspect ratio structures and large substrate areas.

S. Ghafourisaleh, M. Vehkamäki, A. Vihervaara, C. Zhang, M.J. Heikkilä, M. Leskelä, M. Putkonen & M. Ritala: Molecular Layer Deposition of Pyrrone Thin Films by Oxidative Polymerization. Adv. Mater. Interface 10 (2023) 2202174 (10 pp.)

In this paper, the deposition of pyrrone thin film materials by molecular layer deposition (MLD) is reported for the first time using pyromellitic dianhydride (PMDA) and 3,3'-diaminobenzidine (DAB) as monomers, and ozone as a promoting precursor. Besides ozone, the effect of water, hydrogen peroxide, and oxygen is also tested to promote the growth of MLD thin films. Ozone as a strong oxidant is the best reactant in this process. Two precursor pulsing sequences are tested and both result in pyrrone films. With the DAB+O_3+PMDA sequence, growth per cycle (GPC) of 1.2 Å is obtained at 250–300 °C, whereas with the DAB+PMDA+O_3 sequence, GPC of 1.5 Å is obtained. When only DAB and O_3 are used, indamine films with GPC of 1.0 Å are obtained. The films are characterized by Fourier transform infrared spectroscopy, scanning electron microscopy, and atomic force microscopy. Chemical, thermal, and electrical properties of the films are also investigated. The films are stable in acidic and basic solutions and organic solvents, and they withstand 300 °C when annealed in air.

X. Li, M. Vehkamäki, M. Chundak, K. Mizohata, A. Vihervaara, M. Leskelä, M. Putkonen & M. Ritala: Atomic Layer Deposition of Boron-doped Al_2O_3 Dielectric Films. Adv. Mater. Interface 10 (2023) 2300173 (8 pp.)

This paper presents preparation of boron-doped Al_2O_3 thin films by atomic layer deposition (ALD) using phenylboronic acid (PBA) and trimethylaluminum (TMA) as precursors. Deposition temperatures of 160–300°C are studied, giving a maximum growth per cycle (GPC) of 0.77Å at 200°C. Field emission scanning electron microscopy (FESEM) and atomic force microscopy (AFM) are used to study the surface morphology and roughness of the films. Attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR), Time-of-flight elastic recoil detection analysis (ToF-ERDA), and X-ray photoelectron spectroscopy (XPS) are used to study the composition of the films. An annealing process is carried out at450 °C for 1 h to investigate its effect on the elemental composition and electrical properties of the boron-doped Al_2O_3 thin films. The boron-doped Al_2O_3 70 nm thick film deposited at 200°C has a boron content of 3.7 at.% with low leakage current density (10^{-9} to 10^{-6} Acm^{-2}) when the film thickness is 70 nm.The dielectric constant of this boron doped Al_2O_3 film is 5.18.

C. Zhang, M. Vehkamäki, M.Leskelä & M. Ritala: Inherent Area-Selective Atomic Layer Deposition of ZnS. Dalton Trans. 52 (2023) 9622-9630.

Atomic layer deposition processes with inherent substrate selectivity are more straightforward for area selective atomic layer deposition (AS-ALD) than approaches using surface passivation or activation with self-assembled monolayers (SAMs), small molecule inhibitors (SMIs) or seed layers. Here, ALD of ZnS using elemental zinc and sulfur as precursors is reported to have excellent inherent selectivity. At 400–500 °C for 250 cycles, substantial ZnS growth was observed on Ti and TiO_2 surfaces while no growth was measured on native SiO_2 and Al_2O_3 surfaces. On TiO_2, the ZnS growth rate remains constant at 1.0 Å per cycle at temperatures of 400–500 °C. On Ti, in contrast, the initial growth rate increases significantly from 1.2 Å per cycle at 350 °C to 6.2 Å per cycle at 500 °C. The high growth rates on Ti are believed to be caused by CVD-like growth during the early ALD cycles, arising from the reservoir effect of the Ti layer for Zn atoms. After the first 100 cycles, the growth rate decreases from 3.5 to 1.0 Å per cycle, the same as the growth rate on TiO_2. Selective adsorption of sulfur on TiO_2 over Al_2O_3 and SiO_2 is assumed to be the selectivity mechanism on TiO_2. Self-aligned deposition of ZnS was successfully demonstrated on a micrometer-scale Ti/native SiO_2 pattern and on a nanometer-scale TiO_2/Al_2O_3 pattern at 450 °C for 250 cycles; ZnS films with a thickness of ~80 nm were selectively deposited on Ti over native SiO_2, and ZnS films with a thickness of ~23 nm were selectively deposited on TiO_2 over Al_2O_3.

E. Atosuo, M. Mäntymäki, L. Pesonen, K. Mizohata, M. Leskelä & M. Ritala: Atomic Layer Deposition of CoF_2, NiF_2, and HoF_3 Thin Films. Dalton Trans. 52 (2023) 10844-10854.

The present study describes atomic layer deposition (ALD) processes and characterization of CoF_2, NiF_2, and HoF_3 thin films. For CoF_2 deposition $CoCl_2$(TMEDA) (TMEDA = N,N,N',N'-tetramethylethylenediamine) and NH_4F were used as precursors. CoF_2 deposition was studied at 180–275 °C, resulting in a growth per cycle (GPC) of 0.7 to 1.2 Å. All the films consist of tetragonal CoF_2 according to XRD. The impurity contents were measured with ToF-ERDA and less than 1 at% of N and Cl were detected in the films, indicating effective reactions. In addition, the F/Co ratio is close to 2 as measured by the same method. The saturation of the GPC with respect to precursor pulses and purges was verified at 250 °C. The common feature of ALD metal fluoride films – remarkable roughness – is encountered also in this process. However, the films became smoother as the deposition temperature was increased. CoF_2 deposition was also demonstrated on graphite substrates. NiF_2 deposition was studied at 210–250 °C by using $Ni(thd)_2$ and TaF_5 or a new fluoride source NbF_5 as the precursors. Tetragonal NiF_2 was obtained, but the oxygen and hydrogen contents in the films were remarkable, up to ~11 at%, as measured by ToF-ERDA. This was observed also when the films were in situ capped with YF_3. NbF_5 was shown to be a potential fluoride precursor by combining it with $Ho(thd)_3$ to deposit HoF_3 films. Orthorhombic HoF_3 was obtained at deposition temperatures of 200–275 °C. The films deposited at 235–275 °C are pure, and the Nb contents in films deposited at 250 and 275 °C are only 0.21 and 0.15 at%. The main impurity in both films is oxygen, but the contents are only 1.5 and 1.6 at%. The saturation of the GPC with respect to precursor pulses was verified at 250 °C. The GPC is ~1 Å.

X. Li, M. Vehkamäki, M. Chundak, K. Mizohata, A. Vihervaara, M. Putkonen, M. Leskelä & M. Ritala: Molecular Layer Deposition of Hybrid Silphenylene-based Dielectric Films. Adv. Composite Hybrid Mater. 6 (2023) 5:183 (11 pp).

Molecular layer deposition (MLD) offers molecular level control in deposition of organic and hybrid thin films. This article describes a new type of inorganic–organic silicon-based MLD process where Aluminium chloride ($AlCl_3$) and 1,4-bis(triethoxysilyl)benzene (BTEB) were used as precursors. Hybrid films were deposited at a temperature range of 300 to 500 °C and high growth per cycle (GPC) up to 1.94 Å was obtained. Field emission scanning electron microscopy (FESEM) and atomic force microscopy (AFM) were used to analyze the appearance of the film surface. The hybrid film was amorphous in low-magnification FESEM images but some particulates appeared in high-magnification FESEM images (200 k). Attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR), Time-of-flight elastic recoil detection analysis (ToF-ERDA), and X-ray photoelectron spectroscopy (XPS) were employed to analyze the structure and composition of the hybrid film. The ratio of Al/Si in the hybrid film was 0.8. The storage environment of the films affected their capacitance, dielectric constant, leakage performance, and breakdown voltage. A film stored in a high vacuum (10–6 mbar) environment had low leakage current density ($< 10^{-6}$ A × cm^{-2} at an applied voltage of 28 V) and a dielectric constant of 4.94, which was much smaller than after storing in a humid ambient environment.

A. Weiß, M. Terletskaia, G. Popov, K. Mizohata, M. Leskelä, M. Ritala & M. Kemell: Atomic Layer Deposition and Pulsed Chemical Vapor Deposition of SnI_2 and $CsSnI_3$. Chem. Mater. 35 (2023) 8722-8732

Halide perovskites, such as $CsSnI_3$, are materials renowned for their exceptional optoelectronic properties. $CsSnI_3$ stands out as a desirable choice for nontoxic and environmentally friendly absorber layers in perovskite solar cells (PSC) due to the absence of lead in its composition. However, the limited ability to deposit conformal and scalable halide perovskite thin films remains a significant obstacle to the wide commercialization of PSCs. In this study, we use atomic layer deposition (ALD) to tackle this obstacle. We present two new ALD processes: SnI_2 and $CsSnI_3$. The SnI_2 process operates at low temperatures within a narrow range (75−100 °C) and has a growth per cycle (GPC) of 0.9 Å. By depositing ALD CsI and subsequently ALD SnI_2 at different temperatures, we successfully obtain phase-pure γ-$CsSnI_3$ films via a conversion reaction. Moreover, we demonstrate an alternative method for γ-$CsSnI_3$ film deposition by replacing the ALD SnI_2 with a pulsed chemical vapor deposition (pulsed CVD) SnI_2 step. This pulsed CVD SnI_2 step operates at temperatures compatible with the ALD CsI process, effectively making it a one-step process (effective GPC > 2.0 Å) compared to the ALD conversion while retaining its conformality characteristics.

Rapidly Synthesized Single-Ion Conductive Hydrogel Electrolyte for High-Performance Quasi-Solid-State Zinc-ion Batteries

by Qing Jiang, Member EUAS

Short Biography

Qing Jiang is a Professor of the School of Materials Science and Engineering, Jilin University since 1992. He received his BSc and MSc in Materials Science from Jilin University of Technology (merged into Jilin University in 2000) in 1982 and 1984, respectively, and PhD in Chemistry from University of Stuttgart, Germany in 1990.

Dr. Jiang was elected as a Member of the EU Academy of Sciences in 2018, and an Academician of the Asia Pacific Academy of Materials in 2015. He is also a Fellow of The Institute of Physics (U.K.), and members of the editor board of several academic journals.

His current research interests include synthesis of nanomaterials as well as their applications in catalysis, energy storage and conversion (fuel cell, batteries, supercapacitors, and electrocatalysis), with focus on kinetics aspects of mass transfer and chemical reaction. He has published more than 800 papers in peer-reviewed journals, including Nat. Nanotechnol., Nat. Chem., Nat. Commun., Sci. Adv., Joule, Chem, Matter, etc. His publications have been cited more than 34,000 times with H-index = 96 (Web of Science).

In 2023, he authored and coauthored 30 papers and several representative ones with their abstracts are listed below:

1. Jong-Hoon Kim, Tian-Yi Dai, Mihyun Yang, Jeong-Min Seo, Jae Seong Lee, Do Hyung Kweon, Xing-You Lang, Kyuwook Ihm, Tae Joo Shin, Gao-Feng Han*, Qing Jiang* & Jong-Beom Baek*, Nat. Commun., 2023, 14, 2319.

Abstract

Potassium oxide (K_2O) is used as a promotor in industrial ammonia synthesis, although

metallic potassium (K) is better in theory. The reason K_2O is used is because metallic K, which volatilizes around 400 °C, separates from the catalyst in the harsh ammonia synthesis conditions of the Haber-Bosch process. To maximize the efficiency of ammonia synthesis, using metallic K with low temperature reaction below 400 °C is prerequisite. Here, we synthesize ammonia using metallic K and Fe as a catalyst via mechanochemical process near ambient conditions (45 °C, 1 bar). The final ammonia concentration reaches as high as 94.5 vol%, which was extraordinarily higher than that of the Haber-Bosch process (25.0 vol%, 450 °C, 200 bar) and our previous work (82.5 vol%, 45 °C, 1 bar).

2. Shu-Pei Zeng, Hang Shi, Tian-Yi Dai, Yang Liu, Zi Wen, Gao-Feng Han, Tong-Hui Wang, Wei Zhang, Xing-You Lang*, Wei-Tao Zheng & Qing Jiang*, Lamella-heterostructured nanoporous FeCo/Ce-O-N electrodes as ultrahigh-current-density and stable catalysts for oxygen evolution, Nat. Commun., 2023, 14, 1811.

Abstract

Developing robust nonprecious-metal electrocatalysts with high activity towards sluggish oxygen-evolution reaction is paramount for large-scale hydrogen production via electrochemical water splitting. Here we report that self-supported laminate composite electrodes composed of alternating nanoporous bimetallic iron-cobalt alloy/oxyhydroxide and cerium oxynitride ($FeCo/CeO_{2-x}N_x$) heterolamellas hold great promise as highly efficient electrocatalysts for alkaline oxygen-evolution reaction. By virtue of three-dimensional nanoporous architecture to offer abundant and accessible electroactive $CoFeOOH/CeO_{2-x}N_x$ heterostructure interfaces through facilitating electron transfer and mass transport, nanoporous $FeCo/CeO_{2-x}N_x$ composite electrodes exhibit superior oxygen-evolution electrocatalysis in 1 M KOH, with ultralow Tafel slope of ~33 mV dec^{-1}. At overpotential of as low as 360 mV, they reach >3900 mA cm^{-2} and retain exceptional stability at ~1900 mA cm^{-2} for >1000 h, outperforming commercial RuO_2 and some representative oxygen-evolution-reaction catalysts recently reported. These electrochemical properties make them attractive candidates as oxygen-evolution-reaction electrocatalysts in electrolysis of water for large-scale hydrogen generation.

3. Tianyu Qiu, Tonghui Wang, Wensi Tang, Yingqi Li,* Yangguang Li, Xingyou Lang,* Qing Jiang, and Huaqiao Tan,* Rapidly Synthesized Single-Ion Conductive Hydrogel Electrolyte for High-Performance Quasi-Solid-State Zinc-ion Batteries, Angew. Chem. Int. Ed. 2023, 62, e202312020

Abstract

Single-ion conductive electrolytes can largely eliminate electrode polarization, reduce the proportion of anion migration and inhibit side reactions in batteries. However, they usually suffer from insufficient ion conductivity due to the strong interaction between cations and cationic receptors. Here we report an ultrafast light-responsive covalent organic frameworks (COF) with sulfonic acid groups modification as the acrylamide polymerization initiator. Benefiting from the reduced electrostatic interaction between Zn^{2+} and sulfonic acid groups through solvation effects, the asprepared COF-based hydrogel electrolyte (TCOF-SGel) receives an ion conductivity of up to 27.2 mS/cm and Zn^{2+} transference number of up to 0.89. In addition, sufficient hydrogen bonds endow the single-ion conductive TCOF-S-Gel electrolyte to have good water retention and superb mechanical properties. The assembled Zn||TCOF-S-Gel||MnO_2 full zinc-ion battery exhibits high discharge capacity (248 mAh/g at 1C), excellent rate capability (90 mAh/g at 10 ^{o}C) and superior cycling performance. These enviable results enlist the instantaneously photocured TCOF-S-Gel electrolyte to be qualified to large-scaled flexible high-performance quasi-solid-state zinc-ion batteries

4. Rui Gao, Tian-Yi Dai, Zhe Meng, Xue-Feng Sun, Dong-Xue Liu, Miao-Miao Shi*, Hong-Rui Li, Xia Kang, Bo Bi, Yu-Tian Zhang, Tong-Wen Xu, Jun-Min Yan*, Qing Jiang, Adv. Mater.2023,35, 2303455

Abstract

Ammonia (NH_3) is essential for modern agriculture and industry, and, due to its high hydrogen density and no carbon emission, it is also expected to be the next-generation of “clean” energy carrier. Herein, directly from air and water, a plasma-electrocatalytic reaction system for NH_3 production, which combines two steps of plasma-air-to-NO_x^- and electrochemical NO_x^- reduction reaction (eNO_xRR) with a bifunctional catalyst, is

successfully established. Especially, the bifunctional catalyst of $CuCo_2O_4$/Ni can simultaneously promote plasma-air-to-NO_x^- and eNO_xRR processes. The easy adsorption and activation of O_2 by $CuCo_2O_4$/Ni greatly improve the NO_x^- production rate at the first step. Further, $CuCo_2O_4$/Ni can also resolve the overbonding of the key intermediate of *NO, and thus reduce the energy barrier of the second step of eNO_xRR. Finally, the "green" NH_3 production achieves excellent FE_{NH3} (96.8%) and record-high NH_3 yield rate of 145.8 mg h^{-1} cm^{-2} with large partial current density (1384.7 mA cm^{-2}). Moreover, an enlarged self-made H-type electrolyzer improves the NH_3 yield to 3.6 g h^{-1}, and the obtained NH3 is then rapidly converted to a solid of magnesium ammonium phosphate hexahydrate, which favors the easy storage and transportation of NH_3.

5. H.Y. Zhou, Y.B. Qu, , Y.C. Fan, , Z.L. Wang, X.Y. Lang*, , J.C. Li, Q. Jiang*, Multi-site intermetallic Ni_3Mo effectively boosts selective ammonia synthesis, Applied Catalysis B: Environmental 2023, 339, 123133

Abstract

Carbon-free electrocatalytic nitrogen reduction reaction (NRR) offers an environmentally sustainable alternative to the current Haber-Bosch process in the industry. However, this process is still limited by the scaling relations and the competitive hydrogen evolution reaction (HER). Using the density functional theory, we theoretically present a strategy for separating the active sites of the N_2 activation and the hydrogenation of NHz (z = 1, 2) intermediates on the Ni_3Mo surface, which subtly optimized the adsorption of intermediates and bypasses the scaling relations, achieving efficient NRR with an ultralow limiting potential of −0.19 V. Besides, the Ni_3Mo greatly protects the active centers of NRR from competitive H adsorption and retard the undesired HER, enabling highly selective NH_3 synthesis. The above theoretical designs are supported by proof-of-concept experimental results, where Ni_3Mo exhibits excellent NRR performance with the NH_3 yield rate of 17.35 ± 0.3 μg h^{-1} cm^{-2} at − 0.35 V.

A Deep Neural Network Approach combined with Findley Parameter to Predict Fretting Fatigue Crack Initiation Lifetime

by Magd Abdel Wahab, Member EUAS

Short Biography

EDUCATION

- *2008* ***DSc,*** *Doctor of Science, Department of Aerospace and Mechanical Engineering, University of Surrey, UK*
- *1995* ***PhD****, Doctor in Engineering, Department of Civil Engineering, Division of Structural Mechanics, K.U. Leuven, Belgium*
- *1991* ***MSc****, Master of Science, Department of Civil Engineering, Cairo University, Egypt*

CURRENT POSITION(S)

- *Professor and chair of applied mechanics, Faculty of Engineering and Architecture, Ghent University, Belgium*
- *Adjunct Professor, Ton Duc Thang University, Vietnam*
- *Adjunct Professor, Nanjing Tech University, China*

FELLOWSHIPS AND AWARDS

- *Fellow of EU Academy of Sciences, 2023*
- *High Level Foreign Talent in China 2023*
- *Leader Award 2023 - Research.com Mechanical and Aerospace Engineering*
- *National Ranking 3 in 2023 - Research.com Mechanical and Aerospace Engineering*
- *World Ranking 491 in 2023 - Research.com Mechanical and Aerospace Engineering*
- *Top % 2 among the World's Scientists - AD Scientific Index 2023.*
- *Medal of honour 2015, national (Belgium) orders award in recognition of outstanding teaching and professional activities*
- *Egyptian Society & Student Union award 2008, University of Surrey, Guildford, Surrey, UK*
- *SCEPTrE Fellowship award 2007. This scheme, The Surrey Centre for Excellence in Professional Training and Education, rewards excellence and promote excellent education that enhances the learning and experiences of students*
- *University of Surrey Teaching and Learning Prize 2005. This scheme acknowledges staffs who are innovative and achieve a high standard of excellence in their teaching activities*
- *PhD Scholarship (1991 – 1995), Department of Civil Engineering, KU Leuven, Belgium*

TEACHING ACTIVITIES

- *1995 – 1999: Assistant lecturer, Finite Element Analysis, KU Leuven, Belgium*
- *1999 – 2008: Main lecturer in charge, Dynamics and Vibration, University of Surrey, UK*
- *2008 – 2009:Main lecturer in charge, Reinforced Concrete/Mechanics of Materials, Xios University College Limburg, Belgium*

- *2008 – 2009: Main lecturer in charge, Kinematics/Finite Element Analysis, Ghent University, Belgium*

INSTITUTIONAL RESPONSIBILITIES

- *2009 – : Head of Finite Element Modelling Research Group, Ghent University,*
- *2009 –: Member of department committee, faculty examination committee, faculty research committee and faculty teaching committee at Ghent University, Belgium.*
- *1999 – 2008:Member of faculty, research and examination committees at Surrey University, UK*

EDITOR IN CHIEF AND CO-EDITORSHIP

- *Editor-in-Chief of Applied Mechanics*
- *Editor of more than **22** books, special issues and conference proceedings.*
- *Lead Guest Editor: special issue Advances in finite element analysis for computational mechanics, Advances in Mechanical Engineering, SAGE publications Inc.*

Abstracts of five publications in 2023

1. Sutao Han, Can Wang, Samir Khatir, Yong Ling, Dagang Wang, Magd Abdel Wahab,
A deep neural network approach combined with Findley parameter to predict fretting fatigue crack initiation lifetime, International Journal of Fatigue, Volume 176, 2023, 107891, ISSN 0142-1123,

Abstract

In the aviation field, the crack initiation stage could be the dominant one of the whole damage failure process of components subjecting to fretting fatigue. Thus, getting an accurate prediction of the crack initiation lifetime become an important topic in research of fretting fatigue problems. In this work, a new prediction method for fretting fatigue crack initiation lifetime is proposed, which is based on Deep Neural Network (DNN), Findley Parameter (FP) and Finite Element Method (FEM). Input features are shear stress amplitude and maximum normal stress in the critical plane, and crack initiation lifetime is set as the output target. Dropout and bootstrapping are considered to improve the performance of DNN. Through comparative analysis, it is shown that this new proposed approach can effectively predict the fretting fatigue crack initiation lifetime. The prediction accuracy and stability are greatly improved compared with the theoretical formulation based on FP.

2. Duong Huong Nguyen, Magd Abdel Wahab, Damage detection in slab structures based on two-dimensional curvature mode shape method and Faster R-CNN, Advances in Engineering Software,
Volume 176, 2023, 103371, ISSN 0965-9978.

Abstract

This paper proposes a novel method based on the two-dimensional (2D) curvature mode shape method, Convolutional Neural Networks (CNN), and Faster Region-based

Convolutional Neural Networks (faster R-CNN) for detecting damage in slab structures. The 2D curvature mode shapes could be measured directly or calculated from the measured mode shapes using the central difference method. The damage indicator is defined as the absolute differences between the 2D curvature mode shapes of the damaged and intact slabs. The contour plot is chosen to convert the damage indicators into images. Four hundred damage scenarios are created using a Finite Element (FE) model of the slab. Images created from those damage scenarios are then used to train CNN and faster R-CNN. Four damage types are considered in this research, namely a single small hole, a single big hole, two small holes, and two large holes. After training, CNN can predict the damage types and faster R-CNN can predict the bounding boxes around the damaged areas. A test sample set is created to test the performance of the proposed method. The effect of noise in the mode shape data is considered. Results show that the classification accuracy for damage type is high. The overlap ratios between the predicted bounding boxes and the real damaged areas are more than 40% for 80% of tested scenarios. Furthermore, the low influence of noise on the predicted results is investigated. The proposed method is robust and has great potential for application to real structures.

3. Thanh Sang-To, Hoang Le-Minh, Magd Abdel Wahab, Cuong-Le Thanh, A new metaheuristic algorithm: Shrimp and Goby association search algorithm and its application for damage identification in large-scale and complex structures, Advances in Engineering Software, Volume 176,2023, 103363, ISSN 0965-9978

Abstract

This paper presents the application of a new Shrimp and Goby Association Search algorithm (SGA) to solve large-scale global optimization problems. The performance of SGA is assessed using 13 benchmark high-dimensional functions, 10 classical benchmark functions, and several real-world engineering applications. For the first time, an efficient optimization approach for structural health monitoring (SHM) in truss-like structures is presented. The proposed approach is applied for damage identification of complex structures. A real structure, namely Canton Tower in Guangzhou, China, is served as an example for damage detection. Interestingly, this tower was the tallest structure in the world in 2009 with a height of 610 m. The great merit of this example is that it provides a real complex structure with a high-dimensional problem to assess the performance of SGA in the real world. The results show that SGA can deal with this problem effectively, at the same time, it operates better to escape from local optima with faster convergence rate than population-based algorithms.

4. Nguyen, K.D., Thanh, CL., Nguyen-Xuan, H. et al. A hybrid phase-field isogeometric analysis to crack propagation in porous functionally graded structures. Engineering with Computers 39, 129–149 (2023).

Abstract

Porosities exist as pores of different sizes within a structure to fabricate lightweight materials and the sintering process. The porous structure gives a lower loading capacity than the perfect design. Crack propagation is also a complicated behavior in this structure.

The hybrid phase-field approach is suitable to provide an effective computational tool to model the crack propagation of functionally graded materials with porosity effects. We show the influence of porosity on both the critical force and crack path of the FGM structure. In the framework of isogeometric analysis (IGA), a local refinement multi-patch algorithm based on the Virtual Uncommon-Knot-Inserted Master–Slave (VUKIMS) technique allows us to reduce the computational cost of the phase-field model significantly. The study revealed that cubic NURBS elements with the effective element size of half length-scale parameter could be used to achieve the desired accuracy while maintaining a reasonable computational cost.

5. Muhammad Imran, Dagang Wang, Magd Abdel Wahab, Three-dimensional finite element simulations of fretting wear in steel wires used in coal mine hoisting system, Advances in Engineering Software, Volume 184, 2023, 103499, ISSN 0965-9978.

Abstract

Fretting wear is a surface damage phenomenon that occurs at contacting surfaces due to the micro relative movements of contacting surfaces. It is not easy to consider the parametric study of this phenomenon by experimental methods. For example, it is not straightforward to measure the contact stresses and wear scars under different loading conditions during the experimental process. Furthermore, the experimental process is economically expensive and time-consuming. In this paper, the fretting wear behavior of steel wire ropes used in coal mine technology is numerically investigated and the results are compared with experimental data. The numerical results of the effect of contact parameters on the fretting wear process during the fretting cycles are also analyzed. For this purpose, a three-dimensional Finite Element (FE) model is created and validated with an analytical solution. The simulations of the FE model are performed using the commercially available FE tool ABAQUS combined with subroutine UMESHMOTION. The available experimental data of fretted wires in the form of coefficient of friction is used to define the interaction between the contacting surfaces of FE model and the maximum wear depth is used to validate the wear depth obtained through the numerical model. A convergence study is also carried out to select the most suitable parameters for the simulation of contacting surfaces. After the validation of the FE model, the effect of fretting amplitude, contact load and different contacting angles of fretted wires on wear characteristics is considered. The results show that higher fretting amplitude and contact load have a significant effect on wear profile, wear depth, and wear scar. The maximum wear depth, wear depth increasing rate and contact stress decreasing rate is high for higher contact angles compared to smaller contact angles.

Design of Responsible Structure-modulated Metastable Materials

by Jürgen Eckert, Member EUAS

Short Biography

Jürgen Eckert obtained his Ph.D. in Materials Science and Engineering at the Friedrich-Alexander-University Erlangen-Nuremberg, Germany in 1990. After his Ph.D. he worked for two and a half years as postdoc at the California Institute of Technology. After a short break in industry, he moved to the Leibniz-Institute for Solid State and Materials Research (IFW) Dresden, one of the leading Materials Research Science Centers in Germany. From 1996 until 2003 he was Head of the Department Metastable and Nanostructured Materials at IFW Dresden, before moving to TU Darmstadt as Full Professor for Physical Metallurgy. In 2006 he moved back to Dresden as Director of the Institute for Complex Materials at IFW Dresden and Chair for Synthesis and Analysis of Materials at Dresden University of Technology (TU) Dresden. Her also served as Scientific Director of IFW Dresden (2013/2014). In 2015 he became Chair Professor of Materials Physics at Montanuniversität Leoben, and Director of the Erich Schmid Institute of Materials Science of the Austrian Academy of Sciences. He held an Adjunct Professor Position at Michigan Technological University, Houghton, USA (2002-2005), was a Visiting Professor at University of Vienna, Austria (2009/2010/2012) and was appointed Honorary Professor at Shenzhen University, PR China (2021) and Honorary Researcher at Henan Academy of Sciences, Zhengzhou, PR China (2023).

He is an international expert in the field of metastable materials and has published more than 1340 papers in archival journals (h-index: 104 (WoSci), more than 53.500 citations), as well as more than 150 conference papers, 19 book chapters, 8 edited books, conference proceedings and journal issues, holds 24 patents, and delivered so far more than 250 plenary, keynote and invited presentations.

Jürgen Eckert was honored as Dr. honoris causa (Dr. h.c.) by the Slovak University of Technology in Bratislava, Slovak Republic (2012), and received the Gottfried Wilhelm Leibniz Award of the German Research Foundation (2009), the highest Science Prize and scientific honor in Germany. Other honors include the THERMEC 2021 Distinguished Award (2021), the European Advanced Materials Award of the International Association of Advanced Materials, Sweden (2021), an ERC-Proof of Concept Grant of the European Research Council (2019), the DGM-Prize 2014 of the German Materials Research Society, an ERC Advanced Grant of the European Research Council (2013), the ISMANAM Senior Scientist Award (2012), the Hsun Lee Lecture Award of the Chinese Academy of Sciences (2006), the Georg-Sachs-Prize of the German Materials Research Society and the Austrian Metal Industry (1997), and the FEMS Materials Science and Technology Prize of the Federation of European Materials Science Societies (FEMS) in 1997. He received the Young Scientist Award of the German Materials Research Society (1994), and the ISMANAM Young Scientist Award (1997). He is corresponding Member of the Section Mathematics-Natural Sciences of the Austrian Academy of Sciences (2017), Member of the European Academy of Sciences (2018), MRS Fellow of the Materials Research Society, USA (2018), Honorary Member of The Indian Institute of Metals, corresponding Member of the Section Technical Sciences of the Saxon Academy of Sciences and Humanities in Leipzig, Germany (2020), Foreign Fellow of the Indian National Academy of Engineering, India (2021), Fellow of the International Association of Advanced Materials (FIAAM), Sweden (2021) and was elected Full Member of Sigma Xi, The Scientific Research Honor Society, USA (2022) and Foreign Fellow of the Indian National Academy of Sciences (NASI), India (2023.)

Jürgen Eckert's research activities focus on phase formation and structure-property correlations of metastable materials processed under non-equilibrium conditions; structural and functional materials with particular emphasis on fundamentals of solidification and solid state reactions; additive manufacturing techniques; high strength, biocompatible and magnetic alloys, and materials for sustainable energy applications (e.g. next generation batteries, supercapacitors, carbon materials, materials for hydrogen production and storage) and thin film systems for flexible electronics; mechanical and electrochemical properties of bulk materials, coatings and surfaces; biologically inspired far-from-equilibrium materials and architected structures; mathematical modelling of advanced materials and processes.

Over the years, Jürgen Eckert and his team have provided seminal contributions in developing metastable advanced high-performance materials. Early work focused on amorphization and quasicrystal formation in metallic systems, and fundamental observations on establishing nanoscale grain sizes in metallic materials. The interest shifted later on to the development and property optimization of bulk metallic glasses and composites, high entropy alloys and structurally modulated systems with hierarchically tuned microstructure for creating plastically deformable and tough engineering materials. This work followed a synergistic approach by understanding how atomic scale structures, microstructural features and stress, along with processing-induced heterogeneities determine the mechanisms of plastic deformation on different length scales such as to overcome the otherwise unavoidable brittleness of glassy or nanoscale materials, and evolved into a comprehensive approach using disorder and heterogeneity concepts for creating new strategies to tailor the properties of advanced materials under non-equilibrium conditions. This allowed to create new high-strength lightweight alloys, hard and soft magnetic materials, porous bulk materials and hybrid structures for biomedical applications, materials for energy applications, and also touched on surface modification and development of architected gradient structures.

Jürgen Eckert's recent research activities focus on in-depth *in situ* and *in operando* investigations of phase transformations and structure-property correlations using local probes and high-resolution techniques for structure characterization and imaging of local structures, chemical compositions and interaction of nanoscale objects with external fields and stimuli (e.g. mechanical, thermal, electrical, magnetic fields) for creating tailored biologically inspired metastable materials with hierarchical structure and tuned disorder. This can be realized in a microscope or through flash annealing at extreme heating and cooling rates. An example for such materials is the *in-situ* design and testing of glassy or nanostructured metallic alloys containing heterogeneities on different length-scales to overcome their intrinsic brittleness. The heterogeneities can be triggered through local chemical variations, modulation of short- or medium-range order or via creating locally tuned stress/strain states. The concept of *in-situ* design and testing is applicable to bulk materials, granular or thin film systems and to a variety of materials, and thus opens new research avenues for designing materials with unique

properties. Some of the key publications in this area include:

- Yu.P. Ivanov, B. Sarac, S.V. Ketov, J. Eckert, A.L. Greer, "Direct Formation of Hard-Magnetic Tetrataenite in Bulk Alloy Castings", *Adv. Sci.* **10**, 2204315 (2023).
- B. Sarac, A.S. Sarac, J. Eckert, "Pd-Based Metallic Glasses as Promising Materials for Hydrogen Energy Applications", *J. Electrochem. Soc.* **170**, 014503 (2023).
- Y.P. Dong, D.W. Wang, Q.Z. Li, X.P. Luo, J. Zhang, K.G. Prashanth, P. Wang, J. Eckert, L. Mädler, I.V. Okulov, M. Yan, "Strong and Ductile Titanium via Additive Manufacturing under a Reactive Atmosphere", *Mater. Today Adv.* **17**, 100347 (2023).
- S.L. Lu, Z.J. Zhang, R. Liu, Z. Qu, S.J. Li, X.H. Zhou, Q.Q. Duan, B.N. Zhang, X.M. Zhao, W. Zhao, P. Ramasamy, J. Eckert, Z.F. Zhang, "Tailoring Hierarchical Microstructures to Improve the Strength and Plasticity of a Laser Powder Bed Fusion Additively Manufactured Ti-6Al-4V Alloy", *Addit. Manuf.* **71**, 103603 (2023).
- G. Wu, S.D. Liu, Q. Wang, J. Rao, W.Z. Xia, Y.-Q. Yan, J. Eckert, C. Liu, E. Ma, Z.-W. Shan, "Substantially Enhanced Homogeneous Plastic Flow in Hierarchically Nanodomained Amorphous Alloys", *Nat. Commun.* **14**, 3670 (2023).
- A. Rezvan, E. Sharifikolouei, V. Soprunyuk, W. Schranz, J. Todt, A. Lassnig, C. Gammer, N.A. Sifferlinger, A. Asci, I. Okulov, S. Schlögl, J. Keckes, Z. Najmi, A. Cochis, A.C. Scalia, L. Rimondini, B. Sarac, J. Eckert, "$Ti_{40}Zr_{10}Cu_{36}Pd_{14}$ Bulk Metallic Glass as Oral Implant", *Mater. Des.* **233**, 112256 (2023).
- D. Şopu, F. Spieckermann, X.L. Bian, S. Fellner, J. Wright, M. Cordill, C. Gammer, G. Wang, M. Stoica, J. Eckert, "Rejuvenation Engineering in Metallic Glasses by Complementary Stress and Structure Modulation", *NPG Asia Mater.* **15**, 61 (2023).

The long-term perspective of these approaches is to further advance the understanding of structure-property correlations for hierarchically modulated structures and hybrid systems over a variety of different length-scales under highly non-equilibrium thermodynamic and kinetic conditions. The goal is to gain a descriptive and quantitative picture of phase formation, transformation, dynamics and property design under extreme conditions, such as ultra-fast heating and cooling on extremely short time scales with or without external mechanical, electrical or magnetic stimulus. Whereas some of these approaches are already followed for crystalline materials, research on disordered and interface dominated materials along these lines touches almost unknown grounds, since the structural diversity represented by disorder in a material represents a holy grail of materials science and

promises to overcome the compositional and structural constraints of crystalline materials. The ability to predict and design disorder in architected materials with unique functionality via property-directed material design provides vast opportunities for new structural and functional materials including high-strength-lightweight systems, sustainable and responsive/responsible materials, biomedical implants or micromechanical components with unique performance characteristics. But not only the basic fundamental mechanisms of structure formation and property development are of interest, but also the question how the findings can be transferred into parts, devices and systems for MEMS/NEMS, sensor and actuator applications, flexible microelectronics, as well as into materials for energy applications and energy harvesting. Also, biocompatible (biodegradable) bulk materials, porous structures, coatings, and surfaces are in the focus of interest, e.g. for personalized orthopedic implants and medical devices.

For this purpose, state-of-the-art techniques from the fields of materials physics, structure analysis, *in situ* structure investigations under different applied fields (e.g. mechanical, electrical, magnetic), and structure-biological mimetic and 3d printing techniques are used to generate architected materials built from disordered building blocks. Modelling and simulation supplement and strengthen the experimental efforts. Multi-scale modelling techniques based on hierarchies of overlapping scales including quantum mechanics-based structure modelling, atomistic modelling and numerical methods can be involved. A variety of simulation and modelling of length and time scales is utilized, and complemented by Bayesian Interference (BI) and machine learning algorithms to better characterize the local property statistics not assessable with direct measurements. The outcome of this approach allows for both a quantitative parameterization of local properties and protocols by which they are, in general, to be measured. This is a vital input for property-directed and machine learning driven material design of disordered systems, and promises to open new avenues for nanoscale structure formation in architected materials with unique functionality through generating an atomic structural – functional understanding of the properties, performance and correlation of hierarchical thin film structures and membranes, tailored interface structures, nano- and multiscale hybrid systems and tailored lattice materials.

Recent in Situ Experimental & Theoretical Advances in Severe Plastic Deformations, Strain-induced Phase Transformations & Microstructure Evolution under High Pressure

by Valery I. Levitas, Member EUAS

Short Biography

Valery I. Levitas
Anson Marston Distinguished Professor in Engineering
Vance Coffman Faculty Chair Professor
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Education and Training:
Kiev Polytechnic Institute, Kiev, USSR Mechanical Engineering M.S. (Honors), 1978
Institute for Superhard Materials, Kiev, USSR Materials Science Ph.D., 1981
Ins. Electronic Machinebuilding, Moscow, USSR Continuum Mechanics Dr. of Sci., 1988
University of Hannover, Germany Continuum Mechanics Doctor-Engineer habil., 1995

Appointments

08.08-present	*Anson Marston Distinguished Professor in Engineering (2018, permanent); Vance Coffman Faculty Chair Professor (17-), Schafer 2050 Challenge Professor (08-17), Dept. Aerospace Engineering, Dept. Mechanical Engineering; Dept. Material Science and Engineering, Iowa State University; Faculty Scientist, Ames Labor.*
08.02-present	*Associate Professor (99-02), Professor (02-08) Lubbock, TX, Department of Mechanical Engineering.*
08.14-12.14	*Visiting Scholar, NIST and Geophysical Lab., Carnegie Institution of Washington.*
01.05-05.05	*Visiting Scholar, Los Alamos National Labs, Los Alamos, NM.*
08.93 -08.99	*Humboldt–Research Fellow (93-95), Visiting & Research Professor (95-99), University of Hannover, Inst. Structural & Computational Mechanics, Hannover, Germany.*
04.78–08.94	*Engineer (78-81), Junior Researcher (81-84), Senior Researcher (84–88), Leading Researcher (89–94); Leader of research group (82–94), Ins. for Superhard Materials of the Ukrainian Academy of Sciences, Kiev, Ukraine.*

Consultant: Los Alamos National Labs; NIST; Geophysical Laboratory, Carnegie Institution of Washington; Ins. for Superhard Materials (Kiev); Seyeon E&S corporation (Daejeon, South Korea).
Products: *472 publications, including 296 refereed journal papers, 3 books, 11 book chapters and 11 patents; 12,500 citations, H-index - 66.*

Selected Awards and Honors
- Elected to the European Academy of Sciences and Arts (2023).
- Fellow of the International Association of Advanced Materials (IAAM), Sweden (2023).
- Elected to the EU Academy of Sciences (2022).
- Paper "Levitas V.I. High-Pressure Phase Transformations under Severe Plastic Deformation by

Torsion in Rotational Anvils. Material Transactions, 2019, Vol. 60, No. 7, 1294-1301" is recognized as the most cited paper in Material Transactions during 2016-2022.
- Phase transformations and other structural changes in materials: special issue of the International Journal of Plasticity in Honor of Professor Valery I. Levitas; Editorial: Liming Xiong, International Journal of Plasticity, 2021, Vol. 139, 102948. - Symposium on Phase Transformations and other Structural Changes in Materials in honor of Khan's Medal Awardee Prof. Valery Levitas at 25th International Conference on Plasticity, Damage & Fracture 2019, Panama, 1/3/19-1/9/19.
- Khan International Medal Award for outstanding contributions to the field of plasticity (2018).
- Symposium on Structural Changes in Materials in honor of Prof. Valery Levitas at 23rd International Conference on Plasticity, Damage & Fracture 2017, Puerto Vallarta, Mexico, 1/3/17-1/9/17.
- ISU Award for Outstanding Achievement in Research (2016).
- Lifetime Achievement Award for outstanding achievements in engineering, science, and education (Int. Biog. Centre, 2011).
- Honorary Doctor of the Institute for Superhard Materials, Kiev, Ukraine (2011).
- ASME Fellow (2007).
- Barnie E. Rushing Faculty Distinguished Research Award (TTU, 2005).
- Best Professor Award (TTU, Fall'01).
- Richard von Mises Award of GAMM (Society of Applied Mathematics & Mechanics, 1998).
- Int. J. Eng. Sciences Best Paper Award (1995).
Alexander von Humboldt Foundation Fellowship, Germany (1993 – 95, 2012).

Recent in Situ Experimental & Theoretical Advances in Severe Plastic Deformations, Strain-induced Phase Transformations & Microstructure Evolution under High Pressure

Severe plastic deformation (SPD) of materials under high pressure are mostly studied postmortem after pressure release. Here, we summarize recent in situ experimental and theoretical studies of coupled SPD, strain-induced phase transformations (PTs), and microstructure evolution under high pressure obtained under compression in diamond anvil cell (DAC) or compression and torsion in rotational diamond anvil cell (RDAC) [1,2], see Fig. 1a. The utilization of x-ray diffraction with synchrotron radiation allowed us to determine the radial distribution of volume fraction of phases and pressure [3-7], dislocation density and crystallite size [6,7] in each phase and find the main laws of their evolution and interaction. Coupling with the finite element simulations of the sample behavior allows the determination of fields of all components of the stress and plastic strain tensors and volume fraction of the high-pressure phase [8,9] and provides a better understanding of ways to control occurring processes. Atomistic [10-12], nanoscale [13-16] (Fig. 1), and scale-free phase-field simulations [17,18] allow elucidation of the main physical mechanisms of the plastic strain-induced drastic reduction in PT pressure (by one to two orders of magnitude [5,19,20]), the appearance of new phases [20,21], and strain-controlled PT kinetics [3,4,9] in comparison with hydrostatic loading. Combining in situ experiments with multiscale theory potentially leads to the formulation of methods to control strain-induced PT and microstructure evolution and designing economic synthetic paths for the defect-induced synthesis of desired high-pressure phases, nanostructures, and nanocomposites.

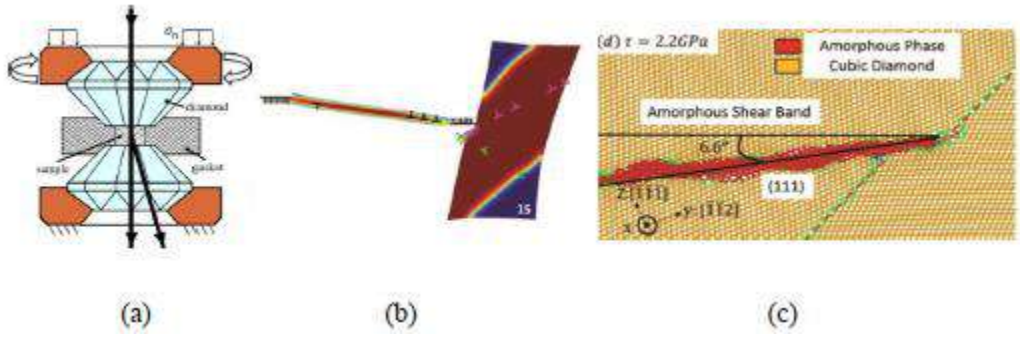

Fig. 1 (a) Schematic of RDAC. Two diamond anvils compress the sample within or without a gasket, like in traditional DAC, to high pressure. Then torque is applied, leading to the superposition of large shear-dominated straining on compression. The X-ray beam is directed along the axial direction. (b) Dislocation pileup in the left grain produces a step at the grain boundary (superdislocation) with a strong stress concentrator leading to PT and dislocation slip in the right grain. The phase-field approach results from [15] are reproduced with changes and permission. (c) Dislocation pileup in the right grain produces a step at the grain boundary in Si I and amorphization in the left grain. Molecular dynamics results from [13] are adopted with permissions.

It was found that the study of strain-induced PT is significantly simplified when steady states for microstructure and pressure-dependent yield strength are reached before the initiation of strain-induced PTs [3,4]. For such a case, (a) crystallite size and dislocation density in both phases in a single-phase state, the minimum pressure for the strain-induced α-ω PT in Zr, and the pressure-dependent yield strength $\sigma_y(p)$ of ω-Zr are independent of plastic strain tensor $\boldsymbol{\varepsilon}_p$ and strain path $\boldsymbol{\varepsilon}_p^{path}$; (b) crystallite size and dislocation density in a single phase ω-Zr are in addition independent of pressure; (c) crystallite size and dislocation density in ω-Zr and (with some outliners) α-Zr during PT are independent of pressure, plastic strain tensor, and strain path and depend on the volume fraction of the high-pressure phase only. It was also found for Zr [3,4] and olivine [6] that there is a correlation between the Hall-Petch effect of the grain/crystallite size on the yield strength and on the minimum pressure for the strain-induced PT, with corresponding theoretical justification. Similar results, including correlation for the inverse Hall-Petch effect and the minimum pressure for the strain-induced PT, were found for Si [5]. Namely, in the region when the yield strength increases with the reduction in grain size, the minimum pressure for the strain-induced PT reduces; when for smaller nanoscale grain sizes, the yield strength reduces, the minimum pressure for the strain-induced PT increases.

The obtained results change the general wisdom that plastic shear is responsible for reducing PT pressure; in fact, any mode of straining and strain path, which belong to some classes, leads to the same PT pressure and steady microstructure (Fig. 2). It also leads to the key problem: for which classes of plastic strain and strain path, and maybe pressure path material remains in each of the steady states, and for which loading classes the material behavior jumps from one steady state to another? This problem is just a translation into the language of plasticity theory of known technological problem: why different SPD technologies lead to different steady microstructures and how to design the loading process to reduce the grain size and PT pressure and increase dislocation density and strength. It is also shown in [3,4] that incomplete PT is a much more effective way to reduce the grain size to produce nanocomposite materials with controllable strength and ductility than SPD alone. In addition, SPD under normal pressure, e.g., by rolling, leading to one of the steady

states followed by compression or HPT at relatively low pressure, is a more economical way to produce nanostructured high-pressure phases than HPT of annealed materials. The possibility of manipulating synthetic paths may lead to new economic technologies of the defect(strain)-induced material synthesis at relatively low pressures, room temperature, and without catalysts, e.g., for cubic and hexagonal diamond, cubic and wurtzitic BN, Si III, etc. Still, the entire field of fundamental study of SPD and plastic strain-induced PT is in its infancy; one needs to find whether the above results are valid for other materials and material classes and to find a much more detailed theoretical description at each of the four scales.

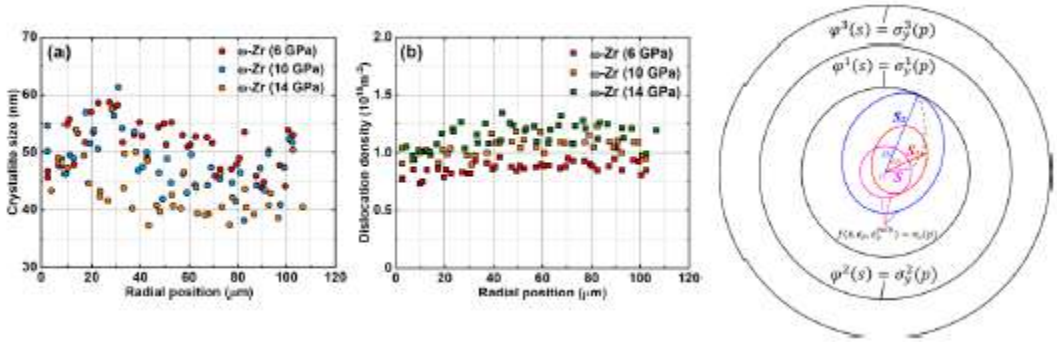

Fig. 2 Radial distribution of the crystallite size (a) and dislocation density (b) in ω-Zr for three compression steps after full transformation. Pressures in the upper right corner designate maximum pressure at the sample center. Since the plastic strain tensor and its path, as well as pressure strongly vary with radius and increasing load, approximate independence of the crystallite size and dislocation density and radius and load indicates that they reached steady values, which are independent of pressure, plastic strain tensor, and its path. (c) Schematic of the evolution of the yield surface $f(\boldsymbol{s}, \boldsymbol{\varepsilon}_p, \boldsymbol{\varepsilon}_p^{path}) = \sigma_y(p)$ until it reaches the fixed surface of perfect plasticity $\varphi(\boldsymbol{s}) = \sigma_y^1(p)$ in "5D" space of deviatoric stresses $\boldsymbol{s}$ at fixed p. The initial yield surface and $\varphi(\boldsymbol{s}) = \sigma_y^1(p)$ are isotropic (circles). Two other yield surfaces depend on $\boldsymbol{\varepsilon}_p$ and $\boldsymbol{\varepsilon}_p^{path}$, and acquire strain-induced anisotropy, namely shifted centers O_1 and O_2 (back stress) and ellipsoidal shape due to texture. When the yield surface reaches $\varphi(\boldsymbol{s}) = \sigma_y^1(p)$, the material deforms like perfectly plastic, isotropic with the fixed surface of perfect plasticity. However, for some classes of straining paths, several other fixed surfaces of perfect plasticity $\varphi^i(s) = \sigma_y^i(p)$ with larger yield strengths $\sigma_y^i(p)$ can be reached. Reproduced with permission from [7].

References

1. V.I. Levitas, High-pressure phase transformations under severe plastic deformation by torsion in rotational anvils, Mater. Trans. 60 (2019) 1294-1301.
2. V.I. Levitas, Recent in situ experimental and theoretical advances in severe plastic deformations, strain-induced phase transformations, and microstructure evolution under high pressure, Mater. Trans. 64 (2023) 1866-1878.

3. K.K. Pandey, V.I. Levitas, In situ quantitative study of plastic strain-induced phase transformations under high pressure: example for ultra-pure Zr, Acta Mater. 196 (2020) 338-346.
4. F. Lin, V.I. Levitas, K.K. Pandey, S. Yesudhas, C. Park, Laws of high-pressure phase and nanostructure evolution and severe plastic flow, (2022) 29 pp.
5. S. Yesudhas, V.I. Levitas, F. Lin, K.K. Pandey, J. Smith, Plastic strain-induced phase transformations in silicon: drastic reduction of transformation pressures, change in transformation sequence, and particle size effect, (2023) 26 pp.
6. F. Lin, V.I. Levitas, S. Yesudhas, J. Smith, Plastic strain-induced olivine-ringwoodite phase transformation at room temperature: main rules and the mechanism of the deep-focus earthquake, (2023) 17 pp.
7. F. Lin, V.I. Levitas, K.K. Pandey, S. Yesudhas, C. Park, In-situ study of rules of nanostructure evolution, severe plastic deformations, and friction under high pressure, Mater. Res. Lett. 11 (2023) 757-763.
8. V.I. Levitas, M. Kamrani, B. Feng, Tensorial stress-strain fields and large elastoplasticity as well as friction in diamond anvil cell up to 400 GPa, NPJ Comp. Mater. 5 (2019) 94.
9. V.I. Levitas, A. Dhar, K.K. Pandey, Tensorial stress-plastic strain fields in α-ω Zr mixture, transformation kinetics, and friction in diamond anvil cell, Nature Communication, 14 (2023) 5955.
10. V.I. Levitas, H. Chen, L. Xiong, Triaxial-stress-induced homogeneous hysteresis-free first-order phase transformations with stable intermediate phases, Phys. Rev. Lett. 118 (2017) 025701.
11. V.I. Levitas, H. Chen, L. Xiong, Lattice instability during phase transformations under multiaxial stress: modified transformation work criterion, Phys. Rev. B 96 (2017) 054118.
12. N.A. Zarkevich, H. Chen, V.I. Levitas, D.D. Johnson, Lattice instability during phase transformations under multiaxial stress: modified transformation work criterion, Phys. Rev. Lett. 121 (2018) 165701.
13. H. Chen, V.I. Levitas, L. Xiong, Amorphization induced by 60^o shuffle dislocation pileup against tilt grain boundaries in silicon bicrystal under shear, Acta Mater. 179 (2019) 287-295.
14. V.I. Levitas, M. Javanbakht, Phase transformations in nanograin materials under high pressure and plastic shear: nanoscale mechanisms, Nanoscale 6 (2014) 162-166.
15. M. Javanbakht, V.I. Levitas, Phase field simulations of plastic strain-induced phase transformations under high pressure and large shear, Phys. Rev. B 94 (2016) 214104.
16. V.I. Levitas, M. Javanbakht, Phase field approach to interaction of phase transformation and dislocation evolution, Appl. Phys. Lett. 102 (2013) 251904.
17. V.I. Levitas, S.E. Esfahani, I. Ghamarian, Scale-free modeling of coupled evolution of discrete dislocation bands and multivariant martensitic microstructure, Phys. Rev. Lett. 121 (2018) 205701.
18. S.E. Esfahani, I. Ghamarian, V.I. Levitas, Strain-induced multivariant martensitic transformations: A scale-independent simulation of interaction between localized shear bands and microstructure, Acta Mater. 196 (2020) 430-443.
19. Y. Ma, E. Selvi, V.I. Levitas, J. Hashemi, Effect of shear strain on the α-ε phase transition of iron: a new approach in the rotational diamond anvil cell, J. Phys: Cond. Matter 18 (2006), 1075-1082.
20. Y. Gao, Y. Ma, Q. An, V.I. Levitas, Y. Zhang, B. Feng, J. Chaudhuri, W.A. Goddard III, Shear driven formation of nano-diamonds at sub-gigapascals and 300 K, Carbon 146 (2019) 364-368.
21. V.I. Levitas, Y. Ma, E. Selvi, J. Wu, J. Patten, High-density amorphous phase of silicon carbide obtained under large plastic shear and high pressure, Phys. Rev. B. 85 (2012) 054114.

Historical Review on Resonance and Cancellation of Simply Supported Beams subjected to Moving Train Loads: from Theory to Practice

by Yeong-Bin Yang, Member EUAS

Short Biography

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Dr. Yeong-Bin Yang received his Ph.D. degree from Cornell University in 1984. He is a member of Chinese Academy of Engineering, EU Academy of Sciences, European Academy of Sciences and Arts, and foreign member of Austrian Academy of Sciences. Currently, he is Honorary Dean of Civil Engineering, Chongqing University, and Professor Emeritus of National Taiwan University (NTU). Also, he is Editor-in-Chief of International Journal of Structural Stability and Dynamics, former President of Asian-Pacific Association of Computational Mechanics, and former Chairman of International Steering Committee of East Asia-Pacific Conference on Structural Engineering and Construction.

Previously, he was President of National Yunlin University of Science and Technology (Yuntech), Dean of NTU College of Engineering, Chairman of NTU Civil Engineering Department, and President of four societies in Taiwan: Institute of Engineering Education Taiwan (IEET), Chinese Institute of Civil and Hydraulic Engineering (CICHE), Society of Theoretical and Applied Mechanics (TAM), and Chinese Society of Structural Engineering (CSSE). He has published over 300 referred journal papers, focused on the following areas: structural nonlinear theory and analysis, vehicle-bridge interaction dynamics, train-induced wave propagation, and vehicle scanning method for bridges. In each area he has also published a monograph. He has a Google citation of 16,670 times and H index of 65. Recently, he received the Zienkiewicz Medal from APACM and the Lifetime Achievement Medal from ASCE Greater China Section.

In 2023, Dr. Yang and his group have published the following papers:

1. Xu, H., Yang, M., Yang, J.P., Wang, Z.L., Shi, K., Yang, Y.B., Vehicle-scanning method for bridges enhanced by dual amplifiers, *Struct. Control & Health Monitoring*, 2023, 6906855.
2. Yang, Y.B., Liu, Y.H., Xu, H., Recovering mode shapes of curved bridges by a scanning vehicle, *Int. J. Mech. Sci.*, 2023, 253, 108404.
3. Wang, Z.L. Tan, Z. X., Yang, D.S., Xu, H., Shi, K., Yang, Y.B., Internal and external cancellation conditions for free vibration of damped simple beams traversed by successive moving loads, *Int. J. Struct. Stab. & Dyn*., 2023, 16-18, 2340007.
4. Pan, L., Yang, X., Yang, Y.B., Zhou, H., Cai, J., Li, N., Liu, J., Wang, M., Effect of material particle size on the permeability characteristics and sediment retention performance of cascade permeable dam, *J. of Hydrology*, 2023, 624,129948.
5. Yang, Y.B., Yau, J.D., Urushdaze, S., Lee, T.Y., Historical review on resonance and cancellation of simply supported beams subjected to moving train loads: from theory to practice, *Int. J. Struct. Stab. & Dyn*., 2023, 23(16-18), 2340008.
6. Yang, Y.B., Zhou, Z.Y., Zhang, X.F., Wang, X.L., Seabed seismic analysis using exact responses of solid-liquid free field for 2D oblique incident waves by finite/infinite element method, *Ocean Eng*., 2023, 285, 115171.
7. Yang, Y.B., Li, J., Nie, Q.Q., Zhou, Z.Y., Xu, H., A hybrid artificial boundary combining perfectly matched layer

and infinite elements for analysing semi-infinite problems, *Eng. Anal. Boundary Elements*, 2023, 155, 528-540.
8. Shi, K., Hu, X.S., Mo, X.Q., Xu, H., Wang, Z.L., Ma, W.R., Yang, Y.B., Theory for computing vehicle-rail contact responses from a multi-DOF test vehicle and detecting track modulus and rail damages, *Applied Mathematical Modelling*, 2023, 121, 403-429.
9. Yang, Y.B. Wang, X.L., Zhou, Z.Y., Zhang, X.F., Li, Z., Seismic analysis of underground tunnels subjected to 3D oblique incident P and SV waves by 2.5D approach, *Underground Space*, 2023, 12, 271-286, https://doi.org/10.1016/j.undsp.2023.03.004
10. Yang, Y.B., Li, Z., Wang, Z.L., Liu, Z., Zhou, Z.Y., Guo, D.Z., Xu, H., Refining the modal properties of damped bridges scanned by a single-axle test vehicle with field proof, *J. Sound Vibr*., 2023, 562, 117849.
11. Xu, H., Liu, Y.H., Yang, D.S., Zhang, H., Yang, Y.B., Separating and detecting the vertical and torsional mode shapes of thin-walled girders from vehicle's contact responses by wavelet transform, *Thin-Walled Struct.*, 2023, 189, 110889.
12. Yang, Y.B., Wang, Z.L., Yao, H., Zhang, B., Xu, H., Shi, K., Weak-end and frequency detection of elastically supported bridges by contact residual response of two-axle test vehicle in round trip," *J. Bridge Eng.*, ASCE, 2023, 28(3), 06023001.
13. Xu, H., Liu, Y.H., Yang, M., Yang, D.S., Yang, Y.B., Mode shape construction for bridges from contact responses of a two-axle test vehicle by wavelet transform, *Mech. Syst. & Signal Processing*, 2023, 195, 110304.
14. Yang, Y. B., Li, J., Wang, Z.L., Nie, Q.Q., Zhou Z.Y., Liu, Q., Enhanced mixed boundary for modeling infinite domain in 2.5D soil vibration analysis, *Soil Dyn. & Earthquake Eng*. 2023, 172, 108021.
15. Yang, Y.B., Liu, Y.H., Guo, D.Z., Zhou, J.T., Liu, Y.Z., Xu, H., Scanning the vertical and radial frequencies of curved bridges by a single-axle vehicle with two orthogonal degrees of freedom, *Eng. Struct.*, 2023, 283, 115939.
16. Yang, Y.B., Zhang, X.F., Zhou, Z.Y., Wang, Z.L., Li, Z., Seismic analysis of a half-space containing a water-filled valley under 2D oblique incident waves by finite/infinite element method, *Soil Dyn. & Earthquake Eng.*, 2023, 169, 107872.
17. Yang, Y.B., Li Z., Wang, Z.L., Liu, Mo, X.Q., Qiu, F.Q., Closely spaced modes of bridges estimated by a hybrid time-frequency method using a multi-sensor scanning vehicle: theory and practice, *Mech. Syst. & Signal Processing*, 2023, 192, 110236.
18. Lin, K.C., Hsieh, H.L., Yang, Y.B., Chiu, C.K., Chang, H.Y., A coupled RKPM and dynamic infinite element approach for solving static and transient heat conduction problems, *Eng. Anal. Boundary Elements*, 2023, 150, 528-541.
19. Xu, H., Liu, Y.H., Yang, M., Yang, D.S., Yang, Y.B., Scanning and separating vertical and torsional-flexural frequencies of thin-walled girder bridges by a single-axle test vehicle, *Thin-Walled Struct.*, 2023, 182,110266.
20. Xu, H., Wang, M.H., Wang, Z.L. Yang, D.S., Liu, Y.H., Yang, Y.B., Generation of surface roughness profiles for inclusion in vehicle-bridge interaction analysis and test application, *Int. J. Struct. Stab. & Dyn*., 2023, 2350094.

Below are the abstracts of some papers that have been published in 2023:

***Int. J. Struct. Stab. & Dyn*., 2023, 23(16-18), 2340008.**

Historical review on resonance and cancellation of simply supported beams subjected to moving train loads: from theory to practice

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Abstract

The advent of railways and especially highspeed railways marks great strides in human transportation history. To guarantee exclusive right-of-way, highspeed railways are often built on equal simply supported beams resting on piers. In this article, a historical review

will be given of the resonance and cancellation phenomena observed for simply supported beams traveled by a set of moving loads, as they are typical of highspeed railways. The phenomenon of resonance was observed by early investigators including Timoshenko, Bolotin, Frýba, Matsuura, etc. However, the phenomenon of cancellation was noted lately in 1997 by Yang et al. By letting the conditions of resonance and cancellation coincident, they proposed the *optimal span length* for suppressing the resonance of simple beams, which is equal to 1.5 times the car length. This 1.5 times rule has been verified and adopted in the design of some highspeed railways. In this article, the theoretical solution for the problem will be revisited for unveiling the key parameters such as the resonance speed (in temporal domain) and resonance wavelength (in spatial domain). Then a rather in-depth review will be given of existing works on the resonance and cancellation of railway bridges from the waves perspective. Some new developments along these lines will also be identified.

Keywords: bridge, cancellation, CRH, highspeed railway, ICE, moving load, resonance, TGV, wavelength.

***Int. J. Struct. Stab. & Dyn.*, 2023, 16-18, 2340007.**

Internal and External Cancellation Conditions for Free Vibration of Damped Simple Beams Traversed by Successive Moving Loads

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Abstract

In this paper, the internal and external cancellation phenomena for damped beams subjected to multi moving loads are investigated in detail. To start, the theory for the vibration of a simply supported beam is revisited by including the effect of damping. For the first time, a simple expression is derived for the free vibration of the damped beam under multi moving loads. Based on the concept of local minimum, two cancellation conditions are identified. One is the *internal cancellation*, which relates to the inherent property of the beam and is conventionally known. The other is the newly formulated *external cancellation* that relates to the number and spacing of moving loads. For comparison, both the resonant condition and the optimal criterion for span length of the bridge are also briefed. By comparing with the classical solution, the present simple expression for the free vibration of the beam is firstly validated. Then the factors affecting the cancellation are investigated against various load cases and damping levels. The results show that external cancellation occurs more frequently due to the increase in the number and spacing of the moving loads. The damping of the beam has a leaking effect on cancellation in that non-zero vibration may occur, but it is also quickly damped out by damping itself.

Keywords: Beam, Cancellation, Damping, Free vibration, Moving load, Resonance

***Applied Mathematical Modelling*, 2023, 121, 403-429.**

Theory for computing vehicle-rail contact responses from a multi-DOF test vehicle and detecting track modulus and rail damages

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Abstract

The vibration data recorded for the test vehicle cannot be directly used to detect the rail and bridge frequencies due to the overshadowing effect of vehicle's frequencies. To overcome this problem, the *vehicle-rail contact* response may be used instead. However, current techniques on this are available only for simple test vehicles with single or two degrees of freedom (DOFs). Normally, a train car contains a car body and two bogies (each of two wheelsets), and should be modeled by a *multi*-DOF system. The objective of this paper is first to solve the *four* wheelset-rail contact responses from the *six* measured vehicle responses. Then the *contact responses* are employed to retrieve the *track modulus*, while detecting the *rail damages*, for their salient feature of being free of the vehicle's frequencies. The railway track is modeled by a dual-beam system, with the upper (rail) and lower (bridge) beams connected by a spring-dashpot layer. The track modulus is retrieved through identification of the *first "plus" frequency* of the dual-beam, and the rail damage is detected from the *instantaneous amplitude squared* (IAS) generated from the driving component of the contact response. Through comparison with results by the finite element method (FEM), it is confirmed that: (1) the proposed procedure for computing the multi contact responses from the multi-DOF vehicle responses is reliable; (2) track irregularity presents a limited influence even for high disturbance; (3) to trade-off between efficiency and accuracy, a medium vehicle speed is suggested for the field measurement; (4) for the dual-beam with sufficient length, the use of simply supported condition is acceptable for rails; and (5) the effect of track damping is small and can be ignored.
Keywords: multi-DOF vehicle; dual-beam model; contact response; track modulus; damage detection; vehicle scanning method (VSM).

***Thin-Walled Struct.*, 2023, 189, 110889.**

Separating and detecting the vertical and torsional mode shapes of thin-walled girders from vehicle's contact responses by wavelet transform

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Abstract

The contribution of this paper is to separate and detect the vertical and torsional-flexural mode shapes of thin-walled girders from the traced contact responses of the two wheels of a single-axle test vehicle. To start, closed-form solutions are derived for the vertical, lateral, and torsional vibrations of a mono-symmetric beam. Next, the two wheels' contact responses back-calculated from the vehicle's responses are manipulated to yield *separately* the vertical and torsional responses of the bridge, which are free of vehicle's frequencies. Then, the wavelet transform is employed to recover the respective vertical and torsional mode shapes. The present treatment on mode shape recovery of thin-walled girders is an extension of the previous work on frequency identification. This study indicates that: (1) the vertical and torsional mode can be separated and detected from the respective responses by the wavelet transform with no knowledge of relative shape amplitudes; (2) more modal properties of the bridge can be detected from the contact than vehicle response; (3) the proposed method for mode shape recovery is robust with regard to various factors; and (4) ongoing traffic facilitates the recovery of bridge mode shapes, including the torsional ones, even under pavement roughness.
Keywords: Bridge; vehicle; rocking; contact point; torsional-flexural frequency; mode shape.

Running on the Sunlit Avenue of Canine Intelligence

by Fuji Ren, Member EUAS

Short Biography

Dr. Fuji Ren is currently the Professor and Director of Affective Computing and Intelligent Robot Laboratory in Tokushima University. He is also the President of International Advanced Information Institute in Japan. He is a member of The Engineering Academy of Japan, a member of EU Academy of Sciences, a fellow of the Japan Federation of Engineering Societies, a fellow of The Institute of Electronics, Information and Communication Engineers, and a fellow of Chinese Association for Artificial Intelligence.

He received his B.E. degree in 1982 and M.E. degree in 1985 from the department of Computer Science, Beijing University of Posts and Telecommunications, Beijing, China. He received his Ph.D. in 1991 from Faculty of Engineering, Hokkaido University, Sapporo, Japan. From 1991 to 1994, he worked at CSK in Tokyo, Japan where he was the chief NLP researcher. He joined the Faculty of Information Sciences at Hiroshima City University as an Associate Professor in 1994. In 2001, he became a Professor in the Faculty of Engineering at Tokushima University. He has been the president of AIA International Advanced Information Institute since 2003. He serves as the Director of the Dept. of Information Science and Intelligent Systems from 2006 to 2010, the vice Dean of Information Solution Branch of Graduate School of Engineering from 2010 to 2012, and Dean of Information Solution Branch Graduate School of Engineering from 2012 to 2016 at Tokushima University.

He also holds professor positions at Dalian University of Technology, Harbin University of Technology and Xi'an Jiaotong University. He holds the roles of Advisory Professor at Beijing University of Posts and Telecommunications, Research Advisor at Tsinghua University, Visiting Professor at University of Science and Technology of China, Yangtze River Professor at Nanjing University, and Advisory Professor at Tongji University. He was a visiting professor at CRL (Computing Research Laboratory) at New Mexico State University, a visiting research professor in the College of Engineering, at Florida International University, and a visiting professor in Harvard University in the USA.

1. British Gentleman Jones Breaks Leg in London, Loyal Dog Bill Adopts Distinctive Limp.

One day, while sitting on the sofa contemplating the special invited presentation on "Metaverse, Artificial Intelligence, and Transcendent Worlds," I happened to see a video on TV showing a beloved canine limping. The story goes like this:

Sir Jones, a gentleman living in London, found himself in an unexpected predicament as he accidentally broke his right leg, necessitating the donning of a cast, relying on crutches to get through daily life. More concerned than anyone else was his 9-year-old pet dog, Bill. One day, Bill

began to mirror Sir Jones's distinctive gait, limping on one leg in imitation of the crutch-assisted walk, as illustrated in Figure 1. Worried that Bill might be injured or sick, Sir Jones took him to the vet for examination and X-rays. To their relief, the results confirmed Bill's perfect health. It turned out that Bill was sympathizing with Sir Jones, mimicking him and walking in the same way. Sir Jones was incredibly grateful to Bill for his empathy, and their bond deepened.

This is the story of British gentleman Jones breaking leg in London, loyal dog Bill adopts distinctive limp.

People often say that dogs understand human emotions, meaning they are loyal, emotional beings with emotional intelligence.

Clearly, dogs also possess intelligence, demonstrating a level of cognitive ability.

I wonder about the intelligence and emotional intelligence of dogs? At least, it is different from the ways we, humans, express emotions. I recall a mischievous classmate from my primary school days when a teacher, despite having a leg injury, diligently hobbled into the classroom with crutches. The mischievous classmate mimicked the teacher, making funny faces as the whole class burst into laughter. Before I could ask the class to stand, the teacher turned around in anger and ordered, "Stand outside the door!" The poor classmate was punished with 30 minutes of standing!

I pondered why Bill wasn't punished to standing.

At that precise moment, the TV began discussing the topic of the metaverse, which coincidentally aligned with the content of the report I was invited to deliver on "Metaverse, Artificial Intelligence, and Transcendent Worlds."

What is the metaverse? What does the term "transcendent worlds" mean?

Fig. 1 Jones and Bill (Image sourced from the internet)

2. The Metaverse: A Future Already Unveiled, Where Reality and Virtuality Coexist; The Transcendent Realm of Blended Reality and Virtuality Represents the Aspiration for the Future.

Exploring the Metaverse, a comprehensive description of the author's proposed transcendent

world, obviously extends beyond the scope of this text. Therefore, I will outline a few key points that I used in my speeches when learning about public speaking, providing a rough outline.

2.1 The Evolution of the Metaverse: Past and Present

The precursor to Metaverse has been variously interpretations. Generally, the term "Metaverse" is believed to have originated from the 1992 science fiction novel "Snow Crash," depicting a vast virtual reality world. In this realm, individuals control digital avatars, competing with each other to elevate their status. Looking back, the portrayal still seems futuristic. A widely recognized origin for the concept of the Metaverse traces back to the creative thinking of Professor Vernor Steffen Vinge, a mathematician and computer expert from the United States. In his 1981 novel "True Names," he imaginatively crafted a virtual world accessed through brain-machine interfaces, offering immersive sensory experiences.

2.2 The Metaverse: An Undefined Definition

Currently, there is no universally accepted definition for the Metaverse. However, its distinctive features are quite apparent.

The Metaverse is a novel integration of various emerging technologies, emerging as a seamless fusion of virtual and real-world internet applications and social structures. It relies on augmented reality to deliver immersive experiences, utilizes digital twin technology to mirror the real world, and establishes an economic system through blockchain technology. It intricately blends the virtual and real worlds in economic, social, and identity systems, empowering each user with content production and world editing capabilities.

The Metaverse amalgamates achievements in information technology, the internet, artificial intelligence, cloud computing, big data, blockchain, as well as virtual reality (VR), augmented reality (AR), mixed reality (MR), and gaming engines.

The emergence of the Metaverse is expected to trigger in-depth research and interdisciplinary interactions across fundamental mathematical disciplines (algorithms), information science (programming, information entropy), life sciences (brain-machine interfaces), blockchain (cryptofinance), quantum computing (computational power), and more. Furthermore, this has the potential to propel groundbreaking advancements in the natural and social sciences, including mathematics, financial economics, futurology, philosophy, logic, ethics, and science fiction.

2.3 The Metaverse: Flourishing and Dominating the Scene

The concept of the Metaverse has experienced a significant surge in popularity.

The first Metaverse-focused stock, Roblox, officially went public on the New York Stock Exchange in March 2021, with an initial market value surpassing $38 billion on the first day.

Facebook declared its transformation into a Metaverse company, rebranding itself as Meta, with plans to achieve this transition within five years.

Apple is set to launch AR headset devices next year, simultaneously incorporating VR functionality into their offerings.

Sony's PS VR stands out in the crowd. Serving as an extension of the gaming console PS, PS VR distinguishes itself by targeting a different user demographic. With the added advantage of high-quality exclusive game content, PS VR's market share and sales have steadily increased, surpassing 5 million units by the end of 2020.

Baidu recently announced the launch of a Metaverse product named "XiRang" and revealed that the Baidu Create 2021 event, scheduled for December 27, 2021, would take place on the XiRang app, enabling interactive engagement for up to 100,000 users simultaneously.

ByteDance, the parent company of TikTok, acquired the Chinese VR device manufacturer Pico in 2021, further solidifying its presence in the Metaverse landscape.

2.4 The Metaverse: The Future that has Arrived

- **From "Hatsune Miku" to "Luo Tianyi" and Beyond to "Hua Zhibing"**

Under the influence of AI, virtual and digitized idols have become increasingly prevalent. Starting with the initial Japanese pop culture character, Hatsune Miku, moving on to the holographic figure Luo Tianyi who participated in the CCTV Spring Festival Gala, and most recently, Tsinghua University accepting its first virtual undergraduate student, Hua Zhibing.

- **From "Surfing the Internet" to "Being Online" to "Being Present"**

The Metaverse will enable a leap from merely "surfing the internet" to "being online" and further to the profound experience of "being present." For instance, a highly competitive World Cup football team is valued at around 1 billion euros. However, hosting a Metaverse-based football match could multiply the team's value by at least tenfold. The "being present" environment breaks the physical space limitations of the game, allowing tens of millions or even hundreds of millions of people to sit in their living rooms, don VR headsets, and feel the atmosphere of the World Cup final as if they were truly there. Due to the dissolution of physical space, many new business models that are large-scale, long-distance, deeply immersive, and highly experiential will be created.

- **From "Three-Dimensional Reality" to "Two-Dimensional Screens" to "Three-Dimensional Virtual Reality"**

Until now, humans have lived in three-dimensional physical reality. The advent of internet introduced two-dimensional screens. If there were no recording, filming, video, or imaging technologies, time passing would mean an inability to restart or revisit those moments. The Metaverse, however, introduces a three-dimensional virtual space, unlocking numerous possibilities. Whether it's time reversal under Einstein's theory of relativity or time-space travel as depicted in science fiction, these reconfigured dimensions will bring tremendous potential benefits to business.

Despite the complete realization of the Metaverse being a distant future, a faint glimpse of its commercial significance is already emerging on the horizon.

2.5 The Metaverse: Five Worlds, Six Layers

The Internet, blockchain, and the Metaverse are all technologies and environments continually created by humanity for better survival. In a certain sense, the Metaverse can be functionally divided into five worlds:

① Virtual World
② Digital World
③ Consciousness World
④ Programmable World
⑤ Interpretable World

Structurally, the Metaverse can be classified into six layers:

① Physical Layer
② Data Layer
③ Algorithm Layer
④ Governance Layer
⑤ Incentive Layer
⑥ Application Layer

2.6 Cold Reflections in the Heat of the Metaverse

In my speeches, I emphasize that the "Metaverse" in the stock market is often a speculative concept, akin to a manipulated market targeting uninformed investors. Most of the so-called "Metaverse" stocks are, in essence, "pseudo-Metaverse" investments driven by short-term speculative trading. More precisely, the current concept of the Metaverse lacks theoretical innovation and technological breakthroughs. For instance, as humans enter the Metaverse, there are

physiological adaptation issues for the senses (especially the eyes) and the brain. This can result in problems like dizziness, nausea, imbalance, and interference with visual functions. Addressing these challenges requires breakthroughs in neuroscience, artificial intelligence theories, and possibly even human evolution.

While a detailed exploration of these issues extends beyond the scope of this text, here are a few key points highlighted during the speeches:

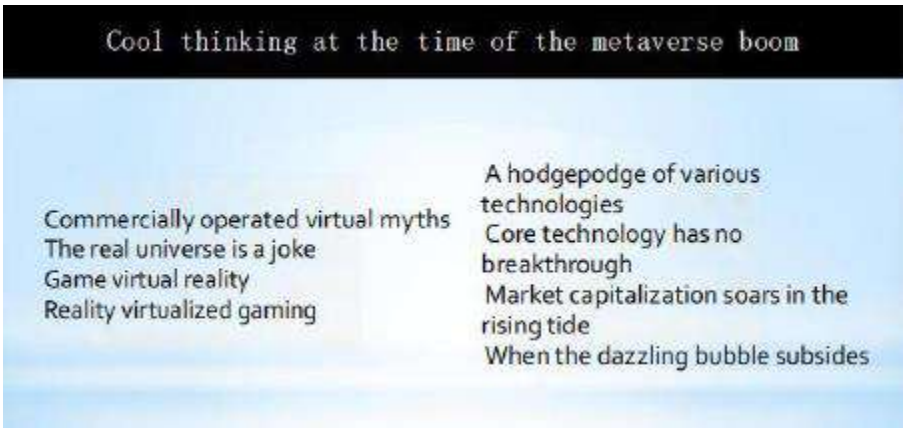

Fig. 2 Contemplation in the Heat of the Metaverse

2.7 Transcendent World: Aspirations for the Future

The Metaverse is envisioned as a networked world where the virtual and the real coexist. However, the author suggests that what humanity may truly need is a Transcendent World. The Transcendent World should be a genuine universe where the real and the virtual seamlessly blend.

The real world can be described using three variables: Time, Space, and the Human Realm. The Human Realm further breaks down into human beings and material.

With technological advancements, especially the emergence of intelligent internet connectivity, personal experiences have expanded from the perceptible spatiotemporal physical world into the virtual realm.

In the Transcendent World, the experience goes beyond a simple binary World. It involves traversing through 24 diverse combinations of positive and negative time, real and virtual space, real and virtual entities, and natural and virtual individuals. This multidimensional combination is referred to as the Transcendent World, as illustrated in Figure 3.

Whether it's the true Metaverse or the Transcendent World envisioned by humanity in the future, it entirely depends on breakthroughs in the core theories and technologies of artificial intelligence.

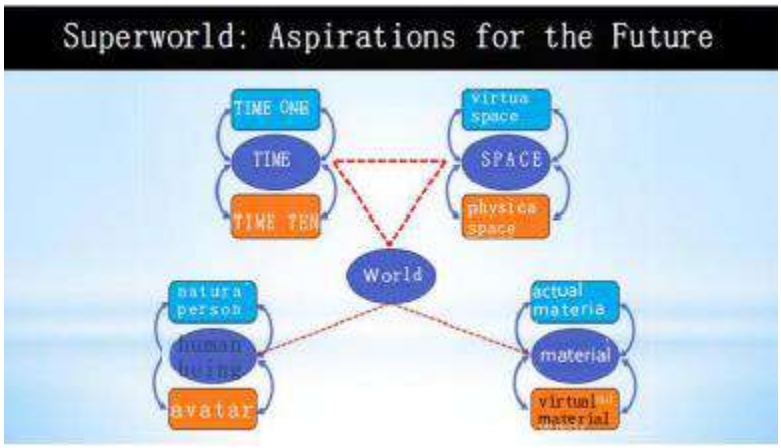

Fig. 3 Concepts of the Transcendent World

3. BIG ANT's dazzling foam finally ebbs, and A BIG ANT's unknown dark horse has a rising period.

Why is the current Metaverse primarily considered a commercial speculation? Let's analyze it through the lens of the core technologies of the Metaverse and the historical development of artificial intelligence.

3.1 The Core Technological System of the Metaverse (BIG ANT - Referring to Big Ants)

Currently, the widely circulated core technological system of the Metaverse is humorously referred to as "Big Ant," symbolized by the BIG ANT panoramic view. This system comprises six major technologies, including Blockchain Technology, Interactivity, Game Technology, Artificial Intelligence, Network Technology, and the Internet of Things.

Figure 4, as conceptualized by the author, symbolically depicts these six core technologies positioned on the six legs of a big ant.

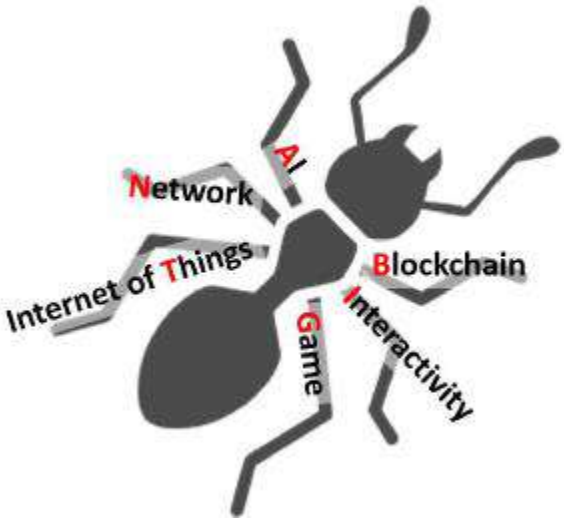

Fig. 4 Conceptual Diagram of the Big Ant (BIGANT)

It's worth noting that while games contribute interactive content to the Metaverse and facilitate traffic aggregation, the Metaverse is not merely a game. Viewing the Metaverse as a super-sized 3D virtual game is one-sided. The true Metaverse represents a novel digital civilization that integrates various new technologies, forming a harmonious blend of the virtual and the real. Therefore, artificial intelligence plays a crucial role.

Artificial intelligence serves as the brain of the Metaverse, playing a decisive role in determining its ultimate form and the integration of the virtual and real. However, as seen in Figure 4, artificial intelligence is portrayed parallel to the other five technologies. Therefore, we argue that the Metaverse constructed by this BIG ANT (referring to Big Ants) is driven by commercial operations, a bubble that will eventually recede.

The eventual explosion of the Metaverse might be ignited by a "singularity". However, the nature of this "singularity" is currently unknown. Artificial intelligence remains the linchpin. As the wind starts from a single ripple, the Metaverse could usher in a completely new era, and currently, no one can predict the outcome.

3.2 Artificial Emotion: A Crucial Element for the Metaverse

The Metaverse is a new type of internet application and social form with humans as the main focus, providing an immersive experience and allowing users to create content and edit worlds. For a considerable time, gaming might be the most prominent scenes in the Metaverse. However, even in the gaming aspect of the Metaverse, it would be incomplete without artificial emotion (including

emotion perception and emotion generation). For instance, users, especially teenagers, immersed in the gaming world may face serious issues if their emotional states are not perceived, including health and social problems. Similarly, without emotional interaction functionality, immersive experiences are lacking. Further details are not elaborated here.

3.3 Artificial Intelligence: the Brain of the Metaverse

In a communication from the Chinese Association for Artificial Intelligence in 2018, the author stated, "Artificial Intelligence, standing behind cloud computing, big data, deep learning, brain cognition, and cognitive brains, will evolve and advance with unstoppable momentum, ultimately possessing tremendous explosive power." As of now, this trend has not changed. Human society is undergoing an unprecedented transformation, with a new wave of technological revolution and industrial upheaval flourishing. Artificial intelligence has become a crucial driving force in this new wave, profoundly impacting global economies, societal progress, and human life. It stands at the forefront of the current technological revolution, intelligently connecting various fields of knowledge and technological capabilities, unleashing the enormous energy accumulated in technological revolution and industrial upheaval. In the Metaverse, artificial intelligence will undoubtedly play a significant role, serving as the intelligent "brain" and innovative content provider for the Metaverse.

Therefore, the author believes that the Metaverse constructed by BIG ANT is driven by commercial operations, a bubble that will eventually recede. The reason lies in not clearly recognizing the core position of artificial intelligence in the Metaverse. Compared to other technologies that constitute the Metaverse, artificial intelligence is the dazzling gem on the crown.

Taking game technology as an example: whether it's traditional online games or blockchain games, game scripts have always been the most critical factor. From content (currently not yet based on understanding to generate game scripts autonomously, but artificial intelligence can be trained using thousands of books and vast amounts of internet text to eventually imitate works written by humans) to the sense of presence, without the traction of artificial intelligence technology, satisfactory cloud universe games for players would be impossible.

This sets the stage for the specific reference to A Big Ant in the upcoming section (6).

3.4 Revisiting Artificial Intelligence Every 30 Years

Artificial Intelligence (AI) technology involves a set of techniques that aim to replicate human intellectual activities, such as recognition, judgment, planning, and learning, on machines. AI research extensively covers various aspects of human intelligence and is actively progressing not only towards highly general systems (referred to as general AI) but also systems that approach or even surpass human accuracy in specific functions or scenarios (known as specialized AI).

On the other hand, Big Data originally referred to the term for a massive amount of data itself, but its collection, storage, and analysis technologies have developed not only towards largescale but also in terms of heterogeneity, uncertainty, time-series, and real-time capabilities. With the maturity and widespread use of sensors and Internet of Things (IoT) devices, large-scale data from the real world can be obtained in various situations. The collection and analysis of this data can be used to accurately and real-time understand and predict the states of phenomena and activities occurring in the real world. In the current scenario where various social problems are becoming increasingly vast and complex, collecting and analyzing big data from the real world to understand and predict situations is an effective means to address these issues that are beyond human capacity to handle.

These AI technologies and Big Data, encompassing both the data itself and processing technologies, are developing concurrently and are interrelated. By collecting Big Data, AI technologies, especially machine learning, will be upgraded to become more accurate. By using AI technologies to analyze Big Data in the real world, a more in-depth and accurate understanding and prediction of real-world phenomena and activities can be achieved. Thus far, various tasks traditionally performed by humans can be automated and streamlined, surpassing human manual processing levels in terms of scale, speed, resolution, and more.

The study of artificial intelligence has given rise to different research paradigms due to varying perspectives, such as symbolic, connectionist, and behaviorist approaches. The history and development of AI, categorized by development processes and generations, have been extensively documented in various literature. This article provides a brief description of the development of artificial intelligence every 30 years, as illustrated in Figure 5.

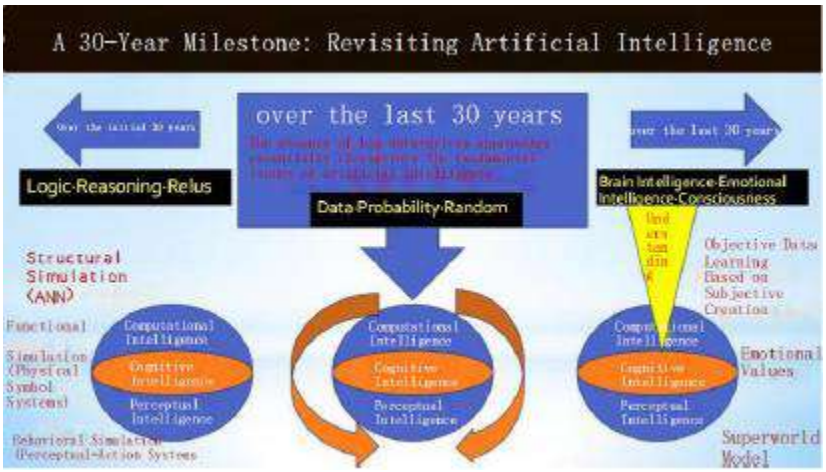

Fig. 5 The Past and Present of Artificial Intelligence

The enduring pursuit of imbuing machines with human-like intelligence has been a cherished ideal throughout history. Stretching back to the Western Zhou period in ancient China, skilled craftsmen in Yanshi fashioned humanoid robots capable of singing and dancing, known as wooden performers. In the later stage of the Spring and Autumn period, Lu Ban utilized bamboo and wood to craft wooden birds capable of sustained flight, as ancient texts attested to their remarkable capability of sustained flight, boasting an endurance of "three days". Transitioning to the Eastern Han Dynasty, the eminent scientist Zhang Heng left an indelible mark with his inventions, including the "seismometer" and the "odometer". Additionally, the widely known "wooden oxen and flowing horses" attributed to Zhuge Liang showcased early instances of automated machinery. However, the formal discipline of artificial intelligence (AI) is widely considered to have originated in 1956. This is the year when the term AI was first coined during a conference at Dartmouth College, led by McCarthy and a group of mathematicians, information scientists, psychologists, neurophysiologists, and computer scientists. Hence, this paper adopts 1956 as the inaugural year of AI research.

- **The First 30 Years (1956-1985): The Rule-Based Era**

In the late 1950s to the mid-1960s, fundamental concepts related to AI were introduced. Although AI emerged as a new academic field during this period, its focus on problem-solving remained limited to toy systems. The 1980s witnessed a paradigm shift with the ascendancy of rule-based methodologies employing dictionaries, ushering in a new era of practical applications. This wave of innovation gave rise to expert systems, as well as advancements in fingerprint and character recognition, culminating in the application of dictionary-based natural language processing.

- **The Next 30 Years (1986-2015): The Data-Driven Era**

Due to limitations posed by rule-based and dictionary descriptions, AI experienced a winter. In 1984, Nagao proposed a Japanese-English machine translation framework based on case analogy. From 1986 onward, data-driven methods gained prominence. With the expansion of the internet, computational capabilities, and the evolution of big data and machine learning, AI applications such as image recognition, speech recognition, machine translation, and achievements in games like Go and shogi demonstrated performance that matched or exceeded human capabilities. Various AI systems have become practical and widely applied in society.

- **The Next 30 Years (2016-2046): Aspiring to be the Understanding-Based Era**

In 2016, AlphaGo emerged, defeating one of the greatest Go players, Lee Sedol, and subsequently securing a 3:0 victory against the then-strongest human player, Ke Jie. Researchers have long been troubled by artificial intelligence, and their sentiments can be described just as it is expressed in an ancient Chinese poem: "tears streaming down their garments upon first hearing" and "joyful ecstasy while leafing through poetry and books". However, the euphoria was short-lived as flaws in existing AI methodologies, including deep learning, became increasingly evident (as discussed in Section 4 of this paper), prompting us to contemplate the future direction of AI in the next 30 years.

If the keywords for AI research in the first 30 years were "logic, reasoning, rules," and the keywords for the next 30 years were "data, probability, randomness," then the keywords for the future 30 years of AI research should be "brain intelligence, emotional intelligence, consciousness." Figure 6 represents the hierarchy of intelligence, showing that emotional intelligence becomes more crucial as one ascends the hierarchy.

The author proposes that the future of artificial intelligence should be based on the paradigm of "understanding." This paradigm does not intend to discard the theoretical frameworks based on logic and knowledge reasoning from the first 30 years, nor does it aim to weaken the data-driven models and stochastic computations driven by big data from the next 30 years. Instead, it seeks to introduce "mind" on the foundation of the past 60 years. If the data-driven paradigm is about "objective data learning," then the understanding-based paradigm, in addition to "objective data learning," also includes "subjective creation." This involves emotions and values, paving the way toward the realization of "general artificial intelligence."

This may sound like a fantasy. Can it be achieved?

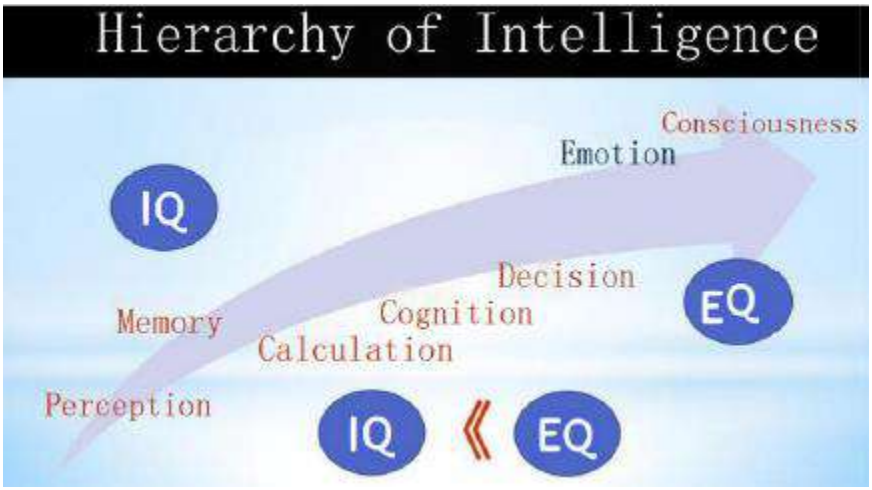

Fig. 6 Hierarchy of Intelligence Conceptual Diagram

3.5 General Artificial Intelligence: A Mirage in the Foreseeable Future

Is General Artificial Intelligence (AGI) a pipe dream? Clearly not. However, the author posits that AGI might be akin to a reflection in water or an image in a mirror in the foreseeable future. Here are several key points, with detailed explanations omitted in this text:

- Achieving general artificial intelligence in the near future is deemed impossible.
- The metaphor of the moon in the water signifies the difficulty in realizing general artificial intelligence. However, just as the moon exists, it is not a mere fantasy. This suggests that instead of solely focusing on the reflection of the moon in the water, we should look up to the stars and invent a lunar spacecraft.
- The analogy of the flower in the mirror illustrates that the path to achieving general artificial intelligence is filled with confusion. However, since the flower exists, one should not only think about obtaining the flower in the mirror but also turn around to find a way to pick the actual flowers.

- Given the likelihood that general artificial intelligence might be akin to the moon in the water or the flower in the mirror in the foreseeable future, research on artificial intelligence for the next 30 years should progress in two directions (including the proposed canine intelligence).

3.6 A BIG ANT Emerging into the Sky

Returning to the concept of the metaverse, based on the analysis above, the author proposes the core technological system of the metaverse, as illustrated in Figure 7.

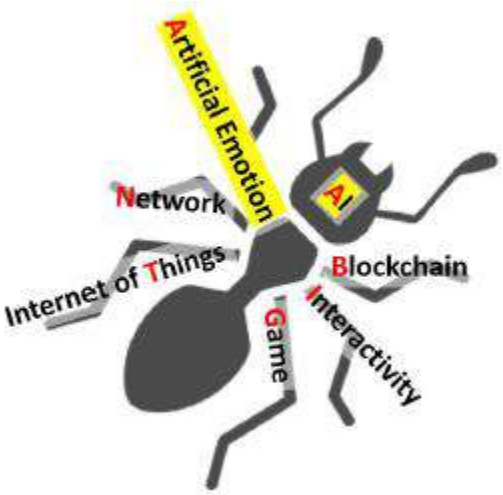

Fig. 7 Conceptual Diagram of A BIG ANT (A BIGANT)

The core ideas can be summarized in two points:

- Artificial Intelligence Will Lead the Process of the Metaverse.
- In particular, the term 'A BIG ANT' implies that constructing a universal metaverse is challenging, and instead, numerous specific metaverses are being built. –

Using "Metaverse Restaurants" as an example, which is a Specific Metaverse rather than a Universal One. Metaverse Restaurants not only offer people immersive consumption experiences but also aim to create a pleasant atmosphere for diners to enjoy their meals. Therefore, Metaverse Restaurants must possess the following elements:

- **Immersive Experience**

Immersion is a crucial element in the current appeal of the metaverse. In a Metaverse Restaurant, it is a significant aspect, providing a deeply immersive dining experience.

- **Authenticity**

Unlike many current metaverse concepts that exist primarily in virtual worlds, a true metaverse restaurant aims to transform dining from virtual to real. For instance, when selecting Hokkaido sashimi in a Japanese restaurant within the metaverse, the "Meta Food Repository" generates an authentic Hokkaido sashimi using intelligent food synthesis technology. You can also enjoy a glass of French red wine aged 15 years with your friend in Paris (this wine is also generated through the “Elemental Food Vault”).

- **Social Interaction**

Due to the immersive virtual environment, diners can engage in conversations with friends and colleagues while dining, without concerns about viruses. This expands the social dimensions of dining, making it more diverse and enjoyable.

- **Health**

When dining in the metaverse restaurant, the 'Elemental Health Guardian' will accurately assess

your health factors, such as whether you have high blood pressure or elevated uric acid levels, among other considerations. Moreover, the various components of the meal you order are instantly visualized. The metaverse restaurant will curate a menu tailored to your taste preferences and most beneficial for your health.

- **Pleasure**

The metaverse restaurant is a high-end establishment that caters to both physiological and psychological needs. While dining in the metaverse restaurant, your emotional changes and states are constantly perceptible and cognizable. The 'Elemental Pleasure Minister' in the metaverse can communicate with you, provide comfort, and assist you based on your emotions at any given moment. Additionally, adjusting the optimal temperature, humidity, lighting, airflow, and other factors according to the diner's condition is seamlessly automated.

- **Distinctive Features**

As the Metaverse Restaurant is limited to the culinary world, it can offer various unique dining experiences and provide knowledge during meals.

The realization of all these elements is impossible without artificial intelligence, and achieving this with general artificial intelligence is challenging. However, due to the specificity of focusing solely on restaurant experiences, or "specializing," as the author puts it, it becomes feasible. The recent developments, such as TV reports about tasteable TV, exemplify the emergence of specialized AI, or what the author refers to as the "A BIG Ant", enabling the creation of Metaverse Pediatric Hospitals, Metaverse Mental Health Clubs, Metaverse Fashion Factories, etc.

4. Intelligence without wisdom will eventually lead to big data conforming to small patterns. Having IQ but lacking EQ makes it difficult to avoid high power consumption with low efficiency.

In this section, the main shortcomings of current artificial intelligence are highlighted. Due to space constraints, only point (7) will be elaborated, while others will not be reiterated.

(1) Intelligence without Wisdom
(2) High IQ, Low EQ
(3) Knowing the Facts, Not the Reasons
(4) No Mistakes in Small Matters
(5) Confusion in Critical Situations
(6) Big Data, Small Patterns
(7) High Power Consumption, Low Efficiency

Artificial intelligence has already seen successful applications in various tasks such as classification, recognition, prediction, and anomaly detection using deep learning, achieving high precision. However, the learning (training) process demands an enormous amount of supervised data. For instance, the quantity of image data for learning image recognition and the number of words for language disambiguation have reached the order of hundreds of millions. To enhance accuracy, besides increasing the data for learning, improvements in algorithms, addition of layers to neural networks, and the development of complex structures are pursued. Consequently, the computational resources used during the training process are constantly growing.

Figure 8 illustrates this trend of increasing computational resources. From the figure, it is evident that the computing power required has increased by 300,000 times from 2012 when AlexNet, significantly surpassing traditional methods in image recognition accuracy, was introduced, to 2017 when AlphaGo Zero, with overwhelming victory rates in Go, required massive computational power.

This highlights the current challenge of high power consumption and low efficiency in deep learning. Addressing this issue might involve incorporating common knowledge into the learning process. However, introducing common knowledge is challenging in the framework of general artificial intelligence, which brings us to the specific concept introduced in this paper - "Canine Intelligence" or AI specialized in certain domains.

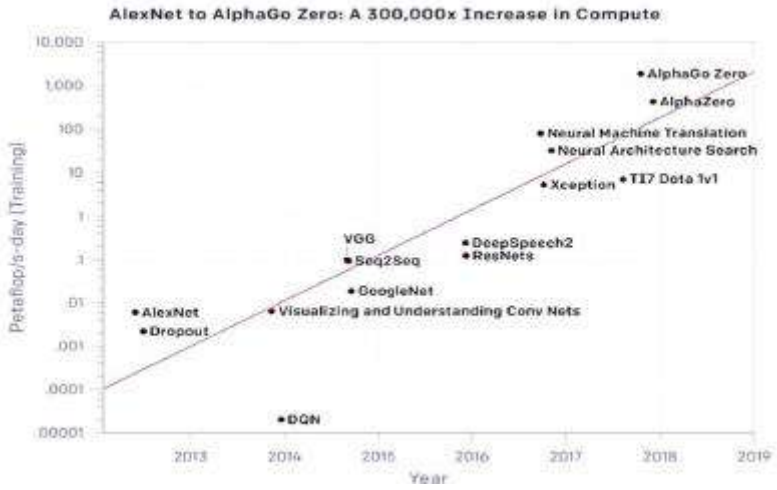

Fig. 8 Trend of Computational Power Increase (Quoted from OpenAI Report)

5. On the moonlit road of artificial intelligence, facing challenges with determination, while canine intelligence forges ahead on the sunlit path, overcoming obstacles.

Artificial intelligence, particularly in the context of general artificial intelligence, is a challenging and complex journey full of obstacles. The author argues that, currently, artificial intelligence has made progress in computational intelligence and perceptual intelligence but lacks any substantial achievements in cognitive intelligence. Furthermore, the author contends that universal artificial intelligence is unattainable without consciousness and values, terming the road to achieve this as the "Moonlight Road."

In contrast, specialized artificial intelligence, referred to as "Canine Intelligence" in this context, represents a more feasible path (at least for the foreseeable future, from an engineering perspective). "Canine Intelligence" will be elaborated upon later in this discussion.

5.1 The Trilogy of Cognitive Intelligence

The author believes that establishing the theory and achieving technological breakthroughs in general artificial intelligence in the visible future is unpredictable. However, it remains an alluring and fascinating direction. Before tackling the challenges of general artificial intelligence head-on, efforts should be directed towards cognitive intelligence. The following is a trilogy of cognitive intelligence, characterized by a gradual progression from the surface to the core, from the external to the internal, and from the local to the global. This paper provides only key terms without detailed descriptions.

① Big Data Deep Learning
Features: Statistical, intuitive, unconscious, and non-interpretable.

② Small Knowledge Shallow Learning
Features: Inductive, logical, semi-conscious, and semi-interpretable.

③ Transcendent World Function Learning
Features: Inferential, abstract, conscious, and fully interpretable.

5.2 Our Past and Present Pursuits

In the field of artificial intelligence, particularly in robotics, our historical and ongoing pursuits have included high fidelity, emotional capabilities, and universality, as depicted in Figure 8.

Fig. 9 High-Fidelity Humanoid Robot

5.3 Artificial Intelligence Tackles Challenges on the Moonlit Path

Embarking on the quest for high fidelity, emotional capabilities, and universality on the path of artificial intelligence is an immensely challenging endeavor. Similarly, as illustrated in Figure 9, the journey towards general artificial intelligence is fraught with obstacles, sometimes leading to pitfalls. The term "Moonlight Road" is aptly chosen because progress along this path is characterized by intermittent brightness and darkness, akin to moonlight shining through. This metaphor provides insight into the fluctuating nature of the journey, where advancements in cognitive science, neuroscience, and related fields continually illuminate the promising future of artificial intelligence despite the twists and turns in the road.

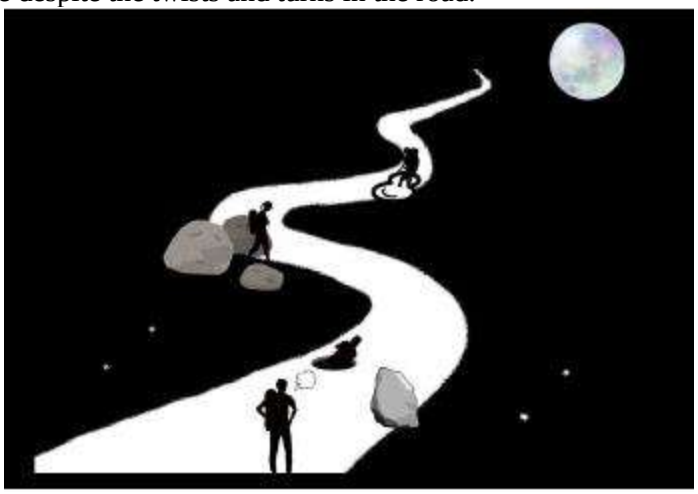

Fig. 10 Conceptual Diagram of Navigating the Thorns on the Moonlit Road of Artificial Intelligence

5.4 Canine Intelligence

Similar to the definition of artificial intelligence, canine intelligence refers to software or systems that use machine simulation of the canine brain to perform intelligent tasks. The concept of canine intelligence, as proposed in this paper, specifically refers to imitating a particular intelligence of dogs, such as olfactory intelligence (e.g., customs detection dogs). In other words, canine intelligence is a form of specialized artificial intelligence, distinct from general artificial intelligence.

Customs detection dogs are responsible for sniffing goods at customs inspection points. When they detect the scent of drugs, they use their paws to signal or bark towards suspicious items. Their

effectiveness, as often seen on television, surpasses that of humans. Despite technological advancements, we have yet to develop customs detection robots that can match the capabilities of these dogs. Why?

Canine intelligence operates across different dimensions similar to human intelligence. In humans, intelligence can be categorized into memory, numerical understanding, reasoning, language, and more. Regarding canine intelligence, experts like Stanley Coren have classified it into three main aspects:

Instinctive Intelligence: Genetic characteristics of a breed.

Adaptive Intelligence: Social awareness and learning from the environment.

Working and Obedience Intelligence: Understanding human commands.

Psychologist and canine researcher Stanley Coren estimates that the intelligence of an average dog is roughly equivalent to that of a 2.5-year-old child.

However, the intelligence of dogs should not be underestimated. Scientists speculate that a dog's sense of smell is 10,000 to 100,000 times more sensitive than that of humans. One reason for this heightened sense is the greater number of scent receptors in dogs; they have approximately 50 times the number of scent receptors for each odor that humans possess. Dogs' olfactory abilities differ from humans; they breathe and smell through separate channels. When dogs breathe, a layer of tissue separates the functions of smelling and breathing. The part of the dog's brain dedicated to analyzing smells is about 40 times larger than ours. Dogs also have significantly more sensitive hearing than humans. They can hear sounds four times farther away than we can and can detect higher-frequency sounds, making it easier for them to discern and locate sounds accurately. Dogs have as many as 18 muscles controlling their ears, while humans have only 6, and our ears can only move slightly, if at all. Therefore, dogs can tilt and rotate their ears to more effectively convey sounds into their inner ears. Additionally, some dog breeds have ears that can amplify sounds. Dog ear canals are much longer than those of humans, and muscles allow them to finely adjust the position of these ear canals to locate sounds more accurately from further away.

- **Characteristics of Canine Intelligence**

Due to space constraints, the characteristics of canine intelligence can be summarized as "small data, shallow intelligence, specialized expertise, and high endurance." These characteristics serve as guiding principles for the development of canine intelligence systems.

- **Advancing on the Sunlit Path of Canine Intelligence**

Due to the characteristics mentioned in (5), as depicted in Figure 10, canine intelligence will stride forward on a sunlit path.

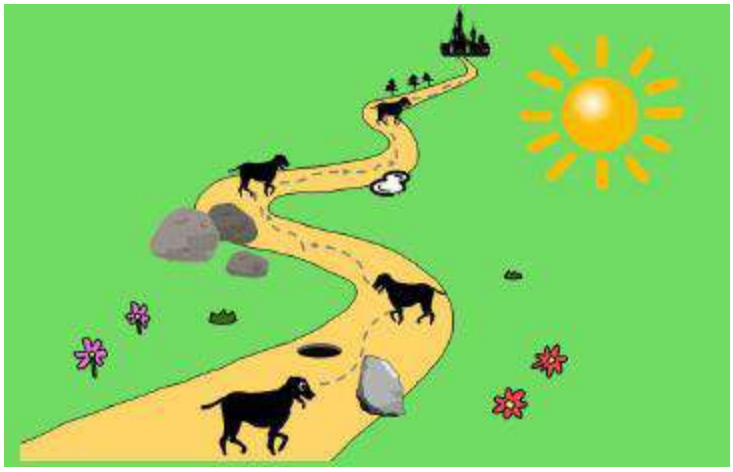

Fig. 11 Conceptual Diagram of Canine Intelligence Forging Ahead on the Sunlit Path

6. Scientific warriors enjoy the moonlight and fresh breeze in solitude, while engineering elites bravely battle, bathed in rain, dew, and sunlight.

It's time to conclude the prelude that cannot end.

Here are some key points from this article:

- The intertwined virtual and real world - Metaverse: the anticipated future.
- The harmonious blend of reality and virtuality - Transcendent World: the vision of the future.
- Artificial intelligence, especially cognitive intelligence, is the key to the stable and far-reaching development of the Metaverse.
- The characteristics of Canine Intelligence are small data, shallow intelligence, specialized expertise, and high endurance.
- Canine Intelligence represents the sunlit path for artificial intelligence in the present and the foreseeable future.
- Let Canine Intelligence realize the Canine Metaverse and move towards the Canine Transcendent World.

In this "technological prose," the author presents personal reflections on recent contemplation, asserting that artificial intelligence (referring to general artificial intelligence) is a challenging and treacherous path, while Canine Intelligence represents a sunlit avenue. In essence, the research and development may split into two fronts (although roles may interchange, and sometimes they may blend): developing various specialized artificial intelligence systems within Canine Intelligence, which will bask in the sunshine for an extended period, albeit on a fiercely competitive battleground. On the other hand, conquering cognitive intelligence and general artificial intelligence requires enduring solitude, embracing loneliness, and enjoying the serenity of the moon and the refreshing breeze.

Bioconversion of Homogeneous Linear C-Lignin to Polyhydroxyalkanoates

by Arthur Ragauskas, Member EUAS

Short Biography

*Dr. Arthur Ragauskas held the first Fulbright Chair in Alternative Energy and is a Fellow of the American Association for the Advancement of Science, the International Academy of Wood Science, and TAPPI. In 2014, he assumed a Governor's Chair for Biorefining based in the University of Tennessee's Department of Chemical and Biomolecular Engineering, with a complementary appointment in the UT Institute of Agriculture's Department of Forestry, Wildlife, and Fisheries and serves in the Energy and Environmental Sciences Directorate, Biosciences Division, at ORNL. His research program is directed at understanding and exploiting innovative sustainable bioresources for the circular economy. This multifaceted program is targeted to develop new and improved applications for nature's premiere renewable biopolymers for biofuels, biopower, and bio-based materials and chemicals. His research program has been sponsored by NSF, USDA, DOE, GA Traditional Industry Program, a consortium of industry partners, and several fellowship programs which are summarized in **725 peer-reviewed** publications. His Fulbright-sponsored activities at the Chalmers University of Technology, Sweden were focused on forest biorefinery and new biofuel conversion technologies for lignocellulosics. Currently, Dr. Ragauskas manages a research group of graduate students, postdoctoral research fellows, a research scientist, and visiting scientists. He is the recipient of the 2014 TAPPI Gunnar Nicholson Gold Medal Award, the 2014 ACS Affordable Green Chemistry Award, the 2017 AIChE Green Processing Award, the 2017 Academia Distinguished Service Award, 2019 AIChE Chase Award and 2022 RSC Environment, Sustainability, and Energy Division open award: Environment Prize. In addition, his students and postdocs have won several awards, including the ACS graduate research award, the ORNL UT-Battelle Award, and the ORNL Supplementary Performance Award.*

Dr. Ragauskas is an Associate Editor for Biofuels, Bioproducts and Biorefining, Biofuels, BioEnergy Research, Industrial Biotechnology, Taiwan Journal of Forest Service, TAPPI J., Holzforschung, Journal of Biobased Materials and Bioenergy, Journal of Petroleum Technology and Alternative Fuels, The Open Biotechnology Journal, Current Biotechnology, and J. Wood Chemistry and Technology. He is an editorial board member of Sustainability and the Journal of Chemical Technology and Biotechnology. Dr. Ragauskas has served on several advisory boards and review panels including the Austrian Science Fund, European Commission Research Directorate, National Science Academy, J. Paul Getty Trust, NSF, USDA, DOE, ARAPA-E, NSERC, TAPPI Research Management Committee, Netherlands Organization for Scientific Research (NWO), Swedish Foundation for Strategic Research, Swedish VINN Excellence Center, Swedish Knowledge Foundation, VTT Technical Research Centre of Finland, ERA Chemistry, Swiss National Science Foundation, Finnish Academy of Science Norway Research Council, The Technology Foundation STW, Agence Nationale de la Recherche and Singapore Agency for Science, Technology, and Research. Dr. Ragauskas has been an invited visiting professor at Universidade da Beira Interior, Portugal; Chalmers University of Technology, Sweden; Royal Institute of Technology/ STFi, Stockholm, Sweden; and Southeast University, China, and South China University of Technology,

China.

Selected Papers 2023

Bioconversion of Homogeneous Linear C-Lignin to Polyhydroxyalkanoates

Zhao, Zhi-Min; Meng, Xianzhi ; Pu, Yunqiao; Li, Mi ; Li, Yibing; Zhang, Yihan; Chen, Fang; Ragauskas, Arthur J. Biomacromolecules (2023), 24(9), 3996-4004

Abstract

A review. The bioconversion of homogeneous linear catechyl lignin (C-lignin) to polyhydroxyalkanoates (PHA) was examined for the first time in this study. C-lignins from vanilla, euphorbia, and candlenut seed coats (denoted as C1, C2, and C3, resp.) varied in their mol. structures, which showed different mol. weight distributions, etherification degrees, and contents of hydroxyl groups. A notable amount of nonetherified catechol units existed within C1 and C2 lignins, and these catechol units were consumed during fermentation These results suggested that the nonetherified catechol structure was readily converted by Pseudomonas putida KT2440. Since the weight-average mol. weight of C2 raw lignin was 26.7% lower than that of C1, the bioconversion performance of C2 lignin was more outstanding. The P. putida KT2440 cell amount reached the maximum of 9.3 x 107 CFU/mL in the C2 medium, which was 37.9 and 82.4% higher than that in the C1 and C3 medium, resp. Accordingly, PHA concentration reached 137 mg/L within the C2 medium, which was 41.2 and 149.1% higher than the C1 and C3 medium, resp. Overall, C-lignin, with a nonetherified catechol structure and low mol. weight, benefits its microbial conversion significantly.

Novel candidate genes for lignin structure identified through genome-wide association study of naturally varying Populus trichocarpa

Bryant, Nathan; Zhang, Jin; Feng, Kai; Shu, Mengjun; Ployet, Raphael; Chen, Jin-Gui; Muchero, Wellington; Yoo, Chang Geun; Tschaplinski, Timothy J; Pu, Yunqiao; Ragauskas, Arthur, J. Frontiers in Plant Science (2023), 14, 1153113

Abstract

Populus is a promising lignocellulosic feedstock for biofuels and bioproducts. However, the cell wall biopolymer lignin is a major barrier in conversion of biomass to biofuels. To investigate the variability and underlying genetic basis of the complex structure of lignin, a population of 409 three-year-old, naturally varying Populus trichocarpa genotypes were characterized by heteronuclear single quantum coherence (HSQC) nuclear magnetic resonance (NMR). A subsequent genome-wide association study (GWAS) was conducted using approximately 8.3

million single nucleotide polymorphisms (SNPs), which identified 756 genes that were significantly associated (-log10(p-value)>6) with at least one lignin phenotype. Several promising candidate genes were identified, many of which have not previously been reported to be associated with lignin or cell wall biosynthesis. These results provide a resource for gaining insights into the molecular mechanisms of lignin biosynthesis and new targets for future genetic improvement in poplar.

One-pot generation of lignin microspheres and digestible substrate with a polyol-DES pretreatment in high solid loading

Cheng, Jinyuan; Zhan, Yunni; Liu, Xuze; Huang, Chen; Zhou, Xuelian; Wang, Jia; Meng, Xianzhi; Yoo, Chang Geun ; Fang, Guigan; Ragauskas, Arthur J. Journal of Cleaner Production (2023), 394, 136322

Abstract

Previous lignin microspheres (LMS) preparation needs multiple steps with very low yield and high cost. Herein, we developed a high-solid DES pretreatment for an effective lignin fractionation and enzymic saccharification of moso bamboo under mild temperature with high-solid loading. Lignin was significantly removed from the plant cell wall, and cellulose properties were also altered during the pretreatment. As a result, the enzymic digestibility of the pretreated bamboo was dramatically increased. Uniform micro-spherical lignin was directly produced from the pretreatment system, and its particle size could be regulated by controlling the solid loadings and pretreatment temperatures The lignin microspheres formation mechanism was investigated by analyzing the lignin's size distribution, mol. weight distribution, chem. structure, and hydrophobicity. The DES showed excellent recyclability, and the recycled DES could still remove 42.78% lignin even after 7th circulation associated with 100% glucan saccharification. The mass balance based on 1000 g biomass showed that 196.28 g LMS was directly recovered, which exhibited a high RhB adsorption. Besides, 404.91 g glucose and 36.67 g xylose were obtained after the enzymic saccharification process. Specifically, GAPI anal. exhibited a near total green and yellow portions of the pictogram, indicating our DES process was green enough to make this biorefinery sustainable. Overall, the proposed DES generated synergistic productions of digestible solid and LMS.

Upcycling disposable face masks into fuel range iso-alkanes through hydropyrolysis coupled with vapor-phase hydrocracking.

Wang, Jia; Jiang, Jianchun; Zhang, Yiyun; Meng, Xianzhi; Ragauskas, Arthur J. Energy (2023), 263(Part_B), 125843

The COVID-19 pandemic has resulted in an alarming accumulation of plastic waste. Herein, an integrated hydropyrolysis and hydrocracking process was performed to upcycle disposable masks into fuel-range iso-alkanes over carbon

supported ruthenium (Ru/C). Exptl. results indicated that catalyst type significantly affected product distribution during the hydropyrolysis and vapor-phase hydrocracking of disposable masks. Compared with zeolites-induced catalytic cascade process where up to ∼25.9 wt% yield of aromatic hydrocarbons such as toluene and xylenes were generated, a ∼82.7 wt% yield of desirable iso-alkanes with a high C5-C12 gasoline selectivity of 95.5% was obtained over Ru/C under 550°C hydropyrolysis temperature and 300°C hydrocracking temperature at 0.2 MPa H2. The cascade hydropyrolysis and hydrocracking process also exhibited high adaptability and flexibility in upcycling single-use syringes, food packaging, and plastic bags, generating 79.1, 81.6, and 80.3 wt% yields of fuel range iso/n-alkanes, resp. This catalytic cascade hydrotreating process provides an efficient and effective approach to convert pandemic-derived plastic waste into gasoline-range fuel products.

Characterization and molecular simulation of lignin in cyrene pretreatment of switchgrass

Wang, Yun-Yan; Wang, Yunxuan; Liang, Luna; Smith, Micholas Dean; Meng, Xianzhi; Pu, Yunqiao; Mazarei, Mitra; Agarwal, Rupesh; Rukmani, Shalini J.; Davison, Brian H.; Ragauskas, Arthur J. Green Chemistry (2023) DOI: 10.1039/d3gc02239k

Biomass-derived solvents have been proposed as a novel pathway in biorefining for the realization of biofuels and bioproducts derived from lignocellulosic biomass. Cyrene derived from cellulose has recently been shown to have a high potential as a green organic solvent for pretreating poplar biomass. In this study, we combine exptl. and computational approaches to examine the impact of cyrene pretreatment with reduced cyrene concentration under mild conditions on switchgrass lignin. Our exptl. studies indicated correlation between pretreatment condition and recovery and structure modification of lignin. Switchgrass lignin extracted by cyrene pretreatment possessed high preservation of β-O-4 ether inter-unit linkage, which could provide versatility in the integration of downstream lignin valorization into the modern biorefinery industries. Mol. modeling examining the solvation of switchgrass lignin polymer and the disaggregation of low-mol. weight lignin aggregates under pretreatment conditions indicated that a preferential interaction exists between cyrene and lignin, which likely drives lignin release, and that the disruption of inter-lignin contacts can be modulated as a non-monotonic function of cyrene : water ratio. The results indicated that loss of pretreatment efficacy caused by low cyrene concentration could be compensated by prolonged pretreatment time and high catalyst dosage.

Effects of Dusting Film Cooling Placement & Configuration on Surface Heat Transfer Characteristics of a Transonic Turbine Squealer Blade Tip

by Phil Ligrani, Member EUAS

Short Biography

Eminent Scholar in Propulsion, Professor of Mechanical and Aerospace Engineering, Department of Mechanical and Aerospace Engineering, Propulsion Research Center, 5000 Technology Drive, University of Alabama at Huntsville

PROFESSIONAL PREPARATION

University of Texas at Austin	*Mechanical Engineering*	*Bachelor of Science, 1974*
Stanford University	*Mechanical Engineering*	*Master of Science, 1975*
Stanford University	*Mechanical Engineering*	*Doctor of Philosophy, 1980*

APPOINTMENTS

2014 – present	*Eminent Scholar in Propulsion, Professor of Mechanical and Aerospace Engineering, Department of Mechanical and Aerospace Engineering, University of Alabama*
2010 – 2014	*Professor of Aerospace & Mechanical Eng, Saint Louis University*
2010 – 2013	*Director of Graduate Programs, Parks College, Saint Louis University*
2006 – 2009	*Statutory Professor, Department of Engineering Science, University of Oxford*
2006 – 2009	*Director, Rolls-Royce UTC (University Technology Centre)*
1997 – 2006	*Professor, Department of Mechanical Engineering, University of Utah*
2002 – 2006	*Adjunct Professor, Department of Bioengineering, University of Utah*
1992 – 1997	*Associate Professor, Department of Mechanical Engineering, University of Utah*

ARCHIVAL JOURNAL PUBLICATIONS AND RELATED ITEMS.

As of December 2023, Dr. Ligrani is author or co-author of more than 226 publications in archival journals, including the International Journal of Heat and Mass Transfer, the ASME Transactions-Journal of Turbomachinery, the ASME Transactions-Journal of Engineering for Gas Turbines and Power, the ASME Transactions-Journal of Heat Transfer, the ASME Transactions-Journal of Fluids Engineering, the International Journal of Thermal Sciences, Nature - Scientific Reports, the Journal of Fluid Mechanics, the AIAA Journal, Experiments in Fluids, Physics of Fluids, the AIAA Journal of Heat Transfer and Thermophysics, the International Journal of Rotating Machinery, Separation Science and Technology, Sensors and Actuators A: Physical, Measurement Science and Technology, Applied Thermal Engineering, and the Journal of Microcolumn Separations. He is also author of 11 book chapters, and about 165 conference presentations and publications. A number of these are invited conference presentations at international meetings, at locations which include Korea, France, the Ukraine, Croatia, Germany, England-United Kingdom, and Belgium. From 1994 to 2023, he has also presented approximately 202 lectures at different institutions and establishments, including many invited lectures. From 2006 to 2023, he presented or is scheduled to present approximately 8 Invited Keynote Papers, 12 Invited Papers, and 12 Invited Plenary Papers at different international conferences. Current SCOPUS Reference Citation H-INDEX is 48. Current GOOGLE SCHOLAR Reference Citation H-INDEX is 56.

EDITOR ACTIVITIES.

From 1998 to 2000, Dr. Ligrani served as Guest Editor for a Special Topical Issue for Measurement Science and Technology. He has also served as Associate Editor for the ASME Transactions-Journal of Heat Transfer from 2003 to 2006, and from 2010 to 2014, and for the ASME Transactions-Journal of Fluids Engineering from 2005 to 2008. Presently, he is Associate Editor, ASME Transactions-Journal of Journal of Engineering for Gas Turbines and Power, which has been underway from 2018 to 2021 and from 2021 to 2024.

SELECTED RECENT HONORS, AWARDS, ACADEMIC RECOGNITIONS

● 2024 ASME Henry R. Worthington Medal. ● 2020 College of Engineering Outstanding Faculty Member Award. University Award, University of Alabama in Huntsville, Huntsville, Alabama, USA. ● 2020 Undergraduate Research and Creative Activity Mentor Award. University of Alabama in Huntsville,

Huntsville, Alabama, USA. ● May 2020. Hermann Oberth Award in recognition of outstanding individual scientific achievement in the field of astronautics and advancement of the aeronautical sciences. AIAA – American Institute of Aeronautics and Astronautics. Greater Huntsville Section of the AIAA, Huntsville, Alabama, USA. ● March 2020. Employee Service Award, Five Years of Service. University of Alabama in Huntsville, Huntsville, Alabama, USA. ● ASME IGTI Outstanding Service Award 2019. ● 2019 University Distinguished Research Award for Excellence. University of Alabama in Huntsville, Huntsville, Alabama, USA. ● Outstanding Senior Faculty Member Award for 2019. College of Engineering, University of Alabama in Huntsville, Huntsville, Alabama, USA. ● Member. European Union Academy of Sciences (EUAS). 2019 to present. ● Guest Professor. School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai, P. R. China. 2019 to 2022. ● Outstanding Mechanical Engineer of the Year Award 2016, ASME – American Society of Mechanical Engineers, NAS - North Alabama Section, USA. ● Marquis Lifetime Achievement Award, Marquis Who's Who, New Providence, New Jersey, USA, 2016. ● Distinguished Advisory Professor, Inje University, South Korea, 2010 to 2022. ● Distinguished Lecture Award, 2011, CEAS Distinguished Lecture Series, College of Engineering, University of Wisconsin, Milwaukee, Wisconsin, USA. ● Distinguished Editorial Review Board membership for Springer Publishing Corporation. ● Carl E. and Jessie W. Menneken Faculty Award for Excellence in Scientific Research. ● NASA Space Act Tech Brief Award for "Development of Subminiature Multi-Sensor Hot-Wire Probes." ● Silver Winner for the Annual 26th Educational Advertising Awards for the Higher Education Marketing Report.

Dr. Ligrani has a strong past and present record of working with many different collaborators and co-workers, from many locations throughout the world. Additional information on selected, currently active research projects is provided within sections which follow. **(i) Traditional Heat Transfer and Fluid Mechanics Investigations** involving electronics cooling, heat transfer augmentation, drag reduction, turbulent boundary layers, flows in channels with dimpled surfaces, flows in curved channels, elastic turbulence, slot impingement cooling, and macro-scale pumps and pump flows. Also included are **aerodynamics investigations with *high-speed, compressible flows at transonic and supersonic Mach numbers***, including SWBLI – Shock Wave Boundary Layer Interactions. Related projects involve **transonic and supersonic experimental testing**. Research interests also include experimental diagnostics in high speed flows, and air breathing propulsion. **(ii) Air Breathing Engines - Gas Turbine Heat Transfer, Cooling, and Aerodynamics Losses**, including internal cooling, film cooling, impingement cooling, cooling of extremities, aerodynamic performance including aerodynamic losses, and transonic turbine flows and heat transfer. This subject area includes the effects of uses of bio-fuels, synthetic fuels, and renewable energy sources in relation to gas turbines and gas turbine heat transfer and cooling technologies. Note that an important area of turbomachinery research interest involves heat transfer and aerodynamics investigations with *high-speed, compressible flows at transonic and supersonic Mach numbers*, including linear cascade studies. **(iii) Micro-Fluidics and Millimeter-Scale-Fluidics**, including micro-pump flows, and the effects of slip phenomena on gas and liquid flows in micro-scale passage flows with and without surface roughness, including the effects of hydrophobic surfaces and elastic turbulence. **(iv) Experimental Techniques**, including development of millimeter-scale multiple-hole pressure probes, subminiature hot-wire anemometry, and infrared thermography.

EFFECTS OF DUSTING FILM COOLING PLACEMENT AND CONFIGURATION ON SURFACE HEAT TRANSFER CHARACTERISTICS OF A TRANSONIC TURBINE SQUEALER BLADE TIP.

Investigated are the effects of dusting hole film cooling placement and configuration on

the surface heat transfer characteristics of a transonic turbine squealer blade tip. Three different blade tip arrangements are investigated, which are denoted C1, C2, and C3. Data are provided which include spatially-resolved and line-averaged distributions of heat transfer coefficient ratio and adiabatic film cooling effectiveness. The University of Alabama in Huntsville SS/TS/WT (supersonic/transonic/wind tunnel) blow down facility is employed with a transonic test section containing a five blade linear cascade for the investigation. Spatially-resolved surface heat transfer characteristics are measured using time- and spatially-resolved infrared thermography, in conjunction with an impulse response transient measurement procedure. Film coolant is supplied with a carbon dioxide injection system. Results indicate that heat transfer coefficient and adiabatic film cooling effectiveness distributions vary significantly as dusting hole placement and configuration are altered. For example, heat transfer coefficients for the C1 and C2 blade configurations are substantially lower, compared to baseline values with no film cooling, within the squealer recess region downstream of the dusting holes. Smaller heat transfer coefficient deviations, relative to baseline values, are present when the C3 configuration is employed. In general, distributions and magnitudes of local adiabatic film cooling effectiveness indicate that all three dusting hole configurations provide reasonably good film coverage within portions of squealer recess regions. For downstream portions of the blades, the C1 and C3 configurations both provide good surface protection which are indicated by film cooling effectiveness values, whereas coverage provided by the C2 arrangement ends abruptly at the location of a structural rib which is located within the squealer recess region.

INTERRELATIONSHIPS OF ENTROPY PRODUCTION AND TURBULENCE KINETIC ENERGY ASSOCIATED WITH SIMPLE ANGLE AND COMPOUND ANGLE FULL COVERAGE FILM COOLING.

Compared are experimentally-measured distributions of entropy generation with numerically-predicted distributions of streamwise vorticity, turbulence kinetic energy, and production of turbulence kinetic energy. These comparisons are provided for two full-coverage film cooling environments which are designed to model the thermal management arrangements employed for combustor liners within gas turbine engines. One of these arrangements includes alternating compound angle values of +30 degrees in one row of holes, followed by -30 degrees in the next row of holes. The other arrangement includes simple angle holes with a zero degree compound angle value. The associated full-coverage film cooled boundary layers are investigated within a double-wall cooling test facility wherein the air for each full-coverage film cooling arrangement is provided by an impingement jet array. Experimentally-measured entropy generation values are obtained from film cooled boundary layer measurements of local total pressure variations, obtained in isothermal flow, relative to the freestream values outside of the boundary layer. The resulting entropy generation values quantify second law losses, which are associated with aerodynamic gains. To obtain the associated numerical-prediction results for a steady-state, three-dimensional flow field, employed is the ANSYS FLUENT Version 2022 R2 computational code with a SST k-ω turbulence closure model. The resulting comparisons of entropy generation, streamwise vorticity, turbulence kinetic energy, and production of turbulence kinetic energy are provided for a blowing ratio BR of 2.9 for simple angle film cooling with a main flow Reynolds number Rems of 138,000, and for compound angle film cooling with a main flow Reynolds number Rems of 142,000. Overall, evidence is provided of strong relationships between local turbulence kinetic energy and local entropy

production since the two quantities are highly correlated with each other over s substantial range of experimental conditions and configurations. For example, ratio of turbulence kinetic energy to entropy generation data collapse for particular spanwise and normal flow locations, and both film cooling arrangements. Here, the value of the TKE/Sgen ratio is approximately constant for these conditions, which evidences direct and simple dependences of local turbulence kinetic energy upon local entropy generation, even for flow locations close to the test surface. The direct and simple dependences of local turbulence kinetic energy upon local entropy generation are further illustrated by the simplicity of linear correlation equations, which represent physical behavior for different conditions and configurations.

NORMAL SHOCK WAVE COHERENCE REALTIVE TO OTHER FLOW EVENTS WITH HIGH AND LOW INLET TURBULENCE INTENSITY.

Considered are interactive relationships between a normal shock wave and the downstream shock wave leg of the associated lambda foot, as well as between a normal shock wave and time-varying static pressure as measured along the bottom surface of the test section. Such relationships are investigated as they vary with two different magnitudes of inlet turbulence intensity, and are characterized using shadowgraph flow visualization data, as well as power spectral density, magnitude squared coherence, and time lag data. Employed for the investigation is a specialty test section with an inlet Mach number of 1.54, as utilized within a transonic/supersonic wind tunnel. The resulting data provide evidence of distinct interactions over a wide range of frequencies between the normal shock wave and the downstream shock wave leg of the lambda foot for low inlet turbulence intensity. Note that these are not present in the same form and over the same ranges of frequency with high inlet turbulence intensity. These differences are partially due to the location where flow events originate. The most significant sources of flow unsteadiness within the present investigation are mostly associated with the normal and oblique shock waves (with low inlet turbulence intensity), and mostly with inlet flow disturbances from unsteady Mach waves (with high inlet turbulence intensity). The present experimental results additionally evidence important connections between the normal shock wave and unsteady flow events within lower portions of the lambda foot, especially near the adjacent boundary layer separation region.

EFFECTIVE DIFFUSION FROM ELASTIC INSTABILITES WITHIN ROTATING COUETTE FLOWS.

Considered is effective diffusion, characterized by magnitudes of effective diffusion coefficients, in order to quantify mass transport due to the onset and development of elastic instabilities. Effective diffusion coefficient magnitudes are determined using different analytic approaches, as they are applied to tracked visualizations of fluorescein dye front variations, as circumferential advection is imposed upon a flow environment produced using a rotating Couette flow arrangement. Effective diffusion coefficient results are provided for a range of flow shear rates, which are produced using different Couette flow rotation speeds and two different flow environment fluid depths. To visualize flow behavior within the rotating Couette flow environment, minute amounts of fluorescein dye are injected into the center of the flow container using a syringe pump. This dye is then redistributed within the flow by radial diffusion only when no disk rotation is used, and by radial diffusion and by circumferential advection when disk rotation is present. Associated

effective diffusion coefficient values, for the latter arrangement, are compared to coefficients values with no disk rotation, which are to molecular diffusion alone, in order to quantify enhancements due to elastic instabilities. Experiments are conducted using viscoelastic fluids, which are based on a 65 percent sucrose solution, with different polymer concentrations ranging from 0 ppm to 300 ppm. Associated Reynolds numbers based on fluid depth and radially-averaged maximum flow velocity range from 0.00 to 0.5. Resulting effective diffusion coefficient values for different flow shear rates and polymer concentrations quantify the onset of elastic instabilities, as well as significant and dramatic changes to local mass transport magnitudes which are associated with further development of elastic instabilities.

CONJUGATE HEAT TRANSFER EVALUATION OF TURBINE BLADE LEADING-EDGE SWIRL AND JET IMPINGEMENT COOLING WITH PARTICULATE DEPOSITION.

Internal cooling structures for gas turbine engines are becoming more complicated to push the hot gas temperature as high as possible. As a consequence, particulates are drawn into the coolant air to be more readily deposited within these passages and significantly affect the associated flow loss and thermal performance. In this study, internal swirl cooling and jet impingement cooling subjected to particulate deposition are evaluated and compared using a conjugate heat transfer method, with an emphasis on the thermal effects of the insulative deposits. To accomplish the goal, an unsteady conjugate mesh morphing simulation framework is developed and validated, which involves particle tracking in an unsteady fluid flow, particle-wall interaction modeling, conjugate mesh morphing of both fluid and solid domains, and a deposit identification method. The swirl and the jet impingement cooling configurations model the internal cooling passage for the leading-edge region of a turbine blade, and are investigated in a dust-laden coolant environment with real engine conditions. Coupling effects between the dynamic deposition process and the unsteady flow inside the two cooling channels are examined and the insulative effects of the deposits are quantified by comparing the temperatures on the external and internal surfaces of the metal channel walls, as well as on the deposit layers. Results demonstrate the ability of the newly-developed, unsteady conjugate simulation framework to identify the deposits from the original bare wall surface and to predict the insulation effects of the deposits in the dynamic deposition process. As this process is underway, the dust almost covers the entire impingement channel, while deposits are only seen in the vicinity of the jets in the swirl channel. Despite this, a dramatical decrease of convection heat transfer is found in the swirl channel because the swirling flow is sensitive to the interruption of the deposits. In contrast, the deposits improve the heat transfer rate in the impingement channel. When the thermal effects of the deposit layer are also considered, the wall temperatures of both two cooling geometries are substantially elevated, exceeding the allowable temperature of the metal material. Due to the denser deposit coverage, the impingement channel wall shows a greater temperature increase than the swirl channel. In terms of flow loss, the presence of the deposits reduces swirl intensity by interrupting the swirling flow and thus reduced the friction loss, whereas the pressure loss is improved by the deposits when impingement cooling is employed.

Experimental and Numerical Study on Fire Endurance of Bonded Post-Tensioned Concrete Slabs

by Thomas Kang, Member EUAS

Short Biography

Dr. Thomas Kang is a professor in the Department of Architecture & Architectural Engineering and the Interdisciplinary Artificial Intelligence Program at Seoul National University (SNU), Korea. Before that, he was a professor in the School of Civil Engineering and Environmental Science at the University of Oklahoma. He also has held various affiliated positions in the U.S., Japan and South Africa, including the University of Illinois at Urbana-Champaign, University of California Los Angeles (UCLA), University of Hawaii at Manoa, University of Tokyo and University of Cape Town. Prof. Kang received his PhD from University of California Los Angeles (UCLA) in 2004, his MS from Michigan State University in 2000, and his BS from SNU in 1998.

Dr. Kang is a Fellow and Technical Advisory Board (TAB) member of Post-Tensioning Institute (PTI), a Fellow of American Concrete Institute (ACI), and a Fellow of the Korean Academy of Science and Technology (KAST), as well as a member of the National Academy of Engineering of Korea (NAEK) and EU Academy of Sciences (EUAS). He received the Kenneth B. Bondy Award for Most Meritorious Technical Paper as Lead Author from PTI twice in 2012 and 2023, the Martin P. Korn Award from Precast/Prestressed Concrete Institute (PCI) in 2023, and the Wason Medal for Most Meritorious Paper as Lead Author from ACI in 2009. He currently serves as an Editor-in-Chief for Wind and Structures and as the Associate Editor for PTI Journal. Prof. Kang published over 184 international journal papers, including 57 in ACI Structural Journal. His research interests include the design and behavior of reinforced, prestressed and post-tensioned concrete structures, as well as dynamic effects (wind, seismic, impact & blast) on structures.

Dr. Kang has chaired numerous sessions/symposiums of structural engineering; delivered many plenary/keynote/invited speeches; and organized several international conferences/workshops as Chair or Co-Chair. He is also one of the founding and voting members of PTI DC-20 Committee, Building Design; and has been a voting member for a variety of technical committees, including: ACI Subcommittee 318-T, Structural Concrete Building Code – Post-Tensioned Concrete; ACI Committee 369, Seismic Repair and Rehabilitation; Joint ACI-PTI Committee 320, Post-Tensioned Concrete Building Code; Joint ACI-ASCE Committees 335, Composite and Hybrid Structures; 352 Joints and Connections in Monolithic Concrete Structures; and 423, Prestressed Concrete; and Joint ACI-ASME Committee 359, Concrete Containments for Nuclear Reactors.

Abstracts of Selected Recent Papers

Experimental and Numerical Study on Fire Endurance of Bonded Post-Tensioned Concrete Slabs (by S. Park and T. H.-K. Kang; Journal of Structural Engineering, V. 149, No. 12, Dec. 2023)

Vulnerability of post-tensioned (PT) slabs to fire has prompted researchers to conduct tests and devise means for numerical analysis. In this study, bonded PT slabs with varying cover thicknesses were subjected to fire test with a numerical model developed based on the results. Tests conducted demonstrate that current codes governing cover thickness adequately address fire resistance. Structural behavior of PT slabs was analyzed based on thermal responses for concrete and steel. Numerical modeling for heat transfer and coupled thermo-mechanical analyses was validated by comparison to fire test results. To confront cover thickness influence on fire resistance performance, a parametric study to develop a numerical means of analysis was conducted and evaluated. It is the authors' hope that identified influencing factors in fire resistance performance for PT slabs and numerical modeling method proposed may be helpful in design of bonded PT concrete slabs with both unrestrained and restrained conditions.

Seismic Behavior of Monolithic Exterior Beam-Column Connections with Unbonded Post-Tensioning (by S. Kim, T. H.-K. Kang, D. Jung, B. Kwon, and D. J. Lee; ACI Structural Journal, V. 120, No. 11, Nov.-Dec. 2023)

This paper presents experimental results on seismic behaviors of post-tensioned monolithic exterior beam-column connections. Lateral cyclic loading tests were carried out for six full-scale exterior beam-column joint subassemblies fabricated with normal and high strength materials. Despite substantial joint cover spalling, the normal strength specimens exhibited satisfactory lateral strengths and hysteretic behaviors up to ±5% drift ratios by virtue of confinement effect of post-tensioning. The post-tensioned, high strength specimens also showed stable hysteretic behaviors with significantly reduced joint damages. It was found that the post-tensioning can increase the joint shear strength by more than 60% in both types of specimens. Furthermore, the post-tensioning was effective in retaining the lateral stiffness of the beam-column joints under the repeated loads, especially in high strength specimens, enabling them to maintain at least 90% of their first-cycle stiffnesses throughout the testing.

Engineering Review of Wind-Induced Torsional Moment and Response of Buildings (by H. Alinejad, T. H.-K. Kang, S. Y. Jeong, and B. Ahn; Journal of Structural Engineering, V. 149, No. 11, Nov. 2023)

For building service and strength design under wind load, torsional moment and response (or torsional-wind load) is a main component. Several factors contribute to torsional-wind load including: asymmetric distribution of wind pressure on the building façade (aerodynamic source), dynamic torsional vibration, and the contribution of resonant components of along-wind and across-wind loads in presence of mass-stiffness eccentricity. In addition, adjacent building influence can be considerable. For low (1 or 2 stories) to mid-rise (less than 10 stories) buildings, the main component in torsional-wind load typically is aerodynamic source. For tall buildings, contribution due to all sources is significant. In this paper, theoretical background and procedures to calculate torsional-wind load, with more of a focus on the concept of equivalent eccentricity and equivalent static wind load, are discussed. Then, procedures and perspectives in several international standards, including ASCE 7-22, AIJ-RLB-2015, AS/NZS 1170.2-2011, KDS 41-2019 and ISO 4354-2009, are introduced to clarify differing points of view and how components of torsional-wind load are included. Finally, main parameters of each standard are compared with wind tunnel test results. The results confirm consistency between the wind tunnel test results and those based on the standards with consideration of their covered ranges.

Structural Performance of Precast Concrete Column Joint with Clamped Headed Bar during Construction (by S. R. Ahn, H. S. Sung, and T. H.-K. Kang; ACI Structural Journal, V. 120, No. 3, May-June 2023)

Proposed is use of a self-supporting precast concrete (SSPC) system using clamped headed bars. The system provides structural safety and serviceability without use of temporary bracing or guying during construction as well as in post construction. To verify proposed system performance, nine mechanical splice component specimens and two full-scale PC specimens were fabricated for material tests, mock-up tests, and quasi-static push-over tests. To evaluate wind and impact resistance performance during PC construction, parametric studies for a temporary installation state were carried out based on the experimental results. Under potential wind and impact loads, the system displayed slip resistance in the elastic range as well as eccentric installation tolerance and satisfactory ultimate strength performance. Moment larger than nominal flexural strength was also observed in SSPC system.

New Aspects in Cancer Prevention and Molecular Carcinogenesis

by Zigang Dong, Member EUAS

Short Biography

Position:*Professor, Vice President of Zhengzhou University and Dean of Medical College*

Education

1978 – 1983 *M.D., Department of Medicine, Henan Medical University, P.R. China*

1983 – 1986 *M.S., Department of Pathophysiology, Henan Medical University, P.R. China*

1987 – 1991 *Dr. P.H., Mailman School of Public Health, Columbia University, New York*

Positions and Honors

1991 – 1995 *Postdoctoral Fellow, PRI/DynCorp, NCI-Frederick Cancer Research & Development Center, Frederick, MD*

1992 – 1995 *Group Leader, PRI/DynCorp, NCI-Frederick Cancer Research & Development Center, Frederick, MD*

1995 – 1997 *Assistant Professor, The Hormel Institute, University of Minnesota, Austin, MN*

1998 – 1999 *Associate Professor, The Hormel Institute, University of Minnesota, Austin, MN*

1997 – 2019 *Full Member, Cancer Center, University of Minnesota, Minneapolis, MN*

2001 – 2019 *Executive Director, The Hormel Institute, University of Minnesota, Austin, MN*

2000 – 2019 *Full Professor, The Hormel Institute, University of Minnesota, Austin, MN*

2009 – present *Professor with tenure, Department of Biochemistry, Molecular Biology and Biophysics, University of Minnesota*

2019 – present *Dean of College of Medicine, Zhengzhou University, Zhengzhou, Henan, China*

2020 – present *Vice president, Zhengzhou University, Zhengzhou, Henan, China*

Awards, Honors and Other Special Scientific Recognition

1999 *The Gallo Award, The Cancer Institute of New Jersey*

2000 *Alice Hamilton Award, Biological Science category, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention (CDC) for research presented in JBC 274: 30611-30616, 1999 (Publication # HI 1442)*

2001 – 2019 *Hormel/Knowlton Professor, The Hormel Institute, University of Minnesota*

2006 – 2019 *University of Minnesota McKnight Presidential Professor in Cancer Prevention*

2008 – 2014 *National Institutes of Health Merit Award*

2010 – 2019 *Internal Advisory Committee, Center for Translational Science Activities, Mayo Clinic*

2010 *World Class Professor, Seoul National University, South Korea*

2011 – 2015 *External Steering Panel for the Division of Cancer Prevention, NCI, NIH*

2011 *Oh Dang Award, The Pharmaceutical Society of Korea, South Korea*

2012 *Stars in Nutrition and Cancer Lecturer Award, Division of Cancer Prevention, NCI, NIH*

2013 – 2019 *I.J. Holton Professor, The Hormel Institute, University of Minnesota*

2013 *International Science and Technology Collaboration Award, Hunan, China*

2014 *Yellow River Friendship Award, China*

2016 *Outstanding Achievement Award, Society of American Asian Scientists in Cancer Research*

2020 *The 8th Overseas Chinese Contribution Award, China*

2020 *Science and Technology Collaboration Award, Henan, China*

2023 *Foreign Full Member, Academician of the Russian Academy of Engineering*

Editorial Work

2004 – 2008	*Carcinogenesis: Editorial Board member*
2003 – 2010	*Journal of Biochemistry and Molecular Biology: Overseas Editor*
2005 – present	*Molecular Carcinogenesis: Associate Editor*
2003 – present	*Biofactors: Editorial Board member*
2006 – present	*International Journal of Biological Sciences: Editorial Board member*
2007 – 2013	*Cancer Research: Editor*
2008 – 2015	*Cancer Prevention Research: Editorial Board member*
2015 – present	*Cancer Prevention Research: Senior Editor*
2010 – 2014	*Carcinogenesis: Editorial Board member*
2011 – 2019	*The Journal of Biological Chemistry, Editorial Board member*
2014 - 2019	*EBioMedicine Editorial Board member*
2016 – 2019	*Nature Partner Journal: Precision Oncology: Editor-in-Chief*

Professor Zigang Dong is the vice President for Medical Affairs and Dean of Medical School of Zhengzhou University, which is one of the largest University in China with 75000 students. Professor Dong has long served as the director of the Hormel Institute of the University of Minnesota. He is also the professor with tenure, Department of Biochemistry, Molecular Biology and Biophysics of University of Minnesota.

Professor Dong is a world leader in cancer prevention and molecular carcinogenesis. He conducted pioneering work in elucidating physical and chemical carcinogen-induced signal transduction pathways as molecular targets for chemopreventive agents in carcinogenesis, especially solar ultraviolet (SUV), UVA and UVB-induced skin cancers. Skin cancer is the most common cancer in the United States. The total incidence of all other cancers in the Americas is almost equal to the number of skin cancers, including melanoma and non-melanoma skin cancer. Because UVC is blocked by the ozone layer, UVA and UVB are the main components of solar UV that can reach the surface of the earth and penetrate human skin. We were the first group to systematically elucidate these signal transduction pathways in skin carcinogenesis. These signaling proteins include protein kinase C, extracellular signal-regulated kinases (ERKs), c-Jun N-terminal kinases (JNKs), ribosomal S6 kinase (RSK), mitogen- and stress-activated protein kinase (MSK), lymphokine-activated killer T-cell-originated protein kinase (TOPK), and transcription factors activator protein-1 (AP-1), nuclear factor kappa B (NF-kappaB), nuclear factor of activated T cells (NFAT), p53, and others. Notably, we showed that UV irradiation directly activates cannabinoid receptors 1 and 2 (CB1/2). Particularly, our data indicated that the absence of the CB1/2 receptors in mice results in a dramatic resistance to UVB-induced inflammation and a marked decrease in UVB-induced skin carcinogenesis. We also reported that the p38-related signal transduction pathway affected by SUV irradiation is critical for SUV-induced skin carcinogenesis. We have also tested the effects of many natural compounds in the prevention of SUV-induced skin cancer and identified their molecular targets. For example, taxifolin (a flavanonol found in macai palm, silymarin and red onion) reportedly exerts multiple biologic effects and we studied the molecular

mechanisms and direct target(s) of taxifolin in skin cancer chemoprevention.

At the same time, he made important contributions to the pathogenesis of lung cancer, liver cancer, esophageal cancer, colorectal cancer and cervical cancer with high incidence in the world through in-depth research on genomics, single cell sequencing, spatial transcriptome and immune microenvironment. For lung cancer study, their initial molecular target–oriented virtual screening revealed that the ginger components, including [6]-shogaol, [6]-paradol, and [6]-gingerol, and butein, a USP8 inhibitor, and 3,6,2',4',5'-pentahydroxy -flavone seem to be potential candidates for the prevention and treatment of NSCLC. Among the compounds, [6]-shogaol showed the greatest inhibitory effects against NSCLC cell proliferation and anchorage-independent growth. [6]-Shogaol induced cell cycle arrest (G1 or G2/M) and apoptosis. Furthermore, [6]-shogaol inhibited Akt kinase activity, a downstream mediator of EGFR signaling, by binding with an allosteric site of Akt. Other inhibitors such as butein, a USP8 inhibitor and 3,6,2',4',5'-pentahydroxy-flavone all showed potent inhibitory effects against lung cancer cells in vitro and in vivo. These inhibitors can overcome EGFR inhibitor resistance in lung cancer.

For esophageal cancer study, he used spatial transcriptomics analysis to sequence specific areas of esophageal squamous epithelial precancerous lesions, and found that the stage of esophageal squamous precancerous lesions was in an immunosuppressive state. The use of machine learning methods to screen and study confirmed that the expression of TAGLN2 significantly increases during the progression of esophageal cancer, while the expression level of CRNN decreases. Further research confirms that TAGLN2 promotes the progression of esophageal cancer, while CRNN inhibits the progression of esophageal cancer. This study suggests that early intervention should be carried out in high-risk populations with abnormal expression of TAGLN2 and CRNN in esophageal precancerous lesions. Professor Dong has published more than 560 articles in highly prestigious journals, including Nature, Nature Structure and Molecular Biology, Nature Cell Biology, Nature Reviews Cancer, Molecular Cell, PNAS, Science Signaling and Cancer Research. His articles are cited frequently with total citations numbering over 36,000. He has been invited by the editors of Science, Nature, and other journals to publish review articles in these high-impact journals. He also serves as a member of several editorial boards and as editor or associate editor of many scientific journals such as Cancer Research, The Journal of Biological Chemistry, Carcinogenesis, Molecular Carcinogenesis, EBioMedicine and Cancer Prevention Research and Founding Editor of a new Nature sister journal: npj Precision Oncology. He presided over more than 50 scientific research projects such as the National Institutes of health of USA and the National Natural Science Foundation of China.

For gastric cancer study, he found that CDK12 is a driver gene in human gastric cancer growth. Mechanistically, CDK12 directly binds to and phosphorylates PAK2 at T134/T169 to activate MAPK signaling pathway. We further identified FDA approved clinical drug procaterol can serve as an effective CDK12 inhibitor, leading to dramatic restriction of cancer cell proliferation and tumor growth in human gastric cancer cells and PDXs. Our data highlight the potential of CDK12/PAK2 as therapeutic targets for patients with gastric cancer, and we

propose procaterol treatment as a novel therapeutic strategy for human gastric cancer. For a long time, H. pylori infection has been considered as the main cause of gastric cancer; However, so far, there is not enough experimental evidence to support this argument. His latest study found that infection with H. pylori and chronic drinking can induce mice to progress from chronic gastritis to gastric cancer. Further research found that IL-10 deletion plays an important role in this process. IL-10 gene knockout can accelerate the occurrence of H. pylori infection and alcohol induced gastric cancer. IL-10 promotes oxidative phosphorylation by inhibiting glucose uptake and glycolysis and by inhibiting lactic acid. Consequently, in the absence of IL-10 signaling, CD8 + cells accumulate damaged mitochondria in a mouse model of gastric cancer induced with the combination of alcohol plus H. pylori infection, and this results in mitochondrial dysfunction and production of IL-1β. Another interesting finding is H. pylori infection in combination with chronic stress can lead to gastric cancer, and the synergistic effects of cytokine production (i.e. IL-1α), T lymphocyte dysfunction contributes to gastric carcinogenesis which will offer treatment opportunities for stress-associated gastric cancer and provide new strategies for the prevention and treatment of gastric cancer in clinics.

Professor Dong got the McKnight Chair Professor which is the highest honor in the University of Minnesota. His research excellence has been recognized by receipt of the Gallo Award (1999) and the Alice Hamilton Award from the National Institute for Occupational Safety and Health (2000). In 2010, Professor Dong was named World Class University Professor by Korea Seoul National University. In 2008, NIH selected him as the winner of the MERIT Award. This award is the highest honor in NIH with continuous support. In 2011, he received the “Oh Dang” Award, which recognizes outstanding scholars who have had a major impact on pharmaceutical research based on his contributions to the development of cancer prevention agents. In 2012, he was named as “Stars of Nutrition and Cancer” by NCI. The award honors individuals viewed as extraordinary contributors or "stars" in the field of cancer and nutrition research. In 2013, he won the “Hunan International Science and Technology Cooperation Award” (China) and in 2014, he received the “Yellow River Friendship Award” (China). In 2016, he received Award of the Society of American Asian Scientists in Cancer Research. Recently, he received the 2020 Award of the 8th China Overseas Chinese community contribution for his outstanding contribution to China's medical and health field after coming back to China. In 2021, Professor Dong was selected as the "top 100000 scientists in the world", ranking third in clinical medicine in Chinese Mainland and first in all scientific fields in Henan Province. In 2023, he was elected as Foreign Full Member, Academician of the Russian Academy of Engineering.

Local Investigation of Superfluid Turbulence

by Patrick Tabeling, Member EUAS

Short Biography

Education

Year	*Faculty/department - University/institution - Country*
1976	*Ph.D. Paris 6 University (France)*
1974	*Master*

Positions - current and previous

Year	*Job title – Employer - Country*
1976 -1990 *1990 – 2018* *2018 -*	*Chargé de Recherche* *Directeur de Recherche* *Emeritus Directeur de Recherche*

Project management experience

Year	*Project owner - Project - Role - Funder*
2000-2003	*Chairman of PSWG (ESA Physical Sciences Working Group).*
2001-2003	*Founder and director of French CNRS network « Microfluidique »*
2001-2005	*Coordinator of the European network « Intermittency »*
2003-2006	*Directeur Adjoint du PIR Microfludique*
2011-2018	*Co-founder and Director of IPGG (Institute Pierre Gilles de Gennes, 250 research.)*
2014-2018	*Founder and Director of Carnot Institute IPGG*
2016-2018	*Founder and Director of UMS CNRS IPGG.*

Other relevant professional experiences

Year	*Description - Role*
2007-2012	*Divisional Editor de Physical Review Letters*
2010-2014	*Associate Editor de Physics of Fluids*
2011	*Elected Member of Academiae Europae*
2022	*Elected Member of EU Academy of Science*

Track record

The total number of publications during the career : approx. 200
Granted patent(s): 30
Industrial or public innovation or design and/or highlights from research or innovation with societal impact: Creation of two startups: MicroFactory (2014), MINOS (2019).

Abstracts of several papers

Local investigation of superfluid turbulence J Maurer, P Tabeling, Europhys. Letters, 43, 1 29 (1998)

In this paper, we showed that superfluid turbulence is similar to ordinary turbulence. It develops Kolmogorov spectra and intermittency, as in newtonian fluids. The experiment was performed in a vessel held at 1.3 K. The fluid was agitated by bladders and local

acoustic measurements were performed. At that time, the behavior of superfluids at large Reynolds numbers was a source of questioning, and this experiment provided a first response.

An introduction to Microfluidics, P. Tabeling, Oxford University Press (2005).

The book appeared in 2005, in an early stage of development of the field of microfluidics. It explained the laws governing the field, emphazing on a physical prospective. The second Edition appeared in July 2023.

Slippage of water past superhydrophobic CNT forests P Joseph, C Cottin-Bizonne, JM Benoit, C Ybert, C Journet, P Tabeling, *Physical review letters* 97 (15), 156104 (2006).

This experiment showed that water flowing above forests of nanotubles develop large slippage. At that time, slippage obtained over hydrophobic walls did not exceed 40 nm. By using carbon nanotubes, slippages up to 400 nm could be obtained.

Two-Dimensional turbulence, P Tabeling, *Physics reports* 362 (1), 1-62 (2002)

The paper reviews the progress made in 2D turbulence, from 1980 to 2000.

Ordered and disordered patterns in two-phase flows in microchannels R Dreyfus, P Tabeling, H Willaime , *Physical review letters* 90 (14), 144505 (2003).

The experiment showed that the behavior of immiscible fluids, driven in microchannels is controlled by the wettability of the walls, independently of the Hydro-Lipophilic balance, classically used in emulsions to determine which type of droplets are obtained.

Foam as a self-assembling amorphous photonic band gap material J Ricouvier, P Tabeling, P Yazhgur, *Proceedings of the National Academy of Sciences* 116 (19), 9202 (2019)

Realizing photonic materials with forbidden band gaps is a challenge. We showed in the paper that foams, ordered or weakly disordered (in a hyperuniform manner), easy to form, provide a natural structure capable of opening complete photonic band gaps.

Hydrogel cages L d'Eramo, B Chollet, M Leman, E Martwong, M Li, H Geisler, J Dupire, ... P.Tabeling, *Microsystems & Nanoengineering* 4 (1), 1 (2018).

The paper presents a novel technology, based on photosensitive polymers, capable of closing and opening microcages, by varying the temperature. One application is the capture of thousands of cancer cells, characterize the transcriptome of each of them, in order to fully characterize the tumor.

High Spatiotemporal Control of Spontaneous Reactions Using Ultrasound-Triggered Composite Droplets **M. Bezagu, C. Errico, V. Chaulot-Talmon, F. Monti, M. Tanter, P. Tabeling, J. Cossy, S. Arseniyadis, O. Couture *J. Am. Chem. Soc.* 136, 20, 7205 (2014).**

In the paper, we showed that chemical reactions can be controlled in a precise manner by using ultrasounds. Droplets containing chemical reagents are transported in microchannels. Being opened by the US excitation, they deliver their contents into the flow and initiate chemical reactions.

Based RNA detection for Ebola virus **L Magro, B Jacquelin, C Escadafal, P Garneret, A Kwasiborski, … P.Tabeling, *Scientific reports* 7 (1), 1 (2017).**

In 2017, with Pasteur, we showed that the presence of Ebola virus can be detected with a high sensitivy, by using molecular diagnostics, and operating a small and inexpensive device, based on paper microfluidics. The study was performed both in France and in French Guinea (Africa)

Cancer Immunotherapy by Tumor Membrane Vesicles (TMV) conjugated to Potent Immunostimulatory Molecules

by Dong Moon Shin, Member EUAS

Short Biography

Dong Moon Shin, MD, FACP, FAAAS
Professor of Medical Oncology and Francis Kelly Blomeyer Chair in Cancer Research
Emory University School of Medicine

Dr. Dong Moon Shin is currently Professor of Medical Oncology, Otolaryngology and Biomedical Engineering, and holds Frances Kelly Blomeyer Distinguished Endowed Chair in Cancer Research in the Department of Hematology and Medical Oncology at Winship Cancer Institute of Emory University. He graduated from Yonsei University College of Medicine and trained for Residency in Internal Medicine at Cook County Hospital, Chicago, IL and fellowship of Medical Oncology at the University of Texas M. D. Anderson Cancer Center, Houston, TX.

He has served as a faculty member in the Department of Thoracic/Head and Neck Medical Oncology at M. D. Anderson Cancer Center and University of Pittsburgh as Professor and Director of Head and Neck Cancer Program before he joined Emory University. He has been consecutively selected for last 18 years as a Best Doctor from Best Doctors in America since he was elected first in year 2003 and he has been also consecutively selected one of the Top Doctors from Castle Connolly Medical Ltd. and Atlanta Magazine for last 16 years since he was elected first in year 2005. Distinguished Leadership Award for Cancer Research from American Biographical Institute, Georgia Cancer Coalition Distinguished Scholar Award, the 2009 Yonsei University's Medicine Grand Prize Award, Honorary Professor at Central South University, China, the Frances Kelly Blomeyer Distinguished Endowed Chair in Cancer Research, and the 18th KBS Global Korean Award (in the category of Science and Technology). And he was also bestowed for Fellow of American Association of Advancement of Science (FAAAS) and many others.

Dr. Shin has also chaired numerous peer-review committees, including but not limited to the American Head and Neck Society, American Association of Cancer Research and the American Society of Clinical Oncology. He has also served as a member of many study sections at the National Cancer Institute, NIH and on the editorial boards (more than 15 scientific journals) including the Journal of Clinical Oncology, Clinical Cancer Research, Cancer Prevention Research, Molecular Cancer Therapeutics, International Journal of Oncology and others. He has published more than 360 articles in peer-reviewed journals (H-index of 70 and more than 27,000 citation numbers as of January 2021) in addition to more than 390 other publications including meeting abstracts, books, book chapters and monographs.

Dr. Shin's research has been well funded through funding from NIH/NCI (R01s, U01s, R21, etc.) and other funding agencies. Specifically he has been Principal Investigator of Emory University's Head and Neck Cancer SPORE program (Specialized Programs of Research Excellence), which

was awarded to Emory in 2007 by the National Cancer Institute (NCI). Another area of his interest has been nanotechnology based anti-cancer drug delivery in collaboration with several other investigators including biomedical engineers, chemists, material scientists, imaging experts and animal scientists.

In the 2023 annual report I would like to describe on update of immune based therapy for cancer, particularly, in the therapeutic tumor membrane vesicle (TMV) vaccine development for head and neck carcer (HNC) in collaboration with several other investigators, specifically, basic immunologists (Drs. Periasamy Sevaraj and Ramireddy Bommireddy) and other collaborative scientists.

The standard of care for surgically resectable HNCs consists of surgery followed by radiation therapy (RT) or chemoradiation therapy (CRT). However, tumor recurrence and/or metastasis frequently occur after definitive treatment for locally advanced HNSCC, and survival for patients with recurrent and/or metastatic disease is very poor (1). Recently, immune checkpoint inhibitors (ICI), pembrolizumab, nivolumab and anti-PD-1 antibody, have been used for the treatment of recurrent or metastatic HNC and have significantly improved the survival of patients compared with single or combination cytotoxic chemotherapy as a first or second line of treatment (2,3,4). More recently, ICIs are being incorporated as initial treatment in combination with CRT or in an adjuvant setting for locally advanced HNC (5,6). Since ICIs act via pre-existing anti-tumor T cell immunity, the lower response rate of anti-PD-1 antibody suggests that either the majority of HNC patients do not have pre-existing anti-tumor T cell immunity (innate resistance) or their tumors use other escape mechanisms (adaptive resistance). One possible way to induce de novo anti-tumor immunity is through vaccination with potent adjuvants to further enhance anti-tumor immunity in HNSCC (5).

Although therapeutic cancer vaccines have shown promising results in animal models, they have failed in human clinical trials including HNC over the years (6). The major reasons for failure of these approaches include: a) lack of strategies to include patient-to-patient variation in target tumor antigens, b) poor adjuvants, and c) immunosuppression (5). For example, many of the previous vaccine approaches employed genetically modified allogeneic tumor cell lines, cell lines developed from patients, single tumor antigens or antigen-specific peptides as vaccine sources (7-10). These approaches for clinical benefit have been limited because the tumors might have escaped immune attack due to their various heterogeneity, as the vaccines did not represent all the variations found in the patient's tumor. To address these limitations, personalized vaccine immunotherapy approaches that include patient-specific tumor antigens with highly promising results are being developed. These include the use of patient-specific neoepitope peptide vaccines and whole tumor lysate pulsed dendritic cell (DC) adoptive cell therapy approaches (11). This suggests that the use of patient-specific antigens is critical in developing efficacious therapeutic cancer vaccines. In this context, we have developed a personalized autologous vaccine immunotherapy approach that is easy to prepare, store and administer, and importantly includes a patient-specific antigenic signature.

In fact, our group is currently developing membrane-based vaccine approach which is autologous vaccine immunotherapy using a novel protein transfer technology to incorporate glycosyl phosphatidylinositol (GPI)-anchored forms of immunostimulatory molecules (GPI-ISMs) such as GPI-B7-1 and GPI-IL-12 onto tumor membrane vesicles (TMVs) (12-16). TMVs are derived from the patient's surgically excised frozen tumor

tissues by homogenizing the tumor tissue and then centrifuging it over a sucrose gradient to isolate TMVs. Therefore, these TMVs are representing tumor heterogeneity with all kinds of different clones of various molecular characteristics from the patients' tumors.

These TMVs will be further modified to incorporate membrane-anchored ISMs by a protein transfer process to produce TMV vaccine. Since the TMV contains the unique antigenic profile of each different clones of the given patient tumor, this personalized approach can provide an effective immunotherapy for HNC, wherein the target antigens will vary from patient-to-patient. Our TMV vaccine simultaneously delivers the patient's unique tumor antigen signature along with potent ISMs to the immune system to induce effective anti-tumor immunity. It is possible that GPI-B7-1 and GPI-IL-12 incorporated onto tumor cell membranes by protein transfer will enhance the delivery of TMVs to immune cells such as DCs, NK, and macrophages and activate them, resulting in a robust anti-tumor T cell immunity (Figure 1). These TMVs are uniform in size (300 to 500 nm) and are suitable for uptake and processing by antigen presenting cells, such as DCs (14-16). Further, IL-12 may provide a third signal for T cell proliferation. The TMVs are cellular plasma membrane vesicles and distinct from secreted immunosuppressive tumor exosomes

Although most immunostimulatory molecules and cytokines are not GPI-anchored, it is possible to convert them to GPI-anchored proteins using recombinant DNA techniques. The GPI anchor consists of a glycosylated moiety attached to phosphatidylinositol which contains two fatty acid tails, anchoring the protein to the cell membrane lipid bilayer (14). This basic concept has been described in the progress report in 2023.

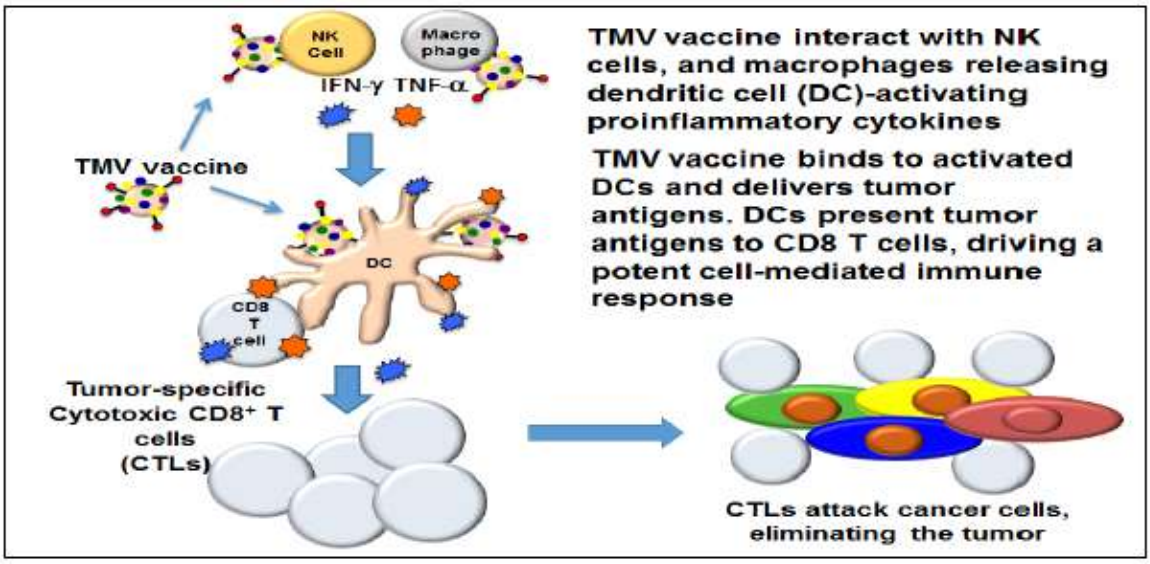

Figure 1. Interaction of TMV vaccine with NK cells, macrophages and dendritic cells

Naturally occurring GPI-anchored proteins are widely distributed in mammalian cells. Studies by Dr. Selvaraj's laboratory have shown that purified GPI-anchored proteins can be spontaneously incorporated onto tumor cell membranes (13-15). This technique of incorporating purified GPI-anchored proteins onto live cell surfaces or isolated membrane vesicles is referred to here as protein transfer. This property of GPI-anchored molecules

permits the manipulation of TMVs to display desired ISMs without the use of gene transfer (13-15). Tumor cells or TMVs expressing such modified GPI-ISMs are capable of inducing protective anti-tumor immunity (12-16). However, T cell marker CD3 and B cell marker CD19 are undetectable in the TMVs.

Our preclinical studies to test this hypothesis in murine HNSCC models show that immunization of mice with TMV vaccine induced immune infiltrates in the tumor and inhibited metastasis. In our recent study to determine whether mice immunized with TMV vaccine are protected (or no tumor growth) from tumor challenge (prophylactic setting), C3H/HeJ mice were administered with TMV vaccine every week for 4 doses and then challenged with SCC VII tumor cells after the last dose of vaccine administration. We have observed that SCC VII tumor growth is delayed in mice vaccinated with TMV vaccine compared to control PBS treated mice (17). To test whether TMV vaccine inhibits tumor growth in a therapeutic setting, SCC VII tumor-bearing mice administered with TMV vaccine on the left flank, and showed that tumors in all tested mice in the PBS control group grew fast while two doses of TMV vaccine failed to inhibit the tumor growth. While all the control naïve mice developed tumors, none of the protected mice in the anti-PD1 mAb group and TMV vaccine therapy group developed secondary tumor growth suggesting a long lasting protective anti-tumor memory response induced by the TMV vaccine, as dose dependent manner as we observed in breast cancer model (18,19) which is being moved to clinical trial.

Our eventual goal is to induce anti-tumor immunity in HC patients using the patient's own tumor tissue as the multi-antigen source which may prevent recurrence and/or metastasis thus increasing the survival of the patients. We may also try to determine the TMV vaccine efficacy in humanized mice using patient-derived xenograft (PDX) tumor tissue and autologous PBMC and to investigate biomarkers of anti-tumor response to predict the efficacy of treatment using genomics approaches from the humanized mouse studies.

We also plan to conduct phase 1 clinical trial of TMV-based immunotherapy alone and/or in combination with ICI for recurrent and/or metastatic diseases in patients with HNC and other malignancies (20-23). We believe that completion of the proposed ongoing studies will advance a novel, personalized vaccine immunotherapy approach for patients with recurrent/metastatic HNSCC and possibly other solid tumors.

In fact we started a pilot study using the resected patients' tumor sample to make TMV vaccine for feasibility to prepare phase 1 clinical in HNC. The pilot feasibility study is described below.

<u>Pilot study on a personalized tumor membrane vesicle (TMV) vaccine immunotherapy for head and neck cancer</u>

Head and neck cancer (HNC) exhibits a high degree of heterogeneity, with low incidence of common therapeutic targets. Our planned phase 1 clinical trial will evaluate a novel personalized immunotherapy approach using TMV prepared from the patients' own surgically excised tumor tissue and modifying them by attaching GPI-B7-1 and GPI-IL-12 as immune stimulating molecules. This personalized therapeutic vaccine will then be administered to boost the tumor-specific immunity. We summarize here the feasibility of

developing an effective personalized therapeutic TMV cancer vaccine from surgically collected tumor tissue from patients with HNC.

After obtaining informed consent, a total of 4 tumor specimens from patients with HNC of various sites were collected (0.29-1.23 grams) and graded for cellularity by a pathologist. Tumor samples were then homogenized using sterile, disposable probes. The homogenate was ultracentrifuged over a sucrose gradient to enrich tumor membrane vesicles (TMV). Yield was evaluated by protein concentration and particle size was assessed by dynamic light scattering. TMV preparations were incorporated with GPI-B7-1 and GPI-IL-12 to generate the TMV vaccine using protein transfer, a spontaneous process. For the simultaneously conducted in vivo murine studies, TMV vaccine is prepared from murine oral cancer (MOC1) tumors and incorporated with murine GPI-B7-1 and GPI-IL-12. To investigate the protective anti-tumor immune response of TMV vaccine in combination with anti-PD1 antibody therapy, we used established murine oral cancer models. We administered two doses of TMV vaccine to naïve C57BL/6 mice and four doses of anti-PD-1 mAb. Mice were monitored for 21 months and then challenged with MOC1 tumor cells 1 week prior to euthanasia. Spleens were flash frozen in liquid nitrogen and stored in -80oC until RNA is isolated for RNA-seq analysis. The yields of TMV were 2.5 – 5 mg per gram of tumor tissue from four human tumor samples. Further refinement of the TMV production process yielded up to 6 mg of TMV/gram of tumor tissue. All samples passed for incorporation of GPI-B7-1 and GPI-IL-12. GPI-B7-1 is able to bind to a natural ligand, CTLA-4 suggesting it is biologically active. All samples also demonstrated biologic activity for GPI-IL-12 as tested using a reporter cell line for IL-12 and displayed acceptable endotoxin levels in a range of 1-34 EU/mg TMV vaccine. RNA-seq data from mouse model suggests that the TMV vaccine showed synergistic activity when combined with anti-PD1 antibody, with enhanced T cell responses. We conclude that TMV vaccine production is feasible for a planned phase 1 clinical trial for patients whose resected tumor is at least 0.5 g in weight and 40% cellularity. Data in mice show that TMV vaccine synergizes with anti-PD1 in inducing anti-HNC tumor responses (24) (the abstract is in press, ASCO 2024).

References

1. Haddad RI and Shin DM. Medical Progress: Recent Advances in Head and Neck Cancer. New Eng J. Med. 359(11):1143-1154, 2008.
2. Saba, N.F., et al., Nivolumab versus investigator's choice in patients with recurrent or metastatic squamous cell carcinoma of the head and neck: Efficacy and safety in CheckMate 141 by age. Oral Oncol, 2019. 96: 7-14.
3. Moskovitz, J., J. Moy, and R.L. Ferris, Immunotherapy for Head and Neck Squamous Cell Carcinoma. Curr Oncol Rep, 2018. 20(2): p. 22.
4. Cohen, E.E.W., et al., Pembrolizumab versus methotrexate, docetaxel, or cetuximab for recurrent or metastatic head-and-neck squamous cell carcinoma (KEYNOTE-040): a randomised, open-label, phase 3 study. Lancet, 2019. 393(10167):156-167.
5. Selvaraj P, Yerra A, Tein L, Shashidharamurthy R. Custom designing therapeutic cancer vaccines: Delivery of immunostimulatory molecule adjuvants by protein transfer. Human Vaccines. 2008;5:1-5.
6. Gerlinger M, Rowan AJ, Horswell S, Larkin J, Endesfelder D, Gronroos E, Martinez P, Matthews N, Stewart A, Tarpey P, Varela I, Phillimore B, Begum S, McDonald NQ, Butler A, Jones D, Raine K, Latimer C, Santos CR, Nohadani M, Eklund AC, Spencer-Dene B, Clark G, Pickering L, Stamp G, Gore M, Szallasi Z, Downward J, Futreal PA, Swanton C. Intratumor heterogeneity and branched evolution revealed by multiregion sequencing. N Engl J Med. 2012;366(10):883-92. Epub 2012/03/09. doi: 10.1056/NEJMoa1113205. PubMed PMID: 22397650.

7. Srivatsan, S., et al., Allogeneic tumor cell vaccines: the promise and limitations in clinical trials. Hum Vaccin Immunother, 2014. 10(1): 52-63.
8. Schuler, P.J., et al., Phase I dendritic cell p53 peptide vaccine for head and neck cancer. Clin Cancer Res, 2014. 20(9): 2433-44.
9. Hellmann, M.D. and A. Snyder, Making It Personal: Neoantigen Vaccines in Metastatic Melanoma. Immunity, 2017. 47(2): 221-223.
10. Sahin, U., et al., Personalized RNA mutanome vaccines mobilize poly-specific therapeutic immunity against cancer. Nature, 2017. 547(7662): p. 222-226.
11. Bachmann, M.F. and G.T. Jennings, Vaccine delivery: a matter of size, geometry, kinetics and molecular patterns. Nat Rev Immunol, 2010. 10(11):787-96.
12. Udenfriend S, Kodukula K. How glycosyl phosphatidylinositol-anchored membrane proteins are made. AnnuRevBiochem. 1995. 64:563-91.
13. Bozeman EN, Cimino-Mathews A, Machiah DK, Patel JM, Krishnamoorthy A, Tien L, Shashidharamurthy R, Selvaraj P. Expression of membrane anchored cytokines and B7-1 alters tumor microenvironment and induces protective antitumor immunity in a murine breast cancer model. Vaccine.2013. 31(20):2449-56. doi: 10.1016/j.vaccine.2013.03.028. PubMed PMID: 23541884; PMCID: 3686649.
14. Bozeman ENH, S, Shafizadeh,Y, Selvaraj,P. Therapeutic efficacy of PD-L1 blockade in a breast cancer model is enhanced by cellular vaccines expressing B7-1 and glycolipid-anchored IL-12. Human Vaccines and Immunotherapeutics. 2015. 11(12):421-30.
15. McHugh RS, Ahmed SN, Wang YC, Sell KW, Selvaraj P. Construction, purification, and functional incorporation on tumor cells of glycolipid-anchored human B7-1 (CD80). Proc Natl Acad Sci U S A. 1995. 92(17):8059-63. Epub 1995/08/15. PubMed PMID: 7544014; PMCID: 41286.
16. Barrios B, Baez NS, Reynolds D, Iribarren P, Cejas H, Young HA, Rodriguez-Galan MC. Abrogation of TNFalpha production during cancer immunotherapy is crucial for suppressing side effects due to the systemic expression of IL-12. PLoS One. 2014. 9(2):e90116. doi: 10.1371/journal.pone.0090116. PubMed PMID: 24587231; PMCID: 3938584.
17. Bommireddy R, Munoz LE, Kumari A, Huang L, Fan Y, Monterroza L, Pack CD, Ramachandiran S, Reddy SJC, Kim J, Chen ZG, Saba NF, Shin DM, Selvaraj P. Tumor Membrane Vesicle Vaccine Augments the Efficacy of Anti-PD1 Antibody in Immune Checkpoint Inhibitor-Resistant Squamous Cell Carcinoma Models of Head and Neck Cancer. Vaccines (Basel). 2020. 8(2) . Epub 2020/04/17. doi: 10.3390/vaccines8020182. PubMed PMID: 32295135.
18. Patel JM, Vartabedian VF, Bozeman EN, Caoyonan BE, Srivatsan S, Pack CD, Dey P, D'Souza MJ, Yang L, Selvaraj P. Plasma membrane vesicles decorated with glycolipid-anchored antigens and adjuvants via protein transfer as an antigen delivery platform for inhibition of tumor growth. Biomaterials. 2015. 74:231-44. doi: 10.1016/j.biomaterials.2015.09.031. PubMed PMID: 26461116.
19. Pack CD, Bommireddy R, Munoz LE, Patel JM, Bozeman EN, Dey P, Radhakrishnan V, Vartabedian VF, Venkat K, Ramachandiran S, Reddy SJC, Selvaraj P. Tumor membrane-based vaccine immunotherapy in combination with anti-CTLA-4 antibody confers protection against immune checkpoint resistant murine triple-negative breast cancer.Human vaccines & immunotherapeutics. 2020. 1-10. doi: 10.1080/21645515.2020.1754691.
20. Selvaraj P, Yerra A, Tein L, Shashidharamurthy R. Custom designing therapeutic cancer vaccines: Delivery of immunostimulatory molecule adjuvants by protein transfer. Human Vaccines. 2008. 5:1-5.
21. Nagarajan S, Selvaraj P. Human tumor membrane vesicles modified to express glycolipid-anchored IL-12 by protein transfer induce T cell proliferation in vitro: A potential approach for local delivery of cytokines during vaccination. Vaccine. 2006;24:2264-74.
22. Hamanishi, J., et al., PD-1/PD-L1 blockade in cancer treatment: perspectives and issues. Int J Clin Oncol, 2016. 21(3):462-73.
23. Chen, L. and X. Han, Anti-PD-1/PD-L1 therapy of human cancer: past, present, and future. J Clin Invest, 2015. 125(9): 3384-91.
24. Bommireddy R, Pack CD, Ramachandiran S, Jacobsen KM, Reddy S, Patel M, Shi Q, Schmitt NC, Steuer C, Saba NF, Selvaraj P, Shin DM. Feasibility study on a personalized tumor membrane vesicle vaccine immunotherapy for Head and Neck Squamous Cell Carcinoma (HNSCC) (in press ASCO 2024).

Deep Learning Aided Topology Optimization of Phononic Crystals

by Wieslaw Ostachowicz, Member EUAS

Short Biography

Prof W. Ostachowicz has led dynamics research at the IMP PAN for over forty years. He specialises in several important sub-disciplines, like structural health monitoring techniques, vibration control, structural dynamics, composite structures, multifunctional materials, smart materials and structures, and damage assessment of structures, working in these fields both theoretically and experimentally. His research focused on developing and using the Spectral Finite Element Method for damage assessment and smart materials applications. His research in guided wave propagation has aimed to create numerous vibroacoustic–ultrasonic methods for damage detection using smart sensor technologies. Those methods have demonstrated effectiveness and sensitivity to minor cracks in metallic and composite structures without restrictions on load, boundaries, temperature, or environmental conditions.

The list of his temporary positions opens Visit Prof at Syracuse University, USA (1980–1981). He was also employed as an expert of UNIDO (United Nations Industrial Development Organization) at the Instituto de Investigaciones Electricas, Cuernavaca, Morelos, Mexico (1987, 1990). He was Visiting Prof at the University of Glasgow, UK (2000–2003) and the Ecole Nationale Supérieure d'Arts et Métiers (ENSAM), Paris, France (2017).

Prof Ostachowicz published 435 archival international journal papers, 532 refereed international conference papers, and over 200 technical reports, predominantly in damage detection, structural health monitoring, and advanced signal processing areas. Also, he has published over 45 papers (in English) in Polish journals. Prof W. Ostachowicz published 5 monographs, 7 book chapters, and 4 structural dynamics and SHM proceedings volumes. These have been published by famous worldwide publishers such as Springer, Wiley, Kluwer, World Scientific, CRC Press, etc. The 388 papers currently represented on the JCR Web of Science are uniformly distributed in the highest–quality international journals and have attracted 7612 citations (6846 without self–citations). Fifteen of his publications have been cited over 100 times (one of them 464 times). His most highly cited book, published in 2012 by Wiley (Guided Waves in Structures for SHM), was cited 217 times. His H index equals H=46 (Web of Science) and H=48 (Scopus). His name was included in the high position (1%) in the ranking list of the World's Top 2% Scientists, which means the most recognisable scientists worldwide (specialists from Stanford University, Elsevier Publishing House, and SciTech Strategies prepared the list).

Prof. Ostachowicz participated in investigating 24 international research projects as a coordinator, leader of WP (Work Package), or the main contractor, including the European Commission, NATO, EPSRC, and the US Army. He was an evaluator of ERC (European Research Council) projects, EPSRC (Engineering and Physical Science Research Council) projects, EC FP–7 Projects, and ESF (European Science Foundation).

Prof. Ostachowicz is the co-author of 4 patents, including one foreign - European Patent Office, titled Structural Health Monitoring System. Patent EP2485026 (A1), joint with the Boeing R&T Europe, 2012 (Kudela P., Ostachowicz W., Kawiecki G., Rodrigez R.M).

Presently, prof Ostachowicz is involved in work (as editor/associate editor) for the following journals: Mechanical Systems and Signal Processing (Elsevier), Structural Health Monitoring (SAGE Publications), Intelligent Material Systems and Structures (SAGE Publ.), Smart Materials and Structures (IOP Publ.), and Editorial Board Member, Strain (Wiley), Jour. of Mechanical Engineering Science (SAGE Publications).

Prof. Ostachowicz was the supervisor of 16 PhD dissertations. Also, he reviewed several PhD theses and professor positions in the United Kingdom, South Africa, USA, Italy, France, Japan,

Spain, Hong Kong, Singapore, Italy, Austria, Sweden, Australia, Netherlands, etc.
Prof. Ostachowicz has received several prestigious awards and distinctions, among others Medal of O.C. Zienkiewicz (2013), the Dragon–STAR Innovation Award (1st place) as confirmation of cooperation between Poland (Polish Academy of Sciences) and China (Hohai University, and The Hong Kong Polytechnic University), 2015, SHM Life Achievements Award (sponsored by Boeing Co.), Stanford University, USA (2019), and Gold Medal "Sapientia et Veritas" (2023).

Deep learning aided topology optimization of phononic crystals, by: Kudela P, Ijjeh A, Radzienski M, Miniaci M, Pugno N, Ostachowicz W, Mechanical Systems and Signal Processing, Vol. 200, doi10.1016/j.ymssp.2023.110636.

Abstract

In this work, a novel approach for the topology optimization of phononic crystals based on the replacement of the computationally demanding traditional solvers for the calculation of dispersion diagrams with a surrogate deep learning (DL) model is proposed. We show that our trained DL model is ultrafast in predicting the dispersion diagrams, and therefore can be efficiently used in the optimization framework. The main novelty of the proposed approach relies on the use of non-uniform rational basis spline (NURBS) curves instead of pixels and/or mesh elements to control the shape of the unit cells of phononic crystals. The surrogate DL model is combined with a genetic algorithm serving as a topology optimization tool. The validity of the approach is shown in the case of phononic crystals made of a continuous matrix with cavities. Several objective functions have been tested as an alternative to the most common gap-to-mid-gap ratio. This allowed us to obtain interesting phononic crystal geometries which can be easily additively manufactured. The proposed method applies to problems involving inverse design and can open new avenues in designing computer-assisted periodic structures.

Integrating hybrid piezoelectric actuators with a single fibre Bragg grating sensor for online monitoring of structures, by: Balasubramaniam, K Soman, R Malinowski, P Ostachowicz, W, Measurement, Vol. 220, doi10.1016/j.measurement.2023.113367

Abstract

The application of fibre Bragg grating (FBG) sensors for detecting ultrasonic guided waves (GW) in a hybrid system with piezoelectric transducers (PZT) is a promising area for structural integrity analysis due to FBG's potential for embedding in structures. However, the directional sensitivity of FBG sensors presents a challenge for signal processing, and the direct application of damage mapping methods designed for omnidirectional PZT sensors is not feasible. The novelty of this study lies in developing a proof-of-study damage mapping method that uses an improved cosine distance (CD) formulation to detect damage paths while accounting for the directional sensitivity of FBG sensors. Additionally, a sectorial elliptical code (SEC) based on CD was used to localize damages in a hybrid FBG-PZT network. This approach was validated with numerical simulations, demonstrating its effectiveness in accurately detecting and localizing damages in

structures. The damage detection with the CD method located all the damage paths that help identify the probable damage region. The SEC method localized damages not only in the inner sensor zone but also in the outer zone. The CD method successfully predicted the probable damage zones, overcoming the directional sensitivity issue. The error predicted with the SEC method was as low as 0.7 cm in the experimental and 0.1 cm in numerical studies.

Reconstruction of radial pseudo-forces on cylinders via mono-laser scanning: Concept and application to characterization of damage, by: Xu W, Ji MC, Xi YS, Xu H, Cao MS, Su ZQ, Ostachowicz W, Mechanical Systems and Signal Processing, Vol. 200, doi10.1016/j.ymssp.2023.110570

Abstract

Damage in a plate can cause perturbation to the equation of out-of-plane motion, which can be equivalently regarded as the transverse pseudo-force applied to the damage region. Thereby, the characterization of damage in the plate can be achieved by identifying the pseudo-force. Nevertheless, it is difficult to formulate the pseudo-force for the characterization of damage in a cylinder because its longitudinal, circumferential, and radial motions are coupled. Moreover, a conventional scanning laser vibrometer equipped with a single scanning head can measure the out-of-plane motions of a plate but is insufficient for measuring the 3D motions of a cylinder. The aforementioned limitation creates a noticeable barrier to extending the pseudo-force approach from a plate to a cylinder. To overcome this barrier, a new concept of radial pseudo-force (RPF) is formulated to represent the damage-induced perturbation to the radial equilibrium of a cylinder, whose motions are dominated by its radial components. The RPF is applied on the lateral surface of the cylinder and is an ideal damage indicator because it appears in the damage region only and almost vanishes at intact locations. Furthermore, a novel method for reconstructing RPFs via mono-laser scanning is proposed. A correction matrix is formed to correct an undeflected laser-axis mode shape component (MSC) that can be directly measured via mono-laser scanning, whereby the radial MSC of the cylinder can be obtained for the reconstruction of the RPF on the cylinder. The concept of the RPF is numerically proved using the finite element method. In addition, the applicability of the RPF approach is experimentally validated on a cylinder with internal damage. The numerical and experimental results reveal that the RPF approach can graphically characterize the occurrence, location, and approximate plane size of damage in cylinders.

A novel DISTINCT method for characterizing breathing features of nonlinear damage in structures, by: Wei QY, Cao MS, Shen L, Qian XD, Dunai L, Ostachowicz W, Mechanical Systems and Signal Processing, Vol. 196, doi10.1016/j.ymssp.2023.110333

Abstract

The detection of breathing cracks in in-service structures is an intractable issue due to the distinctive dynamic behaviour, typically the opening and closing of the crack subjected to

cyclic loading. The existing methods to identify breathing cracks generally rely on the hypothesis of crack-induced nonlinear features, mostly represented by super-harmonics. Nevertheless, an inservice structure even free of cracking somehow has nonlinear components in material, geometry, boundary etc., such that it tends to present inherent nonlinear features, i.e., nonlinearities prior to cracking, which could impair the effectiveness of super harmonics-like methods to depict breathing cracks. In such a circumstance, a sophisticated method that can characterize breathing cracks-induced nonlinearity by accommodating inherent nonlinear of the structure is desired. Herein, a novel method termed DISTINCT (Difference in Split Temporal signal with Inherent Nonlinear Components Tolerated) method, is proposed. This method is formulated by splitting a whole response of a structure bearing breathing cracks into positive and negative response components. Each response component largely reflects structural dynamic behaviour with regard to the crack-opening state or crack-closing state. From positive or negative response components, the dynamic property, such as the frequency spectrum arising from the Fast Fourier Transform, corresponding to crack-opening state or crack-closing state, can be derived. To this end, the differences between the two frequency spectra relatively purely manifests the characteristic of breathing cracks including their presence and severity. The feasibility of the DISTINCT method is numerically verified via the identification of a breathing crack in a cantilever beam and a shell, with emphasis on its stronger noise resistance than the traditional super-harmonics-based method. Furthermore, the method's effectiveness is experimentally validated via the inspection of breathing cracks in a scaled arch dam model subject to excitations induced by artificial seismic accelerations. The results show that the proposed DISTINCT method can quantify the severities of four levels of damage comprising breathing cracks by tolerating the inherent nonlinearity of the structure. The advantages of the DISTINCT lie in its tolerance to structural inherent nonlinearities.

Corrosion damage identification in concrete underwater based on time reversal of stress waves, by: Wei L, Shen L, Cao MS, Wang J, Wang ZJ, Ostachowicz W, Mechanical Systems and Signal Processing, Vol. 194, doi10.1016/j.ymssp.2023.110281

Abstract

The time reversal method (TRM) of stress waves is capable of identifying damage in concrete due to its self-adapting spatial and temporal focusing characteristics. However, the application of TRM in identifying the damage to underwater concrete structures is rarely reported. In this study, TRM is further utilized to identify corrosion damage (introduced by hydrochloric acid solution) in order to characterize the mechanical degradations of concrete underwater. First, as one of the innovations of this work, the existence of non-zero initial values of damage indexes (DIs) is numerically proved, and two modified damage indexes (MDIs) are correspondingly defined. A carefully designed experiment verifies the correctness of MDIs obtained by TRM. On the one hand, one concrete beam with embedded modified piezoelectric aggregate (MPA) transducers is immersed in a hydrochloric acid solution to mimic the long-term corrosion damage of concrete underwater. TRM is experimentally used to determine the MDIs representing the corrosion damage identification. On the other hand, the compressive strength and elastic modulus of concrete cubes with the same degree of corrosion damage are measured in

compression tests. The good agreements between the degradations of these representative mechanical properties and the evolutions of MDIs demonstrate the feasibility of TRM in identifying damage in underwater concrete structures.

Deep learning for automatic assessment of breathing-debonds in stiffened composite panels using non-linear guided wave signals, by: Sikdar S, Ostachowicz W, Kundu A, Composite Structures, Vol. 312, doi10.1016/j.compstruct.2023.116876

Abstract

This paper presents a new structural health monitoring strategy based on a deep learning architecture that uses nonlinear ultrasonic signals for the automatic assessment of breathing-like debonds in lightweight stiffened composite panels (SCPs). Towards this, nonlinear finite element simulations of ultrasonic guided wave (GW) response of SCPs and laboratory-based experiments have been undertaken on multiple composite panels with and without baseplate-stiffener debonds using fixed a network of piezoelectric transducers (actuators/sensors). GW signals in the time domain are collected from the network of sensors onboard the SCPs. These signals in the frequency domain represent nonlinear signatures as the existence of higher harmonics. These higher harmonic signals are separated from the GWs (raw) and converted to images of time-frequency scalograms using continuous wavelet transforms. A deep learning architecture is designed that uses the convolutional neural network to automatically extract the discrete image features for the characterization of SCP under healthy and variable breathing-debond conditions. The proposed deep learning-aided health monitoring strategy demonstrates a promising autonomous inspection potential with high accuracy for such complex structures subjected to multi-level breathing-debond regions.

Spatial domain localization method for multi-damage in plate-like structure based on a coefficient matrix of reflected guided waves, by: Zhang Y, Radzienski M, Soman R, Ostachowicz W, Journal of Sound and Vibration, Vol. 552, doi10.1016/j.jsv.2023.117636

Abstract

Structural health monitoring (SHM) is a multidisciplinary damage detection technique that incorporates various mechanisms, of which guided waves (GWs)-based damage detection is one of the critical fields of research. To realize the complete process of SHM, research on GWs has concentrated on diagnosis and localization. GWs-based damage detection technology is widely used in plate structure, combining different sensor placement algorithms and equipment such as scanning laser Doppler vibrometry (SLDV) to achieve accurate damage location. Simultaneously, developing the finite element method (FEM) allows for precise simulation in discontinuous media and complex sharp structures. Therefore, this paper combines the theoretical calculation approach of elastic wave propagation with the orthogonal matching pursuit (OMP) algorithm, using the excitation signal and signal reflected by damage as the input matrix and target matrix, respectively. Thus, the reflection-waves coefficient matrix (RCM) containing damage information could

be obtained after calculation by the OMP algorithm. Besides, a prediction approach of reference reflected signal based on four-layers recurrent neural networks (RNNs) is proposed with experiments data to reduce the difficulty of expanding a dictionary matrix in a plate with multiple defects, which allows for predicting the damage reflection signal under different distances with 88.14% accuracy. And finally, considering the aluminium plate with hole damage as an example, the experiment results show that the proposed approaches are effective for the localization of single damage and muti-damage. Meanwhile, the prospects and limitations of the algorithm for precise localization are also addressed in the last.

Development of deep belief network for tool faults recognition, by: Kale AP, Wahul RM, Patange AD, Soman R, Ostachowicz W, Sensors, Vol. 23(4), doi10.3390/s23041872

Abstract

The controlled interaction of work material and cutting tool is responsible for the precise outcome of machining activity. Any deviation in cutting parameters such as speed, feed, and depth of cut causes a disturbance to the machining. This leads to the deterioration of a cutting edge and unfinished work material. Recognition and description of tool failure are essential and must be addressed using intelligent techniques. Deep learning is an efficient method that assists in dealing with a large amount of dynamic data. The manufacturing industry generates momentous information daily and has enormous scope for data analysis. Most intelligent systems have been applied toward the prediction of tool conditions; however, they must be explored for descriptive analytics for on-board pattern recognition. In an attempt to recognize the variation in milling operation leading to tool faults, the development of a Deep Belief Network (DBN) is presented. The network intends to classify in total six tool conditions (one healthy and five faulty) through image-based vibration signals acquired in real time. The model was designed, trained, tested, and validated through datasets collected considering diverse input parameters.

Guided waves-based damage localization based on mode filtering using fibre Bragg grating sensors, by: Soman R, Radzienski M, Kudela P, Ostachowicz W, Smart Materials and Structures, Vol. 31(9), doi10.1088/1361-665X/ac820d

Abstract

Fiber Bragg grating (FBG) sensors have long been thought of as the ideal sensors for structural health monitoring (SHM) due to their small size, light weight, ability to be embedded and ability to be multiplexed. So, FBG sensors have been commonly used for strain based SHM. Their use for ultrasonic guided wave (GW) measurements in the traditional wavelength division multiplexing approach was tried as well, but did not get accepted widely due to the low sensitivity. In the recent times, a renewed interest is seen in the use of FBG sensors for GW measurements using the edge reflection approach which increases the sensitivity several folds. This paper reports a very interesting phenomena, shown by the FBG sensors. The mechanism of the measurement of the incident GW is

different based on the relative ratio of the wavelength of the incident GW (lambda(GW)) and the grating length (L) of the FBG sensor. For lambda(GW)/L >> 1 the propagating wave leads to uniform strain over the FBG resulting in the shift of the Bragg wavelength. For the lambda(GW)/L approximate to 1 the FBG experiences non-uniform strain over the FBG which results in the distortion of the spectrum (widening or narrowing) of the peak. By separating these effects on the FBG, mode filtering may be achieved. The mode-filtered data is then used for damage detection and damage localization. Modifications have been proposed to the elliptical approach, which makes use of the filtered modes and removes the unwanted peaks in the signal stemming from the other mode. The methodology is validated on a simple aluminium plate with simulated damage scenarios (added mass). The results indicate that indeed the mode-filtered signals improve the damage localization performance of the actuator-sensor network.

Spectral element modeling of ultrasonic guided wave propagation in optical fibers, by: Fiborek P, Soman R, Kudela P, Ostachowicz W, Ultrasonics, Vol. 124, doi10.1016/j.ultras.2022.106746

Abstract

Recent advancements in fiber optic methods have enabled their use for guided wave sensing. It opens up new possibilities for Structural Health Monitoring. The aim of this paper is to provide insight for the physics related to guided wave propagation and coupling between the optical fiber and solid structure. For this purpose, a new approach for a non-matching interface based on Lagrange multipliers and the time domain spectral element method was developed. A parallelized code has been implemented in order to simulate the guided wave propagation in the structure, its coupling into the optical fiber and the propagation in the fiber in a computationally efficient way. The paper presents four studies showing the efficacy of the modelling approach. The paper first shows the improvement in the computation speed through the use of parallelization and a more efficient implementation. Then, the results of the simulation of wave propagation in the fibre are compared with results from previous simulation studies using commercially available software. The third study shows that the spectral element method is able to capture the directional sensitivity of optical fibre-based sensors. Lastly, the simulation is used to detect simulated damage using the spectral element method-based simulation. The results indicate that indeed the spectral element implementation is able to recreate the wave coupling phenomena, capture the physics of the system including directional sensitivity and reflections from damage.

New Activities in Materials Science, Engineering and Engineering Education

by Derek O. Northwood, Member EUAS

Short Biography

Professor Derek O. Northwood is a Distinguished University Professor Emeritus and Professor of Engineering Materials in the Department of Mechanical, Automotive and Materials Engineering at the University of Windsor, Windsor, Ontario, Canada. Professor Northwood has an earned doctorate in Chemical Physics (Crystallography) from the University of Surrey (UK) and a BSc (Eng) in Engineering Metallurgy from the Imperial College, University of London (UK). He is a licensed Professional Engineer in Ontario, Canada (PEng) and is a Chartered Professional Engineer (CPEng; NER), APEC Engineer, and International Professional Engineer (IntPE(AUS), in Australia. In the 40+ years as an academic, Professor Northwood has held various administrative positions including Department Head, Dean, Associate Dean of Research, Director of the Office of Research Services, President of the Industrial Research Institute, and, Research Leadership Chair, both at the University of Windsor and Ryerson University, Toronto, Canada. Professor Northwood has taught, researched and facilitated joint research and educational programs at 14 universities worldwide, including the UK, the USA, Australia, Taiwan, China, Singapore and Canada. He has published 707 papers in refereed international journals and conference proceedings, 9 chapters in books and has edited 10 books, on a wide range of topics including materials and their applications, and engineering and technology education. He has been elected Fellow of six international professional societies in Australia, Canada, the UK and the USA; namely, Fellow of the Royal Society of Canada (FRSC); Fellow of the Institution of Engineers Australia (FIEAust); Fellow of the World Institute for Engineering and Technology Education (FWIETE); Fellow of the Institute of Materials, Minerals and Mining (FIMMM); and Fellow of ASM International (FASM); and Fellow of Alpha Sigma Mu (FAΣM), The International Professional Honor Society for Materials Science and Engineering. In 2023, Professor Northwood was recognized again as being among the world's top 100,000 - or top 2% of scientists - according to the database published by Stanford University. Professor Northwood continued in his role as Associate Editor of both the Global Journal of Engineering Education and World Transactions on Engineering and Technology Education.

RESEARCH ACTIVITIES AND PUBLICATIONS 2023

As Covid-19 restrictions were lifted during 2023, I have been able to resume co-operative research with my partners across the globe.
As in past years, work had been conducted in two principal areas:

1. Developing the potential properties of traditional materials/ Processing of ores and other products for metal recovery.

2. Innovation in Engineering Education

Developing Properties/Processing

The cooperative work with Professor Cheng Liu at Yangzhou resulted in one publication in 2023, on the failure analysis of a carburized18CrNiMo7-6 steel roller from a roll forming mill used to manufacture automotive flywheels. A detailed microstructural and microhardness study of sections taken from the roller showed that the failure originated from an inhomogeneous microstructure formed during quenching after the carburizing. The carburizing/quenching process for rollers was redesigned to alleviate the problem.

Failure behavior of a roller in automotive flywheel manufacturing. (2023) *Engineering Failure Analysis* , 150, art. No. 107336.

Lyu, B., Wan, X., Northwood, D.O., Liu, C.

Abstract

The failure behavior of a carburized 18CrNiMo7-6 steel roller from a roll forming mill used to manufacture automotive flywheels is investigated. Microstructural observations using optical and scanning electron microscopy are carried out, and the hardness determined using a Vickers hardness testing machine. The carburized layer is mainly comprised of fine tempered martensite, small carbides and retained austenite. The depth of the carburized layer around the roller groove is thinner than the required standard. The decrease in microhardness with increasing distance from the surface to the core is found to be due to the different carbon concentrations. However, a pronounced variation of the microhardness value is detected around the roller groove surface. This is related to the formation of an inhomogeneous microstructure during quenching after the carburizing process. The results indicate that the crack nucleates at the bottom surface of the roller and propagates along the direction vertical to the roll forming with a transgranular character.

A new research collaboration was initiated with Dr. Hao Ma, and associated researchers, at BGRIMM Technology Group, Beijing, China.The work was focused on the recovery of valuable metals from ores, refractory concentrates, waste hydrogenation catalysts, and waste automotive exhaust purifier catalysts. Valuable metals recovered include: Cu; Co; U; Nb; Rare Earth minerals; Ni; Mo; Pt; Pd; Rh; V.

Agitation leaching behavior of Copper-Cobalt oxide ores from the Democratic Republic of the Congo. (2023) *Minerals* , 13(6), art. no. 743

Zheng, C., Jiang, K., Cao ,Z., Northwood, D.O., Waters, K.E., Wang, H., Liu, S., Zhu, K., Ma, H.

Abstract

Agitation leaching is a promising technology in hydrometallurgy for treating copper–cobalt oxide ores. In this work, the behavior of oxide ores containing around 2.3% Cu and 0.3% Co received from Congo was investigated for varying particle size, acidity, pulp density, temperature, leaching time, and reduction potential. XRD, optical microscopy (OM), and ICP-OES methods were used to examine the chemical composition, morphology, and metal content of the samples. The copper and cobalt recovery reached 88.2% and 82.5%, respectively, at room temperature, with a leaching time of 4 h, a pulp density of 33%, an acidity of 178 g/L, and no reductant. The Cu and Co remaining in the leaching residue were found to be in their sulfide forms and coated with dense and fine calcium sulfate. To improve the metal recovery, a combination of flotation and agitation leaching of the flotation tailings method was adopted, after which the Cu and Co recovery reached 96.6% and 86.0%, respectively.

Recovery of valuable metals from polymetallic refractory concentrate by a sulfuric acid curing and leaching method.

(2024) *Separations*,11, 7, 11010007

Jiang, W., Xue, J., Jiang, K., Jiang, X., Wang, S., Hu, J., Northwood, D.O.., Waters, K.E., Ma, H.

Abstract

Sulfuric acid curing and leaching is a promising technology for treating refractory ores. In this work, a refractory concentrate containing 3191 ppm uranium (U), 2135 ppm niobium (Nb), and 0.7% rare earth minerals (REMs) went through two stages: curing by high-concentration H2SO4 and leaching by low-concentration H2SO4. We investigated the behavior of those valuable metals during the two stages. For both curing and leaching, the operating parameters include the acid-to-solid ratio, time, temperature, and H2SO4 concentration. The recovery for U, Nb, and REMs was as high as 95%, 86%, and 73.5% using a curing acid-to-solid ratio of 1:1, curing temperature of 200 ◦C, curing time of 1 h, H2SO4 concentration of 98%, leaching liquid-to-solid ratio of 4:1, leaching time of 2 h, leaching temperature of 60 ◦C, and leaching H2SO4 concentration of 5 g/L. A “sulfuric acid curing–leaching-U extraction by N235–Nb recovery by resin adsorption–REMs’ recovery by resin adsorption” method was implemented, where the overall U, Nb, and REMs recovery reached 93.1%,84.5%, and 69.6%, respectively.

Reduction-sulfurization smelting process of waste hydrogenation catalysts, automotive exhaust purifier waste catalysts, and laterite nickel ore.
(2023) *ACS Omega,*, 8 (43), pp. 40713-40728

Wang, Z., Wang, H., Jie, X., Zhao, X., Waters, K.E., Northwood, D.O., Cui, S., Ma, H.

Abstract

Reduction-sulfurization smelting is an effective method for treating solid hazardous waste and recovering valuable components from them. In this work, a waste hydrogenation catalyst (WHC), an automotive exhaust purifier waste catalyst (AEPWC), a vulcanizer, and laterite nickel ore were mixed, and the reduction smelting behavior of this solid waste was investigated. XRD (X-ray diffractometry), TG-DSC (thermogravimetric/differential scanning calorimetry), SEM-EDS (scanning electron microscopy-energy dispersive spectroscopy), OM (optical microscopy), and ICP-OES (inductively coupled plasma-optical emission spectrometry) methods were used to examine the chemical composition, thermal stability, structure, and morphology, as well as the metal content of the samples. Under the Al2O3-FeO-SiO2 ternary slag system, at a smelting temperature of 1450 °C, smelting time of 2 h, mass ratio of coke, pyrite, and CaO to waste catalysts of 16, 25, and 0%, respectively, nickel (Ni) and molybdenum (Mo) recovery reached 91.1 and 92.9%, respectively, where average PGMs (platinum group metals, platinum (Pt), palladium (Pd), rhodium (Rh)) recovery reached 96%, although vanadium (V) recovery was only 25.1%. The characterization of the slag shows that Al, Si, and Fe are mainly bound in the form of chemical compounds, while V is intercalated with ferro- or aluminosilicate, which hinders the reduction and sulfurization of V. A series of tests using reduction smelting without sulfurization were also conducted, after which the Ni, Mo, and V recovery reached 96.8, 96.6, and 89.7%, respectively, while PGMs (Pt, Pd, Rh) recovery ranges from 90.2 to 98.0%. The collaborative disposal of primary ore and multisource solid waste has been achieved through two process paths: reducing smelting and reducing sulfurization smelting, which provide reference for the collaborative smelting of multisource secondary resources.

Innovation in Engineering Education

Although there were no publications in 2023, work was ongoing in two areas:

1. The Teaching –Research Nexus
2. Overteaching

The teaching-research nexus.

For many years there has been the strong belief that teaching (knowledge transfer) and research (knowledge generation) are harmonious and mutually beneficial activities. Some have gone as far as to claim that the best teachers are, without exception, our best scholars. However, many have questioned the assertions of senior university administrators about the necessary interrelationship between research and teaching as lacking any serious evidential basis. A detailed examination of the literature on qualitative and quantitative studies of the relationship between teaching effectiveness and research activity generally shows that, apart from anecdotal and informal observation, there is no relationship, or a negative relation, between high research output and the effectiveness of undergraduate teaching at the individual faculty member or departmental level. Based on the general consensus of the quantitative empirical research, Marsh and Hattie [*H.W. Marsh, J. Hattie, The relation between research productivity and teaching effectiveness, The Journal of Higher Education, 73(5), 603-641, 2002*] have gone even further stating that teaching

effectiveness and research productivity are "independent constructs". In this context, it is interesting that Leisyte et al [*L. Leisyte, J. Enders, H. Boer, The balance between teaching and research in Dutch and English universities in the context of university governance reforms, Higher Education, 58(5), 619-635, 2009*] in their study of university governance reforms in Dutch and English universities found that ***teaching and research are increasingly falling apart as two distinct activities***. A more in-depth look at the quantitative measures used to evaluate teaching effectiveness, showed that they consisted of SET (student evaluation of teaching) scores and/or peer/or self-evaluations - none used a direct measure of student learning [*C.S. Galbraith, G.B. Merrill, Faculty research productivity and standardized student learning outcomes in a university teaching environment: a Bayesian analysis of relationships, Studies in Higher Education, 37(4), 469-480, 2012*].

Prosser et al [*M. Prosser et al., University academics' experience of research and its relationship to their experience of teaching, Instructional Science, 36, 3-16, 2008*] have proposed what is effectively a Research-Teaching-Learning nexus, where learning is defined as "understanding of subject matter". Research activities can help the teacher better understand the subject matter and in the course of "teaching", both instructor and teacher "learn". For this approach to be successful there needs to be a change from information transmission and teacher-focused approaches to student-focused approaches to teaching. Another facet to the Teaching-Research-Learning (TRL) nexus has been proposed, namely, Industry (TRIL nexus). This leads to student focused approaches to learning such as work-based learning/experiential learning. As stressed by the Council of Ontario Universities: Classroom Learning + Real-Life Learning = Career Success [*Bringing Life to Learning at Ontario Universities, 31 pages, ISBN: 0-88799-500-4, 2014*].

Overteaching

Elizabeth Wells [*E. Wells, Are you 'overteaching'?, University Affairs, 64(6), 44, November-December 2023*] has suggested that much of the burnout that is increasingly being felt by professors and students, can be related to a concept that she calls ***overteaching – where an instructor will devote too much time, energy and emotional labour to teaching and teaching prep.*** She proposes that: ***the many technologies and methodologies the modern academic now employs aren't leading to more learning or more student success.*** The list of technologies/methodologies includes: quizzes, exams, reviews, questionnaires, journals, learning portfolios, group activities, online chats, discussion boards and gamification.
Paula Brown [*P.E. Brown, Be a more effective teacher: how to avoid overteaching in the collegiate business classroom, Proceedings of ASBBS (American Society of Business and Behavioural Sciences), 16(1), 4pp, 2009*] has defined overteaching in a somewhat different manner:

Overteaching is when we do more for our students than we should.

Brown explores several aspects of overteaching and focusses her discussion on the three aspects of every course: content, pedagogy, and policies/procedures. With respect to "content", Brown notes: *Overteaching takes place in content when more information is given to students than they can effectively comprehend during the set time period, the*

teacher talks more than the students do, and when the teacher ends up doing most of the work that encompasses the learning process. She suggests that one method to avoid overteaching in the content area is to teach fewer topics. With respect to pedagogy, the methods used to develop content, Brown suggests that: *Overteaching happens in pedagogy for several reasons: most teachers teach like they were taught, lecture too much, and give too many answers*.. She suggests a number of ways to avoid pedagogical overteaching, including effective in-class exercises, students as teachers, and technology. With respect to policies/procedures, i.e. the rules under which a course is taught, Brown suggests: *Overteaching in this area comes about when some segment of the population is put at a disadvantage because of rules and requirements.* Items to be checked with respect to policies/procedures include: attendance, requirements for grades, office hours, deadlines, and help. In the "help" category, Brown stresses that faculty should help students learn how to plan their work.

Graham Noble [G. Noble, Over-teaching, https://grahamnoble.com/2019/05/30/over-teaching/, 1-10, May 30, 2019] considers overteaching: is the opposite of inquiry based learning; is inefficient; assumes material is learned after it has been taught; doesn't usually lead to deep understanding; neglects the purposes of education whereby "teachers support students until they are able to manage learning on their own". Similar thoughts were echoed by Paula Brown [*P.E. Brown, Be a more effective teacher: how to avoid overteaching in the collegiate business classroom, Proceedings of ASBBS (American Society of Business and Behavioural Sciences), 16(1), 4pp, 2009*] who believes:

We overteach because we have gotten into the habit. It's easier than letting students spend the time and the trouble in learning themselves. We have to start letting them struggle more, as we did, in order to promote longer lasting, more effective learning.

How do we achieve the right balance between overteaching and underteaching? Robert Noyd [*R.K. Noyd, Applying Aristotle's Golden Mean to the classroom: Balancing underteaching and overteaching* , Tomorrow's *Professor, U.S. Air Force Academy, 2005*] suggested that to achieve the right balance, teachers should ask themselves:

Am I giving the right student the right amount of assistance, at the right time, for the right reason, in the right manner?

Fifty years of the Fluid—Mosaic Model of Biomembrane Structure and Organization and its importance in Biomedicine with particular emphasis on Membrane Lipid Replacement

by Garth L. Nicolson, Member EUAS

Short Biography

Professor Emeritus Garth L. Nicolson, PhD, MD (H)

Professor Emeritus Garth L. Nicolson is the Founder, President, Chief Scientific Officer and Emeritus Research Professor of Molecular Pathology at the Institute for Molecular Medicine in Huntington Beach, California. He is also a Conjoint Emeritus Professor at the University of Newcastle (Australia). He was previously the David Bruton Jr. Chair in Cancer Research and Professor and Chairman at the University of Texas M.D. Anderson Cancer Center in Houston, and he was Professor of Internal Medicine and Professor of Pathology and Laboratory Medicine at the University of Texas Medical School, Houston. Professor Nicolson has published over 700 medical and scientific papers, including editing 20 books, and he has served on the Editorial Boards of 30 medical and scientific journals and was Senior Editor of four of these. Professor Nicolson has won many awards, such as the Burroughs Wellcome Medal of the Royal Society of Medicine (United Kingdom), Stephen Paget Award of the Metastasis Research Society, U.S. National Cancer Institute Outstanding Investigator Award, the Innovative Medicine Award of Canada and the EU Academy of Sciences. He is also a Colonel (O6, Honorary) of the U. S. Army Special Forces and a U.S. Navy SEAL (Honorary) for his work on Armed Forces and veterans' illnesses.

Professional Experience:

Primary Appointment:

1996-Present, President and Founder, Chief Scientific Officer and Emeritus Professor of MolecularPathology, The Institute for Molecular Medicine, PO Box 9355, S. Laguna Beach, CA 92652

Secondary Appointments:

2003-Present, Conjoint Emeritus Professor, Faculty of Science and Technology, University of Newcastle, Newcastle, Australia

Previous Appointments:

1989-00, Professor, Department of Internal Medicine, The University of Texas Medical School, Houston, TX
1981-99, Adjunct Professor, Department of Pathology, School of Veterinary Medicine, Texas A & M University, College Station, TX
1982-99, Professor, Department of Pathology and Laboratory Medicine, The University of Texas Medical School, Houston, TX
1980-96, David Bruton Jr. Chair in Cancer Research, Professor and Chairman, Tumor Biology, The University of Texas M. D. Anderson Cancer Center, Houston, TX
1980-96, Professor, The Graduate School of Biomedical Sciences, The University of Texas Health Science Center, Houston, TX
1980-87, Florence M. Thomas Professor of Cancer Research, The University of Texas M. D. Anderson Cancer Center, Houston, TX
1978-80, Professor, Department of Physiology and Biophysics, College of Medicine, University of California, Irvine, CA
1977-80, Associate Director, Oncology Program, University of California, Irvine, CA
1975-80, Professor, Department of Developmental and Cell Biology, University of California, Irvine
1974-76, Chairman, Department of Cancer Biology, The Salk Institute, La Jolla, CA
1972-74, Head, Cancer Council Laboratory, Director, Electron Microscopy Laboratory, The Salk Institute, La Jolla, CA
1970-71, Senior Research Associate, Cancer Council Laboratory, The Salk Institute, La Jolla, CA
1967-70, USPHS Predoctoral Fellow University of California, San Diego, CA

Honors and Awards:

European Union Academy of Sciences, 2019-
Doctor of Medicine, M.D. (H), University of the Republic of Uruguay, 2015

Yanagimachi Distinguished Lectureship, University of Hawaii School of Medicine, 2012
John Drulle Memorial Lectureship, International Lyme and Associated Diseases Society (ILADS), 2008
Annual Award of the Common Cause Medical Research Foundation (Canada), 2006
Innovative Medicine Award (Canada), 2002
Stephen Paget Award, Metastasis Research Society, 1998
Albert Schweitzer Award (Portugal), 1998
First Norman N. Durham Lectureship, Environmental Institute, OSU, 1996
Indo-American Society for Health & Laboratory Professionals Award, 1996
Distinguished Presentation Award, Third International Cancer Molecular Biology Symposium, 1996
COLONEL (Honorary), U. S. Army Special Forces, 1995
SEAL (Honorary), U.S. Navy Special Forces, 1995
Haskel Visiting Professorship, University of Pennsylvania, 1995
Burroughs Wellcome Medal, Royal Society of Medicine Foundation, London, 1991
Outstanding Faculty Award, The University of Texas Health Science Center at Houston, 1991
U.S. National Cancer Institute U.S.S.R. Scientist Exchange Award for Collaborative Research on Molecular and Genetic Aspects of Tumor Metastasis, 1991
Evan and Marion Helfaer Distinguished Lectureship, The Cancer Center of the Medical College of Wisconsin, 1990
Dean's Teaching Excellence List, The University of Texas Health Science Center at Houston Graduate School of Biomedical Sciences, 1985-1994
Teaching Excellence Award for Best Course, The University of Texas Medical School at Houston, 1990
NCI/NIH Outstanding Investigator Award, 1987
Annual Award of the Japan Histochemical Society, 1976
Eli Nadel Memorial Lecture in Biochemistry, 1983
Rita Ferdinand Memorial Lectureship, 1982
Guy Lipscomb Memorial Lecture in Chemistry, 1980
Upjohn Biology Education Award, 1976
Presidential Award, Electron Microscopy Society of America, 1971

1. Nicolson GL, Ferreira de Mattos G. Fifty years of the Fluid—Mosaic Model of biomembrane structure and organization and its importance in biomedicine with particular emphasis on Membrane Lipid Replacement. *Biomedicines* 2022; 10: article 1711.

The Fluid–Mosaic Model has been the accepted general or basic model for biomembrane structure and organization for the last 50 years. In order to establish a basic model, some general principles had to be established, such as thermodynamic assumptions, various molecular interactions, component dynamics, macromolecular organization and other features. Previous researchers placed most membrane proteins on the exterior and interior surfaces of lipid bilayers to form trimolecular structures or as lipoprotein units arranged as modular sheets. Such membrane models were structurally and thermodynamically unsound and did not allow independent lipid and protein lateral movements. The Fluid–Mosaic Membrane Model was the only model that accounted for these and other characteristics, such as membrane asymmetry, variable lateral movements of membrane components, cis- and transmembrane linkages and dynamic associations of membrane components into multimolecular complexes. The original version of the Fluid–Mosaic Membrane Model was never proposed as the ultimate molecular description of all biomembranes, but it did provide a basic framework for nanometer-scale biomembrane organization and dynamics. Because this model was based on available 1960s-era data, it could not explain all of the properties of various biomembranes discovered in subsequent years. However, the fundamental organizational and dynamic aspects of this model remain relevant to this day. After the first generation of this model was published, additional data on various structures

associated with membranes were included, resulting in the addition of membrane-associated cytoskeletal, extracellular matrix and other structures, specialized lipid–lipid and lipid–protein domains, and other configurations that can affect membrane dynamics. The presence of such specialized membrane domains has significantly reduced the extent of the fluid lipid membrane matrix as first proposed, and biomembranes are now considered to be less fluid and more mosaic with some fluid areas, rather than a fluid matrix with predominantly mobile components. However, the fluid–lipid matrix regions remain very important in biomembranes, especially those involved in the binding and release of membrane lipid vesicles and the uptake of various nutrients. Membrane phospholipids can associate spontaneously to form lipid structures and vesicles that can fuse with various cellular membranes to transport lipids and other nutrients into cells and organelles and expel damaged lipids and toxic hydrophobic molecules from cells and tissues. This process and the clinical use of membrane phospholipid supplements has important implications for chronic illnesses and the support of healthy mitochondria, plasma membranes and other cellular membrane structures.

2. Nicolson GL, Breeding PC. Membrane Lipid Replacement with glycerolphospholipids slowly reduces self-reported symptom severities in chemically exposed Gulf War veterans. *International Journal of Translational Medicine* 2022; 2(2): 164-173.

Chemically exposed veterans of the 1991 Gulf War have few options for treatment of conditions and symptoms related to their chemical exposures. Membrane Lipid Replacement (MLR) with oral membrane glycerolphospholipids is a safe and effective method for slowly removing hydrophobic organic molecules from tissues, while enhancing mitochondrial function and decreasing the severity of certain signs and symptoms associated with multi-symptom illnesses. Methods: A preliminary open-label study utilizing 20 male veterans who were deployed to combat areas, exposed to environmental toxic chemicals and subsequently diagnosed with Gulf War Illnesses (GWI) were utilized. These subjects took 6 g per day oral glycerolphospholipids for 6 months, and the severities of over 100 signs and symptoms were self-reported at various times using illness survey forms. Results: In the sixteen patients that fully complied and completed the study, there were gradual and significant reductions of symptom severities in categories related to fatigue, pain, musculoskeletal, nasopharyngeal, breathing, vision, sleep, balance, and urinary, gastrointestinal and chemical sensitivities. There were no adverse incidents during the study, and the all-natural oral study supplement was extremely well tolerated. Conclusions: MLR with oral glycerolphospholipids appears to be a simple, safe and potentially effective method of slowly reducing the severities of multiple symptoms in chemically exposed veterans.

3. Ferreira G, Santander A, Chavarría L, Cardozo R, Sobrevia L, Nicolson GL. Functional consequences of lead and mercury eposomes in the heart. *Molecular Aspects of Medicine* 2023; 87(4): 101048.

Lead and mercury are heavy metals that are highly toxic to life forms. There are no known physiological processes that require them, and they do not have a particular threshold concentration to produce biologic damage. They are non-biodegradable, and they slowly accumulate in the environment in a dynamic equilibrium between air, water, soil, food, and living organisms. Their accumulation in the environment has been increasing over time, because they were not banned from use in anthropogenic industrial production. In their +2 cationic state they are powerful oxidizing agents with the ability to interfere significantly with processes that require specific divalent cations. Acute or chronic exposure to lead and mercury can produce multisystemic damage, especially in the developing nervous systems of children and fetuses, resulting in variety of neurological consequences. They can also affect the cardiovascular system and especially the heart, either directly through their action on cardiomyocytes or indirectly through their effects on innervation, humoral responses or blood vessel alterations. For example, heart function modified by these heavy metals are heart rate, contraction, excitability, and rhythm. Some cardiac molecular targets have been identified and characterized. The direct mechanisms of damage of these heavy metals on heart function are discussed. We conclude that exposome to these heavy metals, should be considered as a major relevant risk factor for cardiac diseases.

4. Ferreira G, Costa C, Santander A, Cardozo R, Savio F, Chavarría L, Nicolson GL. Bacterial toxins and heart function: heat labile *E. Coli* enterotoxin B promotes changes in cardiac function with possible relevance for sudden cardiac death. *Biophysical Reviews* 2023; 15: 447-473.

Bacterial toxins can cause cardiomyopathy, though it is not its most common cause. Some bacterial toxins can form pores in the membrane of cardiomyocytes, while others can bind to membrane receptors. Enterotoxigenic *E. coli* can secrete enterotoxins, including heat-resistant (ST) or labile (LT) enterotoxins. LT is an AB_5-type toxin that can bind to specific cell receptors and disrupt essential host functions, causing several common conditions, such as certain diarrhea. The pentameric B subunit of LT, without A subunit (LTB), binds specifically to certain plasma membrane ganglioside receptors, found in lipid rafts of cardiomyocytes. Isolated guinea pig hearts and cardiomyocytes were exposed to different concentrations of purified LTB. In isolated hearts, mechanical and electrical alternans and an increment of heart rate variability, with an IC50 of ~0.2 μg/ml LTB, were observed. In isolated cardiomyocytes, LTB promoted significant decreases in the amplitude and the duration of action potentials. Na^+ currents were inhibited whereas L-type Ca^{2+} currents were augmented at their peak and their fast inactivation was promoted. Delayed rectifier K^+ currents decreased. Measurements of basal Ca^{2+} or Ca^{2+} release events in cells exposed to LTB suggest that LTB impairs Ca^{2+} homeostasis. Impaired calcium homeostasis is linked to sudden cardiac death. The results are consistent with the recent view that the B subunit is not merely a carrier of the A subunit, having a role explaining sudden cardiac death in children (SIDS) infected with enterotoxigenic *E. coli*, explaining several epidemiological findings that establish a strong relationship between SIDS and ETEC *E. coli*.

5. Nicolson GL, Ferreira de Mattos G. The Fluid—Mosaic model of

cellular membranes: a brief introduction, historical features, some general principles and its adaptation to current information. *Biochimica et Biophysica Acta Biomembranes* 2023; 1865: 184135.

The Fluid–Mosaic Membrane (FMM) model was originally proposed as a general, nanometer-scale representation of cell membranes (Singer and Nicolson, 1972). The FMM model was based on some general principles, such as thermodynamic considerations, intercalation of globular proteins into a lipid bilayer, independent protein and lipid dynamics, cooperativity and other characteristics. Other models had trimolecular structures or membrane globular lipoprotein units. These latter models were flawed, because they did not allow autonomous lipids, membrane domains or discrete lateral dynamics. The FMM model was also consistent with membrane asymmetry, cis- and trans-membrane linkages and associations of membrane components into multi-molecular complexes and domains. It has remained useful for explaining the basic organizational principles and properties of various biological membranes. New information has been added, such as membrane-associated cytoskeletal assemblies, extracellular matrix interactions, transmembrane controls, specialized lipid-protein domains that differ in compositions, rotational and lateral mobilities, lifetimes, functions, and other characteristics. The presence of dense, structured membrane domains has reduced significantly the extent of fluid-lipid membrane areas, and the FMM model is now considered to be more mosaic and dense than the original proposal.

6. Sfera A, Hazan S, Klein C, Zapata-Martin del Campo CM, Sasannia S, Anton JJ, Rahman L, Andronescu CV, Sfera DO, Kozakidis Z, Nicolson GL. Microbial translocation disorders: assigning an etiology to idiopathic illnesses. *Applied Microbiology* 2023; 3(1): 212-240.

Gut microbes are immunologically tolerated in the gastrointestinal tract but trigger aggressive immune responses upon translocation across the gut barrier. Although oral tolerance, a physiological process that dampens immune responses to food proteins and commensal microbiota, remains poorly defined, significant progress was made during and after the Human Immunodefi- ciency Virus epidemic in the 1980s and the discovery of regulatory T cells in 1995. Additional insight was gained after the discoveries of innate lymphoid cells in 2008 and the functional elucidation of mucosal mast cells. Prior to the historical discovery of human pathogens, the etiologies of most human diseases were considered unknown. The same was true about many genetic disorders prior to the Human Genome Project. Here, we hypothesize that many of the remaining idiopathic conditions, including autoimmune, fibroproliferative, and neuropsychiatric diseases as well as some cancers, can be considered microbial translocation disorders triggered by the host immune responses to extraintestinal gut microbes and/or their constituent parts. In addition to microbial translocation, we also discuss potential interventions for intestinal barrier rehabilitation, including antibodies against tumor necrosis factor-like ligand 1A and membrane lipid replacement supplements.

7. Ferreira G, Santander A, Cardozo R, Chavarría L, Domínguez, Mujica N, Benítez M, Sastre S, Sobrevia, Nicolson GL. Nutrigenomics of inward rectifier potassium channels. *Biochimica et Biophysica Acta Molecular Basis of Disease* 2023; 1869: article166803.

Inwardly rectifying potassium (Kir) channels play a key role in maintaining the resting membrane potential and supporting potassium homeostasis. There are many variants of Kir channels, which are usually tetramers in which the main subunit has two trans-membrane helices attached to two N- and C-terminal cytoplasmic tails with a pore-forming loop in between that contains the selectivity filter. These channels have domains that are strongly modulated by molecules present in nutrients found in different diets, such as phosphoinositols, poly- amines and Mg^{2+}. These molecules can impact these channels directly or indirectly, either allosterically by modulation of enzymes or via the regulation of channel expression. A particular type of these channels is coupled to cell metabolism and inhibited by ATP (KATP channels, essential for insulin release and for the pathogenesis of metabolic diseases like diabetes mellitus). Genomic changes in Kir channels have a significant impact on metabolism, such as conditioning the nutrients and electrolytes that an individual can take. Thus, the nutrigenomics of ion channels is an important emerging field in which we are attempting to understand how nutrients and diets can affect the activity and expression of ion channels and how genomic changes in such channels may be the basis for pathological conditions that limit nutrition and electrolyte intake. In this contribution we briefly review Kir channels, discuss their nutrigenomics, characterize how different components in the diet affect their function and expression, and suggest how their genomic changes lead to pathological phenotypes that affect diet and electrolyte intake.

8. Spinoso A, Settineri R, McLaren C, Nicolson GL. The effects of a multi-modality treatment for peripheral neuropathy utilizing LED light, extracorporeal shockwave, platelet rich plasma and an oral supplement. *International Journal of Clinical Medicine* 2023; 14: 250-259.

Peripheral neuropathy (PN) is a significant contributor to disability in the elderly. It is also one of the most prevalent complications of type 2 diabetes, prediabetes and metabolic syndrome. PN is commonly associated with pain, numbness, tingling, burning, and cramping in the feet and legs. Current treatment options are limited to controlling pain, seizures and use of antidepressant medications. These treatments have undesirable side effects and don't stop PN progression. Here we utilized a combination of individual-specific modalities to improve local circulation and relieve PN symptoms. Methods: We conducted an open-label, multicenter pilot trial with 34 subjects (19 males and 15 females ranging from 40 - 85 years of age). All of the participants were diagnosed with peripheral neuropathy and had bilateral symptoms in their feet, and many reported the same symptoms (pain, numbness, tingling, burning, and cramping) in their lower legs. The duration of symptoms ranged from four months to over six years. On Day 0, subjects were

given a 90-day supply of the oral supplement with dosing instructions and a LED light therapy device. They also received three platelet-rich plasma (PRP) injections in their lower extremities. Subjects also received an extracorporeal shockwave therapy (ESWT) treatment for each foot and subsequently twice per week for the first six weeks, then once weekly for the duration of the study. Subjects filled out the Brief Pain Index (BPI) at weekly intervals. On Day 90, subjects completed the Patient Global Impression of Change (PGIC) survey. Results: There were significant responses to pain, as evidenced by BPI scores at weeks 8, 9, 10 and 11 ($p = 0.02$, 0.01, 0.02, and 0.003, respectively). Analysis of the final day PGIC survey showed a favorable outcome for 73% of participants ($p = 0.003$), with the majority reporting Very Much Improved. Conclusions: By utilizing a multi-modality treatment protocol that includes PRP, LED light therapy, ESWT and an oral dietary supplement, we observed significant reductions in BPI scores. Quality of life and their overall impression of change (PGIC) were significantly improved, and there were no significant side effects.

9. Nicolson, G.L. The Fluid—Mosaic model of cell membranes: some general principles. *Universal Journal of Fluid Mechanics* 2023; 11: 23-38.

In 1972 the Fluid–Mosaic Membrane (FMM) model was proposed as a nanometer-scale representation of cell membranes. It was based on some general principles, such as thermodynamic considerations, intercalation of globular, amphipathic proteins and glycoproteins into a glycerophospholipid bilayer, independent protein and lipid dynamics, cooperativity, trans-membrane linkages and other characteristics. Earlier models proposed trimolecular structures (proteins/phospholipids/proteins) or sheets of repeating globular lipoprotein units. These earlier models were flawed, because they did not allow discrete membrane domains, autonomous proteins and lipids, or individual lateral dynamics. The FMM model was also consistent with membrane asymmetry, cis- and trans-membrane linkages and associations of components into dynamic multi-molecular complexes/domains. The FMM has remained useful for conceptualizing the basic organizational principles and properties of biological membranes. Additional important information has also been incorporated into the FMM, such as membrane-associated cytoskeletal assemblies, extra-cellular matrix interactions, transmembrane controls, and specialized lipid-protein domains. The presence of dense, structured membrane domains has reduced significantly the extent of fluid-lipid membrane areas, and the FMM model is now considered to be more mosaic and dense than the original 1972 proposal.

10. Sfera A, Hazan S, Bota PG, Anton JJ, Nicolson GL. Local hormones and neurolipidomics in schizophrenia. *American Journal of Neurology Research* 2023; 2(2): 1-4.

Chronic mental illnesses, including schizophrenia, have been associated with premature brain aging manifested on neuroimaging as gray matter loss. This has been associated with impaired insight (anosognosia) and suboptimal treatment outcome. Novel strategies for addressing premature brain aging are urgently needed and somatostatin up regulation may avert gray matter loss. Recent studies, involving non-pituitary growth hormone and p53,

have offered early glimpses into the molecular underpinnings of cellular senescence in SCZ. Moreover, age-downregulated somatostatin and activation of Human Endogenous Retroviruses likely drive the negative and cognitive symptoms of SCZ. In this perspective article, we discuss the following: 1) neuropsychiatric implications of premature brain aging, 2) potential therapies for restoring the homeostasis of somatostatin and non-pituitary growth hormone.

11. Nicolson GL, Ferreira G. Membrane Lipid Replacement for reconstituting mitochondrial function and–moderating cancer-related fatigue, pain and other symptoms while counteracting the adverse effects of cancer cytotoxic therapy. *Clinical & Experimental Metastasis*, 2024; in press.

Cancer-related fatigue, pain, gastrointestinal and other symptoms are among the most familiar complaints in practically every type and stage of cancer, especially metastatic cancers. Such symptoms are also related to cancer oxidative stress and the damage instigated by cancer cytotoxic therapies to cellular membranes, especially mitochondrial membranes. Cancer cytotoxic therapies (chemotherapy and radiotherapy) often cause adverse symptoms and induce patients to terminate their anti-neoplastic regimens. Cancer-related fatigue, pain and other symptoms and the adverse effects of cancer cytotoxic therapies can be safely moderated with oral Membrane Lipid Replacement (MLR) glycerolphospholipids and mitochondrial cofactors, such as coenzyme Q_{10}. MLR provides essential membrane lipids and precursors to maintain mitochondrial and other cellular membrane functions and reduce fatigue, pain, gastrointestinal, inflammation and other symptoms. In addition, patients with a variety of chronic symptoms benefit from MLR supplements, and MLR also has the ability to enhance the bioavailability of nutrients and slowly remove toxic, hydrophobic molecules from cells and tissues

Intelligent Design of Concrete Incorporating Solid Wastes and 3D Printing Construction

by Xiangyu Wang, Member EUAS

Short Biography

Education:

Ph.D., Purdue University, USA, 2005
Master, University of Washington, USA, 2002
Bachelor, Tongji University, 2000

Employment History:

- *2011, 10 – presence, Professor, Curtin University, Australia*
- *2013 – 2018, Woodside Chair, Curtin University/Woodside Energy Ltd.*
- *2012 – 2013, Acting Woodside Chair, Curtin University/Woodside Energy Ltd.*
- *2016-2018, College of Experts, Australian Research Council (ARC), Federal Government*
- *2012-2017, Director, Australasian Research Centre for Building Information Modelling, Curtin University*
- *2012-2018, Editor-in-Chief, Visualization in Engineering, Springer*
- *2011, Senior Lecturer, University of New South Wales*
- *2006, 05 - 2010, 12, Lecturer, University of Sydney*
- *2005,10 – 2006, 04, Postdoc Research Associate, Purdue University, USA*

Recognition and Awards:

1. *2024, Vice President (Industry), International Association of Automation and Robotics in Construction (IAARC)*
2. *2024, Fellow, International Association of Advanced Materials (IAAM)*
3. *2023, World Top 2% Scientist (Single year ranking top 9,000 out of 200,000 scientists across all disciplines; ranked #58th out of 38,433 scientists in the disciple of "Building and Construction")*
4. *2022, Clarivate Highly Cited Researcher (Engineering)*
5. *2018, Fellow, European Union Academy of Sciences (EUAS)*
6. *2018, Albert Nelson Marquis Lifetime Achievement Award*
7. *2018, Kyung Hee Award, South Korea*
8. *2018, Best Paper Award, International Journal of Production Research*
9. *2018, Best Paper Award, iCCPMCE 2018, Sydney*
10. *2019, Best Paper Award, AUBEA 2019, Brisbane*
11. *2016, Australian Research Council (ARC) College of Experts*
12. *2013, Woodside Chair for Oil, Gas, and LNG Construction and Project Mgmt*
13. *2015, Distinction Paper Award, CRIOCM2015, China*
14. *2012, Runner-Up Award of Curtin Commercial Innovation*

Career Summary

Professor Xiangyu Wang is a Fellow of the European Academy of Sciences (EUAS)

and recognized as a Highly Cited Researcher (2022, Engineering) by Clarivate Analytics, leads globally in the number of highly cited papers within the fields of Architecture & Building, Civil Engineering, and Transportation in 2022. He was among only ten scientists honored as a Highly Cited Researcher in these domains for the year.

Professor Wang earned his PhD from Purdue University, his Master's degree from the University of Washington, and his Bachelor's degree from Tongji University. He currently holds the position of Executive Director and Distinguished Professor at the Institute for Smart Civil Infrastructure Construction and Maintenance at East China Jiaotong University. Previously, he was a Lifetime Chair Professor at Curtin University (ranked 178th in the 2023 QS World University Rankings) and served as Director at the Australasian Joint Research Centre for Building Information Modelling (BIM). He is the Woodside Chair Professor for Oil, Gas & LNG Construction, representing one of Australia's top ten listed companies.

Over the last decade, Professor Wang has spearheaded more than 100 projects both domestically and internationally, securing over 30 million AUD in research and transformation funding. Since 2014, his team has secured 15 Australian Research Council (ARC) grants, alongside significant projects from the National Science Foundation of the United States, the National Research Foundation of Korea, and Fortune 500 companies like Shell, Huawei, and China Communications Construction. As the founder and chairperson of the Curtin Advanced Technology Research and Innovation Alliance (CATRINA), his innovative work has been extensively applied across the energy, mining, infrastructure, and construction sectors, generating global economic benefits to billions of dollars. His work has gained significant media attention globally and he has been the recipient of numerous prestigious awards, including the Marquis Who's Who Lifetime Achievement Award.

He has delivered keynote speeches at more than a hundred influential international academic conferences. He has published over 500 papers including more than 300 peer-reviewed journal papers indexed by Web of Science (Web of Science h-index = 61 and citations = 11646, SCOPUS h-index = 66 and citations = 14415, Google Scholar = 83 and citations = 25300), among them, 30 papers have been selected by the Essential Science IndicatorsSM as highly-cited papers and 10 as hot papers. As an editorial board member of several international journals, he contributes significantly to the academic community. He has been a Guest Editor for 20 special issues in international journals and conference proceedings (6 of them have EU researchers as Co-Editors). He also collaborates extensively with international researchers and has graduated over 20 PhD students and completed over 30 postdocs, including many from Europe.

“Intelligent design of concrete incorporating solid wastes and 3D printing construction”

The first main research domain is the properties investigation of cementitious incorporated with various types of solid wastes. A series researches has been conducted to assess and activate the potential of various waste materials. These waste materials include glass particles, construction and demolition waste, copper slag, red mud, ultra-fine fly ash, Ground Granulated Blast Furnace Slag (GGBS), and sugar beetroot microsheets. These methodologies are meticulously designed to evaluate the mechanical strength, electrical conductivity, and hydration kinetics of cementitious composites when integrated with these

activated waste materials. The experimental methodologies involved a broad and detailed approach to the activation and integration of waste materials within cementitious composites, leveraging both traditional and innovative techniques to unearth the potential of solid wastes in enhancing the sustainability and performance of construction materials.

Specifically, to enhance the pozzolanic activity of waste glass particles, the research adopted a comprehensive approach combining mechanical, chemical, and hydrothermal activation. This method was intricately designed, aiming to maximize the waste glass's contribution to the composite's overall strength and durability. The study concluded that such activation processes significantly improve the reactive surface area of the glass particles, making them more effective as pozzolanic materials in cementitious composites. Similarly, the investigation of construction and demolition waste focused on its potential to reinforce cement-stabilized soil. Through mechanical compaction tests and unconfined compressive strength measurements, By varying the proportions of this waste, the study identified optimal mixing ratios that enhance the soil's load-bearing capacity. The findings suggest that construction and demolition waste can effectively increase the mechanical strength of stabilized soil, thereby contributing to more durable and resilient infrastructure.

In the realm of electrical conductivity and mechanical strength enhancement, another research delved deep into the nano-modification of cementitious composites using copper slag. This process involved a sophisticated methodology where copper slag was not only used as a filler but also activated at the nanoscale to improve its interaction with the cement matrix. The resultant composites underwent rigorous testing, including four-point bending tests and electrical resistivity measurements, to assess improvements in mechanical robustness and electrical pathways. Besides, another innovative study involved the electrochemical characterization of cementitious composites infused with sugar beetroot microsheets. This study embarked on an in-depth analysis using cyclic voltammetry and electrochemical impedance spectroscopy to understand how the incorporation of these bio-based materials influences the hydration kinetics and ion diffusion within the cement matrix. The methodology encompassed not only the preparation and dispersion of these microsheets within the cement but also a comprehensive evaluation of their impact on the composite’s electrochemical properties and mechanical performance. Moreover, the research on utilizing red mud, ultra-fine fly ash, and GGBS in a ternary composite delved into the geopolymerization mechanism. The study explored the chemical interactions and synergistic effects among these waste materials. The outcomes indicate that such a combination leads to enhanced mechanical properties and durability, showcasing the potential of waste materials in creating high-performance, sustainable construction materials. This research underscores the importance of innovative waste utilization strategies in the construction sector, contributing to environmental sustainability and material innovation.

These experimental methodologies underscore the comprehensive and innovative approaches taken to harness the potential of waste materials, contributing to the development of more sustainable, durable, and functional construction materials. The methodologies, experiments, and analyses detailed in these studies collectively underscore the viability and environmental benefits of incorporating solid waste into construction materials, marking a significant step forward in sustainable construction practices.

The second main research domain involves the integration of artificial intelligence (AI)

and machine learning (ML) with smart materials, which is revolutionizing the construction industry by enhancing material sustainability and efficiency. A series of innovative studies were conducted to leverage AI and ML to predict, optimize, and visualize the properties and applications of various cementitious materials enhanced with waste products and smart modifications.

In the realm of using waste glass as a supplementary cementitious material, machine learning algorithms were used to predict the pozzolanic activity enhancements through mechanical and chemical activation of waste glass. This approach not only promotes recycling but also enhances the mechanical properties of cementitious composites. Another research focused on the utilization of recycled aggregate concrete (RAC), where AI models, such as Back Propagation Neural Networks (BPNN), Support Vector Machines (SVM), Random Forest (RF), were harnessed to predict the strength and durability of RAC with high accuracy. This study demonstrates how ML can optimize the use of construction and demolition waste, thereby contributing to more sustainable building practices. ML algorithms were also applied in exploring the reinforcement potential of copper slag in cementitious materials. Specifically, SVM models refined with genetic algorithms, were utilized to precisely forecast enhancements in mechanical strength and durability afforded by this industrial by-product. Besides, another study utilized ML models to delve into the seismic behavior of steel tubular columns incorporating recycled aggregate concrete. AI's analytical power was instrumental in dissecting the impact of various parameters on seismic durability, thereby providing valuable guidance for the architectural design of structures poised to withstand seismic events. The versatility of machine learning was also demonstrated in a study that predicted the mechanical properties of lightweight coal gangue shotcrete. By integrating BPNN with particle swarm optimization, the research achieved high accuracy in predicting compressive and splitting strength.

Moreover, the application of Partial Dependence Plots (PDP) significantly enhanced the interpretability of ML prediction. In the investigation of steel tubular columns filled with recycled aggregate concrete, PDPs clarified how parameters like slenderness ratio and axial compression affect seismic performance. Similarly, in the study assessing the mechanical properties of lightweight coal gangue shotcrete, PDPs provided insights into the impact of coal gangue particle size and the proportions of various components on the material's strength and density. By visualizing the influence of these variables, PDPs have facilitated a deeper understanding of the material properties, guiding more effective material design and optimization strategies.

These studies represent a significant stride towards integrating AI and ML in the development of sustainable, durable, and innovative construction materials. By accurately predicting material properties, optimizing the use of waste materials, and providing clear visualizations of complex data, AI and ML are setting a new standard for materials science research and application in the construction industry.

The third main research domain involves the investigation of 3D printed concrete incorporating various waste materials and innovative treatments, aiming to enhance sustainability, material properties, and functional applications. This burgeoning field of study harnesses the capabilities of 3D printing technology to revolutionize the construction industry by offering bespoke solutions that align with environmental sustainability and efficient material use. This series of researches focused on enhancing the sustainability,

mechanical properties, and functional applications of 3D printed concrete through the incorporation of different types of solid wastes like coal gangue, copper slag, antimony tailings, waste rubber particles, and recycled glass. These materials undergo meticulous mechanical, chemical, and thermal activation processes to unlock their potential as supplementary cementitious materials or aggregates, improving the pozzolanic activity and compatibility with cementitious composites.

One study systematically explored the impact of various curing conditions, particularly focusing on the benefits of steam curing on the mechanical properties of 3D printed concrete. By employing steam curing, a notable enhancement was observed in early strength development and durability, demonstrating the method's effectiveness in improving the material's performance. Leveraging AI and ML technology, predictive models were developed to forecast the mechanical behavior of 3D printed composites under different conditions. These models successfully captured the effects of anisotropy caused by the layer-by-layer construction technique, allowing for accurate predictions of compressive and tensile strengths based on the orientation and geometry of printed layers. The predictive power of AI-based tools facilitated the optimization of mix designs and curing processes, tailoring them to specific structural requirements and environmental conditions. Through the application of machine learning algorithms, the interplay between material composition, printing parameters, and curing methods can be analyzed to identify optimal configurations for enhanced mechanical performance. This data-driven approach significantly streamlined the experimental process, reducing the time and resources required to develop materials with desired properties.

Besides, significant strides were made in integrating waste materials like coal gangue, copper slag, and rubber particles into the fabrication of 3D printed concrete to achieve specific functional outcomes, such as electromagnetic wave absorption. The research meticulously investigated the design and implementation of wave-shaped superstructures and fiber orientations within the concrete matrix. This was achieved by embedding copper slag to leverage its electrical conductivity properties and incorporating rubber particles to enhance the composite's capacity to mitigate electromagnetic interference. These efforts were directed towards optimizing the material's ability to absorb electromagnetic waves, particularly focusing on the low-frequency range, and were aimed at reducing reflectivity through the strategic disruption of electromagnetic wave paths. The studies underscored the practical implications of such material innovations in environments requiring minimized electromagnetic pollution, marking a pivotal contribution to the field of functional and sustainable construction materials. Another significant contribution is the exploration of lightweight concrete through the surface treatment of coal gangue aggregates with silica fume. This not only addresses the issue of waste material disposal but also contributes to the production of concrete with reduced density without compromising mechanical strength, opening avenues for its application in a wider range of structural and non-structural contexts.

In summary, these studies highlight the multifaceted benefits of integrating solid waste materials into 3D printed concrete, from enhancing material sustainability and efficiency to introducing innovative functionalities. It underscores the potential of 3D printed concrete as a versatile, sustainable, and innovative solution in the construction industry, paving the way for more environmentally friendly and technologically advanced building practices.

Relevant Web of Science ESI Top 1% Highly Cited Papers

[1] Sun, J., Aslani, F., Wei, J., & Wang, X. (2021). Electromagnetic absorption of copper fiber oriented composite using 3D printing. Construction and Building Materials, 300, 124026.
[2] Sun, J., Lin, S., Zhang, G., Sun, Y., Zhang, J., Chen, C., ... & Wang, X. (2021). The effect of graphite and slag on electrical and mechanical properties of electrically conductive cementitious composites. Construction and Building Materials, 281, 122606.
[3] Zhang, G., Chen, C., Li, K., Xiao, F., Sun, J., Wang, Y., & Wang, X. (2022). Multi-objective optimisation design for GFRP tendon reinforced cemented soil. Construction and Building Materials, 320, 126297.
[4] Sun, J., Wang, Y., Liu, S., Dehghani, A., Xiang, X., Wei, J., & Wang, X. (2021). Mechanical, chemical and hydrothermal activation for waste glass reinforced cement. Construction and Building Materials, 301, 124361.
[5] Sun, J., Tang, Y., Wang, J., Wang, X., Wang, J., Yu, Z., ... & Wang, Y. (2022). A multi-objective optimisation approach for activity excitation of waste glass mortar. journal of materials research and technology, 17, 2280-2304.
[6] Ren, Z., Zeng, H., Zeng, X., Chen, X., & Wang, X. (2023). Effect of nanographite conductive concrete mixed with magnetite sand excited by different alkali activators and their combinations on the properties of conductive concrete. Buildings, 13(7), 1630.