Frontiers of Science Symposium

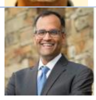
on

MATERIALS FOR SOCIETY

Organized by the *Indian Academy of Sciences*

October 1, 2020 **10 AM-12:15 PM and 2 PM-4 PM**

Science, engineering and, in essence, human thought have been profoundly impacted by the societal developments of the past century. It is now broadly understood that complexity originates from inter-connectedness of different disciplines, processes, and techniques, increasing as their inter-dependence grows. The development of different materials/ components/ technologies for a variety of applications, or in a broader sense, the fundamental knowledge base that is employed in research and development, display such complexity. In today's world, most development that benefits the human society necessitates interdisciplinary science and research. The researchers in the field of interdisciplinary engineering science face challenges stemming from intrinsic complexity of scientific ideas and the means to bring them together, leading to a sustainable development. It is also the key to exploit such interactions to address the numerous societal needs—be it energy, security, economy, food, or public health. In particular, the translational research on biomaterials is driven by unmet clinical challenges. Two such unmet clinical needs, that will be discussed in this symposium, are bioactive therapeutic interventions, such as implants and scaffolds, and models for understanding disease mechanisms and potentially discovering new therapeutic modalities. While addressing these two issues by two globally acclaimed scientists, this symposium will also address the key opportunities and challenges as India needs to translate indigenous technologies to commercially viable products for societal applications, by one of the recognized leaders from an established multinational company. In one of the lectures, the experimental correlative strategies will be discussed to demonstrate as how to combine multiscale, multimodal and time lapse information on microstructure in 3D space to investigate a spectrum of performance-limiting properties and phenomena for key materials of societal relevance. It is expected that this symposium will excite many young minds in the field of interdisciplinary science and engineering.

Indian Standard Time		Speaker	Title of Lecture
10:00 – 10:15 AM		**Professor Partha Majumdar** (National Science Chair and President, Indian Academy of Sciences)	Welcome and Purpose of the Symposium
10:15 – 11:15 AM		**Professor Sanjay Kumar** (Chancellor's Professor and Chair of the Department of Bioengineering, University of California, Berkeley)	Engineering approaches yield new insights into invasive brain tumors
11:15 – 12:15 AM		**Professor Serena M. Best FREng CBE** (Professor, University of Cambridge, UK)	Design of Tissue Engineering Scaffolds - Still Learning our ABC?
		BREAK – RECONVENE AT 2 PM	
2:00 - 3:00 PM		**Professor Philip Withers FREng FRS** (Regius Professor of Materials, The University of Manchester, UK)	Gaining inside information on the Behaviour of Advanced Materials
3:00 - 4:00 PM		**Dr. Debashish Bhattacharjee FNAE** (Vice President, Technology and New Materials Business, TATA Steel Limited)	Challenges and enablers in the development of advanced materials from concept to commercialization

To join

https://ias.webex.com/ias/onstage/g.php?MTID=eb74f7e5755c10e9986f6ae1b27574207

or

https://youtu.be/Lt-VhRf65kY

Biosketches

Professor Sanjay Kumar
UC Berkeley, USA

Sanjay Kumar, M.D., Ph.D., is Chancellor’s Professor and Chair of the Department of Bioengineering at UC Berkeley, where he has been a faculty member since 2005. He also holds appointments in the Department of Chemical and Biomolecular Engineering at UC Berkeley and the Biological Systems & Engineering Division of Lawrence Berkeley National Laboratory. Dr. Kumar earned his B.S. in Chemical Engineering at the University of Minnesota (1996) and his M.D. and Ph.D. in Molecular Biophysics from Johns Hopkins University (2003). Prior to joining the UC Berkeley faculty, he completed postdoctoral training at Boston Children’s Hospital and Harvard Medical School. He and his research group have been fortunate to receive a number of honors, including the Presidential Early Career Award for Scientists and Engineers (PECASE), The NIH Director's New Innovator Award, The Arnold and Mabel Beckman Young Investigator Award, the NSF CAREER Award, and the Stem Cells Young Investigator Award. Dr. Kumar has also received awards by student vote for Excellence in Graduate Advising (UCSF/UC Berkeley Joint Graduate Group in Bioengineering) and Outstanding Teaching (Bioengineering Honor Society) and has served as a Presidential Chair Teaching Fellow. Dr. Kumar is a Fellow of AIMBE and BMES, and he will co-Chair the 2024 GRC on Signal Transduction by Engineered Extracellular Matrices. He has co-authored more than 100 peer-reviewed publications and mentored more than 30 graduate students and postdoctoral fellows.

Professor Serena Best
University of Cambridge, UK

Serena Best is a Professor of Materials Science at the University of Cambridge and Fellow of St. John’s College, Cambridge. She co-directs the Cambridge Centre for Medical Materials. She has published around 300 journal papers, books and book chapters, she holds more than 10 patents in the fields of biomaterials and skeletal repair and has played a part in the spin out two companies associated with this work. She has been invited to plenary lectures around the World and has presented the Hatfield, Linacre and Lamor Lectures in the UK. She is President of the Institute of Materials, Minerals, a Fellow of the Royal Academy of Engineering, a Fellow of Federation of Institutions for Biomaterials Science and Engineering (FBSE) and the American Institute for Medical and Biological Engineering (FAIMBE). She has received a number of international awards and medals for her work from Societies and Professional Bodies. She was awarded a CBE in the Queen’s Birthday Honours List in 2017 for services to Biomaterials Engineering.

Professor Philip Withers FREng FRS

- Regius Professor of Materials | The University of Manchester
- Chief Scientist | Henry Royce Institute
- Fellow of the Royal Academy of Engineering
- Fellow of the Royal Society

Professor Philip Withers is the Chief Scientist of the **Henry Royce Institute** and the inaugural Regius Professor of Materials at **The University of Manchester**. He is recognised as the world-leading authority on the behaviour of engineering materials, particularly under demanding

His research has made a seminal contribution to our fundamental understanding of the performance of materials, the effects of residual stresses and damage accumulation through his pioneering use of neutron, synchrotron X-ray and laboratory X-ray beams to provide new insights on behaviour often in operando.

In 2008 this expertise led Prof. Withers to establish the **Henry Moseley X-ray Imaging Facility**, one of the most extensive suites of X-ray imaging facilities in the world, with a special focus on in situ time-lapse 3D X-ray imaging. In 2014, the Facility was awarded the Queen's Anniversary Prize in 2014 for "New Techniques in X-Ray Imaging of Materials Critical for Power, Transport and Other Key Industries", recognising the special contribution the team's research and expertise has made to the UK's strategic development in advanced materials and manufacturing.

In 2015 he and a co-author were awarded the George Stephenson Gold Medal of the Institute of Mechanical Engineers for his work exploiting X-ray imaging to study powder metallurgy processes in situ in 3D. In September 2012 he became the founding Director of the $100m **BP-International Centre for Advanced Materials**, a position he held until taking up the role of Chief Scientist at the Henry Royce Institute in 2017.

The importance of this body of work to society as a whole has been recognised by his election to the **Royal Academy of Engineering**. In 2016 he was elected as **Fellow of the Royal Society** and a Foreign Member of the Chinese Academy of Engineering in 2019. In July 2018 he was awarded a Platinum Medal by The Institute of Materials, Minerals and Mining.

Dr. Debashish Bhattacharjee

Vice President of the Technology and New Materials Business. TATA Steel

Dr. Debashish Bhattacharjee is the Vice President of the Technology and New Materials Business wing of Tata Steel. He is setting up business in non-steel business such as composites and graphene. He also oversees technology and R&D, ranging from raw materials to finished products in the steel and non-steel businesses. An alumnus of Jadavpur University, he has done his M. Tech from IIT Kanpur and PhD in Materials Science and Engineering from the University of Cambridge.

A fellow of the Indian National Academy of Engineering (FNAE), and the Indian Institute of Metals (IIM), Dr. Bhattacharjee has also served as Visiting Professor at Imperial College London, University of Warwick and USTB in China. Dr. Bhattacharjee has also received the highly prestigious "Metallurgist of the Year Award", Govt of India, in 2004. He is Director on the Board of Tata Advanced Materials Ltd. He is a personality with specializations in Physical and Mechanical Metallurgy of Iron and Steel and is rich in skills such as change management, process improvement, continuous improvement, minerals and many more. He has made major contributions in the field of material science by the development of advanced and ultra high steel products for the automotive sector and development of new generation of coatings on steel. Along with this, there are more than 20 patents and more than 50 peer reviewed publications to his name. His hobbies are playing cricket and acting in plays.

Abstracts

Engineering approaches yield new insights into invasive brain tumors

Sanjay Kumar, M.D., Ph.D., UC Berkeley, USA

The invasion of solid tumors is a highly physical process involving adhesion and transmission of mechanical force against the solid-state tumor microenvironment. Here I describe our group's efforts to use engineering approaches to model and mechanistically dissect invasion in glioblastoma (GBM), a highly infiltrative brain tumor that is nearly universally fatal within two years of diagnosis. First, we have engineered hyaluronic acid (HA) scaffolds to capture key mechanical and architectural features of the brain tumor microenvironment. We recently used these materials to discover a new mechanism through which GBM cells attach to and invade brain tissue using CD44- dependent "microtentacles" [1]. We have also deployed these materials in tumor-onchip microdevices that enable imaging and molecular analysis of GBM invasion [2]. Second, we have deeply investigated the role of GBM tumor cells' force-generating machinery in driving tumor progression. We have demonstrated that by targeting pathways within GBM stem/initiating cells that promote actin polymerization [3] or matrix mechanosensitivity [4], we can slow GBM progression in vitro and in mouse models. An important hallmark of these studies is the tight integration of molecular/cell biology, biomaterials, and biophysics. Our work illustrates the power of engineering tools to glean mechanistic insight into tumor progression and unveil novel therapeutic targets.

[1] K. J. Wolf, P. Shukla, K. Springer, S. Lee, J. D. Coombes, C. J. Choy, S. J. Kenny, K. Xu, and S. Kumar (2020). A mode of cell adhesion and migration facilitated by CD44-dependent microtentacles. Proceedings of the National Academy of Sciences (PNAS) 117: 11432-11443.

[2] K. J. Wolf, S. Lee, and S. Kumar (2018). A 3D topographical model of parenchymal infiltration and perivascular invasion in glioblastoma. APL Bioengineering 2: 031903.

[3] J. Chen, B. Ananthanarayanan, K.S. Springer, K.J. Wolf, S.M. Sheyman, V.D. Tran and S. Kumar (2020). Suppression of LIM Kinase 1 and LIM Kinase 2 Limits Glioblastoma Invasion. Cancer Research 80: 69-78.

[4] S. Y. Wong, T. A. Ulrich, L. P. Deleyrolle, J. L. MacKay, J.-M. Lin, R. T. Martuscello, M. A. Jundi, B. A. Reynolds, and S. Kumar (2015). Constitutive activation of myosin-dependent contractility sensitizes glioma tumor-initiating cells to mechanical inputs and reduces tumor invasion. Cancer Research 75: 1113-1122.

Design of Tissue Engineering Scaffolds - Still Learning our ABC?

Professor Serena M. Best, University of Cambridge, UK

For many years, there has been interest in the use of biomaterials to replace human tissues damaged by injury or disease. Over time, the materials of choice have gradually changed from those that simply offer mechanical support to those that interact directly with the biological environment. Focus is now on the recruitment and delivery of biological cells to assist in the repair process. With this move from tissue replacement to cell-mediated tissue reconstruction and regeneration (or tissue engineering), there is increasing need for the design of optimised, porous biomaterial structures – often referred to as "Scaffolds". By first understanding the nature of the tissues that we want to regenerate, it is possible to address the requirements for particular clinical applications.

This talk will consider two scaffold materials: collagen, a highly versatile and bioactive natural macromolecule; and hydroxyapatite, a calcium phosphate material similar in composition to bone mineral. To optimise tissue repair processes, it is important to understand the influence on cell behaviour of the structure of the scaffold, and the interconnections between the pores within them. Choice of scaffold surface chemistry also allows us to balance scaffold "activity" and mechanical performance. There is also a need to consider an appropriate testing environment to mimic the cellular interactions which take place within the body.

This talk will cover the recent work undertaken to study the structure and properties of scaffolds for a range of clinical applications in soft and hard tissue repair. By developing these bioactive materials we hope to offer materials that serve- and improve the health of members of society for the 21st Century

Gaining inside information on the Behaviour of Advanced Materials

Prof. Phil Withers, FRS, Regius Professor of Materials

Chief Scientist of the Henry Royce Institute for Advanced Materials, University of Manchester

Natural, and increasingly manufactured materials, rely on complex hierarchical structures to provide a suite of interesting properties and functionality. Often they exploit anisotropy and heterogeneity through interfaces, chemistry and crystallography from the nanoscale to the component scale. To date much has been learnt about materials behaviour from 2D images. However two dimensions don't always tell the whole story. Tomographic methods enable us to build up 3D pictures of structure. In many cases we need to be able to follow the response of these features to external loads and environments. Because it is non-destructive, X-ray computed tomography (CT) enables to acquire sequences of 3D images over time, to carry out time-lapse studies.

There are now a plethora of techniques able to characterise materials. Rather than apply them separately on different specimens, correlative tomography enables us to combine and integrate these methods to examine in detail a region of interest and to build up a multifaceted picture of how these hierarchical structures perform enabling us to identify the key length scales. We exploit multiscale correlative strategies to enable multiple chemical, structural and property datasets can be brought together at key regions of interest in three dimensions.

Through a series of examples I will look at how combining multiscale, multimodal and time lapse information can help us to investigate a very wide range of phenomena from the pupation of butterflies and the self-healing of ceramics, to corrosion and cracking in metals, to the nucleation, growth and accumulation of damage in 3D woven composites.

Challenges and enablers in the development of advanced materials from concept to commercialization

Dr. Debashish Bhattacharjee FNAE

Vice President, Technology and New Materials Business, TATA Steel Limited

There are at least three clearly different phases in the development of materials from concept to commercialization. If the whole journey is defined in technology readiness levels (TRL) with 1 as early concept and 9 as creating value in the market, then TRLs 1 to 3 constitute the laboratory phase. This phase sees a divergence of ideas, small scale experimentation and acquisition of deep understanding. TRLs 4-6 represent scaling up by around 5-10x of some of the successful experimental routes to be tried at pilot scale. Taking the material or product to market at this stage will be fraught with technology risk and will be commercially sub-optimal. However, this stage serves as a valuable proof of concept on effect of upscaling. TRLs 7 to 9 represent further scaling up by around 5-10x of a very limited number of routes and testing the final product in the market. The nature of infrastructure, ecosystem, capabilities, funding and leadership need to be different at each stage. While TRLs 1-3 are generally academia led, needing fundamental research infrastructure and capabilities, TRLs 7-9 need to be industry led with a clear view to application in the market. The amount of development funds needed in the latter stages of TRLs are an order of magnitude higher than needed in the early stages. Successful and timely commercialization of new materials needs the differences at different TRLs to be recognized, and policies to be set to enable through-TRL view of development and close partnership of academia, industry and government.

A through-TRL view comprises multiple factors: (i) focus on possible application that has a large impact on society, such energy and materials conservation, decreasing environmental footprint and addressing a country’s strategic needs, etc. This focus runs as a thread through the development process. (ii) Government funding at different TRLs should ensure continuity of thought from concept to commercialization around the focus areas in the grant proposals. (iii) At low TRLs, the grants can be many but smaller in amounts while at the high TRLs, the grants can be limited in number, but need to be high in amount. Industry needs to be incentivized to take the risk of investing in a new material and product. (iv) Grants for development projects should ensure adequate capability and ecosystem development across the TRLs to ensure the valleys of death at the critical up-scaling points are bridged effectively.

The talk will give examples from materials development across centuries, covering steel production in 1850s through carbon fibre composites in 1950s to graphene in early 2000s and many others in between. The talk will show how lack of ecosystem thwarts a perfectly good technology and material and how focused market pull concentrates resources and accelerates materials development over the valleys of death. A through TRL view is vital.