ASME

SETTING THE STANDARD

MATERIALS DIVISION

100th Anniversary

TSU-WEI CHOU
Honorary Member

Tsu-Wei Chou, Ph.D., the pierre s.du Pont chair of engineering at the University of Delaware, is honored for pioneering and formative research in functional composite materials for energy storage, electromagnetic wave interference shielding, and 4D-printing, as well as contributions to mechanical engineering education, mentoring, and sustained service to the international composite community.

Dr. Chou's recent work, particularly in carbon nanotube- and graphene-based continuous fibers and films, and nanocarbon-based supercapacitors as flexible energy storage devices, has established him as a world leader in his fields.

Dr. Chou has received three ASME awards: the Charles Russ Richards Memorial Award in 1996, the Worcester Reed Warner Medal in 2002, and the Nadai Medal in 2013. He was named an ASME Fellow in 1998.

A prolific author, Dr. Chou's pivotal paper, published in *Advanced Energy Materials* in 2014, was the first to demonstrate that a stretchable wire-shaped supercapacitor based on continuous carbon nanotube fibers offers a unique combination of electrochemical performance and mechanical durability. His paper in *Carbon* on electromagnetic wave interference shielding verifies the superb potential of nanocarbon materials for EM wave absorption and protection of portable electronics and wireless devices. His formative paper in *Composites Science and Technology* on additive manufacturing demonstrates comprehensive design and additive manufacturing of 3D orthogonal fiber preforms for composites.

Dr. Chou was among the first to recognize the opportunities of the strength and damage tolerance of laminates in the through thickness direction. This led to his pioneering contributions to the engineering science of textile structural composites.

He was named 34th among the top 100 materials scientists in the world between 2000-2010 by Times Higher Education. Dr. Chou has received numerous other awards. He received a B.S. from National Taiwan University in 1963, an M.S. from Northwestern University in 1966, and a Ph.D. from Stanford University in 1969.

From Mechanics of Materials to Mechanomaterials: a Perspective

Huajian Gao
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Nanyang Technological University
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Scientific Director
Institute of High Performance Computing, A*STAR

Abstract

The classical subject of mechanics of materials has been extensively implemented in developing structural and functional materials, giving rise to recent advances in nanostructured materials, biomedical materials, mechanical metamaterials, soft actuators, flexible electronics, tunable mechanochromics, regenerative mechanomedicine, etc. While conventional mechanics of materials offers passive access to mechanical properties of materials in existing forms, a paradigm shift, referred to as mechanomaterials, is emerging toward proactive programming of materials' property and functionality during the manufacturing process by leveraging the force–geometry–property relationships. Here, we provide a couple of recent examples that illustrate this emerging paradigm, which include the designs of fatigue resistant metals via a nanotwinned microstructure, deformable micro-/nanolattices and acellular epicardial patches for the treatment of myocardial infarction.

Brief Biography

Huajian Gao received his B.S. degree from Xian Jiaotong University in 1982, and his M.S. and Ph.D. degrees in Engineering Science from Harvard in 1984 and 1988, respectively. He served on the faculty of Stanford from 1988-2002, as Director at the Max Planck Institute for Metals Research from 2001-2006 and as Walter H. Annenberg Professor of Engineering at Brown from 2006-2019. At present, he is one of 6 Distinguished University Professors at Nanyang Technological University and Scientific Director of the Institute of High Performance Computing in Singapore.

Professor Gao's research has been focused on the understanding of basic principles that control mechanical properties and behaviors of materials in both engineering and biological systems. He is the Editor-in-Chief of Journal of the Mechanics and Physics of Solids. His list of honors includes election to National Academy of Sciences and National Academy of Engineering, and numerous awards such as the Timoshenko and Nadai Medals from ASME.

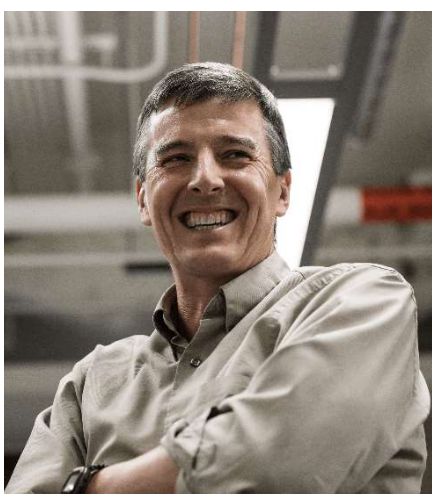
Mechanics, Materials and the Metaverse

John A. Rogers
Northwestern University

Abstract

Advanced, immersive systems for virtual and augmented reality (VR/AR) promise to transform the way that we interact with computer-generated environments and, by extension, with one another. Although audio-visual aspects of VR/AR hardware are increasingly well developed, a frontier, underexplored opportunity is in the development of interfaces that add spatio-temporally controlled physical sensations to the VR/AR experience, where the skin, including but not limited to the fingertips, serves as the input interface. This talk introduces a collection of foundational ideas in mechanics and materials that build on work in skin-integrated electronics for health monitoring, to enable a unique, new class of technology for this purpose – thin, soft, lightweight sheets that embed wirelessly controlled arrays of millimeter-scale vibro-haptic actuators, capable of gently laminating onto the skin at nearly any region of the body. These systems qualitatively expand the VR/AR interface through complex patterns of physical sensory inputs, time-coordinated with visual and auditory cues. The latest systems and examples in social media, medicine, rehabilitation, gaming, entertainment and navigation will be presented.

Brief Biography



John A. Rogers is the Louis Simpson and Kimberly Querrey Professor of Materials Science and Engineering, Biomedical Engineering and Medicine at Northwestern University, with affiliate appointments in Mechanical Engineering, Electrical and Computer Engineering and Chemistry, where he is also Director of the Querrey Simpson Institute for Bioelectronics. He has published more than 800 papers, he is a co-inventor on more than 100 patents and he has co-founded several successful technology companies. His research has been recognized by many awards, including a MacArthur Fellowship (2009), the Lemelson-MIT Prize (2011), the Smithsonian Award for American Ingenuity in the Physical Sciences (2013), the Nadai Medal (2018), the Benjamin Franklin Medal (2019), the Sigma Xi Monie Ferst Award (2021) and a Guggenheim Fellowship (2021). He is a member of the National Academy of Engineering, the National Academy of Sciences, the National Academy of Medicine, the National Academy of Inventors and the American Academy of Arts and Sciences.

Full-Field Methods for Characterizing Soft Tissues

Ellen M. Arruda
Department of Mechanical Engineering, University of Michigan

Abstract

Soft tissues of the body such as ligaments and tendons tend to have irregular shapes and attachment sites to bones and muscles (entheses and myotendinous junctions). As a result, they deform heterogeneously throughout their volumes, and accurate computational modelling of their mechanical response requires the ability to access the full-volume, finite deformation maps under applied loads. Moreover, these full-volume deformation fields enable characterization of the non-linear, anisotropic response with a limited number of experiments, particularly when all components of the resulting strain tensor are non-zero and finite. We obtain full-field displacement data directly from the phase signal of the magnetic resonance imaging of soft materials such as the anterior cruciate ligament (ACL) of the knee and the supraspinatus tendon (rotator cuff) of the shoulder using a custom built in-situ loading apparatus. The in-situ MRI approach to understanding the mechanical properties of soft tissue is a finite deformation, full-volume technique. No contrast agents or other fiducial markers that could interfere with the mechanics of the tissue are needed for this method. We use these data with the applied traction boundary conditions and inverse computational methods to characterize the mechanical properties of the tissue. Two methods have been explored to do this, the virtual fields method in which the form of the constitutive model is chosen a priori, and the variational system identification method in which the form of the model is learned through an iterative process. Once the tissue is characterized we develop a finite element (FE) model of it to simulate the experiment and compare the predictive capability of our approach. The heterogeneous displacement fields throughout the interior of the ACL bundles demonstrate that uniform axial loading assumptions cannot be used in the characterization of these soft tissues. Full-field methods are needed and greatly enhance our ability to characterize the mechanics of soft tissues, a critical step on the path to computational models of joints (such as the knee) needed to predict injurious events.

Brief Biography

Professor Ellen M Arruda is the Tim Manganello / BorgWarner Department Chair and Maria Comninou Collegiate Professor of Mechanical Engineering at the University of Michigan. She also holds appointments in Biomedical Engineering and in Macromolecular Science and Engineering. She received her BS and MS degrees from Penn State and her PhD from MIT. She joined the UM faculty in 1992. Professor Arruda teaches and conducts research in the areas of theoretical and experimental mechanics of macromolecular materials, including polymers, elastomers, composites, soft tissues and proteins. Her research programs include experimental characterization and analytical and computational modeling of soft materials, including native and engineered tissues. Her polymer mechanics work has focused on the mechanics of these highly strain rate and temperature dependent materials with emphasis on the relationships among the structures at various length scales to the deformation mechanisms of those structures to predict the mechanical responses. More recently she has pioneered efforts to characterize the complex mechanical responses of soft tissues such as ligaments and tendons via full-volumetric-field methods. She is a Fellow of ASME, SES, AAM, and AIMBE and a member of the National Academy of Engineering.

Mechanics-guided 3D assembly of complex mesostructures and functional devices

Yonggang Huang
Departments of Civil and Environmental Engineering, Mechanical Engineering, and Materials Science and Engineering, Northwestern University, Evanston, IL, 60208, USA.

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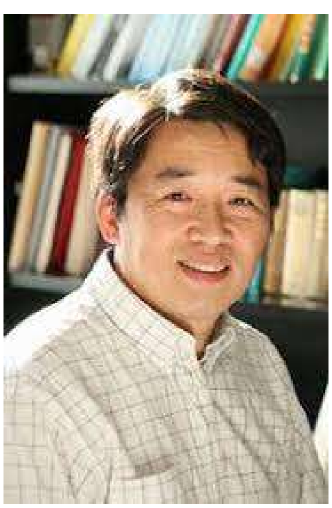
Abstract

A rapidly expanding research area involves the development of routes to complex 3D structures with feature sizes in the mesoscopic range (that is, between tens of nanometres and hundreds of micrometres). A goal is to establish methods to controll the properties of materials systems and the function of devices constructed with them, not only through chemistry and morphology, but also through 3D architectures. Hwever, existing approaches of 3D assembly/fabrication are only compatible with a narrow class of materials and/or 3D geometries. In this talk, I will introduce a mechanics-guided assembly approach that exploits controlled buckling for constructing complex 3D micro/nanostructures from patterned 2D micro/nanoscale precursors that can be easily formed using established semiconductor technologies. This approach applies to a very broad set of materials (e.g., semiconductors, polymers, metals, and ceramics) and even their heterogeneous integration, over a wide range of length scales (e.g., from 100 nm to 10 cm). To enrich the class of 3D geometries accessible to the proposed assembly approach, we devised a set of mechanics-driven design strategies, such as kirigami/origami designs of 2D precursors, heterogeneous substrate designs and loading-path controlled shape morphing strategies. I will also introduce a series of mechanics models for the direct postbuckling analysis, as well as inverse design methods that map target 3D topologies onto unknown 2D precursor patterns, which could provide an important theoretical foundation of the rational 3D assembly. The compatibility of the approach with the state-of-the-art fabrication/processing techniques, along with the versatile capabilities, allow transformation of diverse existing 2D microsystems into 3D configurations, providing unusual design options in the development of novel functional devices. I will demonstrate a few examples in this presentation, including biomedical devices conformally integrated with organoids/tissues/organs, 3D MEMS capable of efficient energy harvesting of low-frequency vibration, bioinspired electronic systems, and 3D microfluidic devices.

Brief Biography



Yonggang Huang is the Jan and Marcia Achenbach Professor at Northwestern University. He is interested in mechanics of stretchable and flexible electronics, and mechanically guided deterministic 3D assembly. He is a Highly Cited Researcher in Engineering (2009), Materials Science (since 2014), and Physics (2018). He is a member of the US National Academy of Engineering, US National Academy of Sciences, and a fellow of American Academy of Arts and Sciences. His recent research awards include the Drucker Medal (2013), Nadai Medal (2016), Thurston Lecture Award (2019), and Honorary Membership (2021) from the American Society of Mechanical Engineers (ASME); Prager Medal (2017) from the Society of Engineering Sciences; Bazant Medal (2018) and von Karman Medal (2019) from the American Society of Civil Engineers. He has also received awards and recognitions for undergraduate teaching and advising from University of Arizona (1993), University of Illinois at Urbana-Champaign (2003, 2004, 2005, 2006, and 2007), and Northwestern University (2016, 2018, 2020).

Gradient Enhanced Physically Based Plasticity with Size Effects: Crystal Plasticity to Gradient Continuum Plasticity

George Voyiadjis
Louisiana State University

Abstract

A physics-based crystal plasticity is presented with evolution relations for dislocation densities to assess the understanding of nonlocal behavior of metals at the microlevel. It incorporates length-scales in conjunction with evolution equations of dislocation densities. It is applied to compression of micropillars with showing the relationship between complicated dislocation patterning. This work develops a nonlocal continuum theory to address the plasticity and heat transfer behavior of metallic materials of small volumes in fast transient times. Over the size scale range in which most of the experiments have been conducted, the number of dislocations is generally so large that a continuum formulation is required to describe the deformation. The thermodynamically consistent strain gradient plasticity (SGP) model is developed to investigate the size effects and mesh-dependency of the material behavior. The proposed model is conceptually based on the dislocation interaction mechanisms and thermal activation energy. This work addresses phenomena such as size and boundary effects and in particular microscale heat transfer in fast-transient processes. Not only the partial heat dissipation caused by the fast transient time, but also the distribution of temperature caused by the transition from the plastic work to the heat, are included into the coupled thermo-mechanical model by deriving a generalized heat equation. The derived constitutive framework and the corresponding finite element models are validated through the comparison with the experimental observations conducted on micro-scale thin films. The proposed model is first applied to the stretch-surface passivation problem for investigating the material behavior under the non-proportional loading condition in terms of the stress jump phenomenon, which causes a controversial dispute in the field of strain gradient plasticity theory with respect to whether it is physically acceptable or not. Finite element implementation for small deformation is performed to investigate the size effects and the grain boundary effect of small-scale metallic materials. The size effects during hardening as well as the mesh-sensitivity during softening are studied by solving the shear band problem.

Brief Biography

Voyiadjis began his career at LSU in 1980 as an assistant professor after receiving his master's in civil engineering from the California Institute of Technology and PhD in engineering mechanics from Columbia University. His research is on multi-scale modelling of size effects in materials, encompassing macro-mechanical and micro-mechanical constitutive modelling, experimental procedures for quantification of crack densities, thermal effects, interfaces, failure, fracture, impact, and defect nucleation and evolution. He is a Foreign Member of the Academia Europaea, the European Academy of Sciences, the European Academy of Sciences and Arts, the Polish Academy of Sciences, and the National Academy of Engineering of Korea. He received the 2008 Nathan M. Newmark Medal of the American Society of Civil Engineers, the 2012 Khan International Medal for outstanding life-long Contribution to the field of Plasticity, and the Damage Mechanics Medal from the 2nd International Conference on Damage Mechanics (ICDM2) in 2015. He has two patents, over 370 referred journal articles and 23 books (12 as editor). He gave over 430 presentations as plenary, keynote and invited speaker as well as other talks. He has secured more than $40 million in research funds from the NSF, the DoD, the AFOSR, the Louisiana Department of Transportation and Development, NASA, NOAA, and major companies such as IBM and Martin Marietta.

Machine Learning for the Experimental Mechanics of Structural Materials

Samantha Daly
Department of Mechanical Engineering
University of California, Santa Barbara

Abstract

This talk will discuss some of the core opportunities and challenges at the intersection of machine learning and experimental mechanics. The application of data-driven and machine learning approaches to the mechanics of structural materials under a range of representative applications will be discussed, largely in the context of enabling high throughput experimentation and analysis, and in enabling new modes of structural health monitoring. Examples will include i) the use of spectral clustering to identify damage mechanisms from their acoustic emission spectra in ceramic matrix composites for the first time; ii) addressing the pervasive data scarcity problem by using generative adversarial networks in the synthesis of realistic morphologies for high throughput predictive simulations; (iii) addressing the spatial and temporal resolutions of limited experimental data that is vital to our understanding of material response, by adapting physics-informed superresolution approaches to materials data structures; and (iv) the high-throughput segmentation, identification, and analysis of the relationships between microstructure and deformation mechanisms.

Brief Biography

Samantha (Sam) Daly is a Professor in the Department of Mechanical Engineering at UCSB. She received her Ph.D. from Caltech in 2007 and subsequently joined the University of Michigan, where she was on the faculty until 2016 prior to her move to UCSB. Her research interests lie at the intersection of experimental mechanics, materials science, and data science. Currently, the group is engaged in the development of new methods of multi-scale material characterization and analyses via machine learning to understand the deformation and failure of advanced structural materials. Prof. Daly is a Fellow of The American Society of Mechanical Engineers (ASME).

Crystallographic Slip, cracking and kinking in atomically layered ternary carbides

Ankit Srivastava
Department of Materials Science and Engineering, Texas A&M University

Abstract

A family of atomically layered ternary carbides and nitrides with a combination of strong intralayer and weak interlayer atomic bonds, referred to as MAX phases, possess unique set of properties. These are lightweight, elastically stiff, thermodynamically stable and refractory, like ceramics, but are also thermal and electrical conductor, thermal shock resistant, damage-tolerant and readily machinable, like metals. Herein, we aim to better understand the single crystal level mechanical response of MAX phases to unravel the nature and origin of their unique set of properties, in particular, their damage-tolerance. To this end, we first characterize the mechanical response of single crystals of MAX phases using compression testing of micropillars with a range of crystallographic orientations. Our results show that MAX phases undergo non-Schmid crystallographic slip. Furthermore, depending on the crystallographic orientation, the micropillars of MAX phases either undergo only crystallographic slip, crystallographic slip followed by cleavage cracking or cleavage cracking without any appreciable amount of crystallographic slip. The non-Schmid crystallographic slip in MAX phases is also found to be sensitive to their atomic stacking. These micropillar experiments are then complemented with crystal plasticity finite element analysis using a novel constitutive model that accounts for the non-Schmid effects on the crystallographic slip. Next, using an in-house designed and build fixture we carried out in situ SEM mechanical testing of carefully grown single crystals of these materials. The results of this exercise show that even though MAX phases readily crack along the weakly bonded crystallographic planes, onset of an abstruse mode of deformation, referred to as kinking in these materials, induces large crystallographic rotations and plastic deformation that physically heal the cleavage cracks. As a whole, these results explain the puzzling observation that MAX phases, instead of undergoing catastrophic fracture, demonstrate unconventional damage tolerance.

Brief Biography

Ankit Srivastava is currently an Associate Professor in the Department of Materials Science and Engineering at Texas A&M University. He was a postdoctoral research associate at Brown University from 2013-2015. He completed his graduate studies from University of North Texas during which he received two MS degrees, one in Materials Science and Engineering and another in Physics along with his Ph.D. in Materials Science and Engineering in 2013. Prior to starting his graduate studies, he worked at Bhabha Atomic Research Centre in India. His research interests lie within Mechanics of Materials with a strong focus on understanding deformation and failure mechanisms of structural materials using computational and experimental methods of Solid Mechanics and Materials Science. He is a recipient of 2016 ACS-PRF Doctoral New Investigator award, 2017 Haythornthwaite foundation research initiation award from Applied Mechanics Division of ASME, 2020 NSF CAREER award, 2022 and 2021 AISI finalist medals, and 2022 TMS-AIME Robert Lansing Hardy award.

ASME Materials Division Centennial Celebration Program At-A-Glance

IMECE 2022 (Columbus, OH)

Monday, October 31, 2022

4:00–6:30 pm	**Material Division Centennial Celebration Symposium – Materials Past, Present, and Future (MD-CCS)** Pheoris West BC Third Fl., Hilton Hotel Speakers: Huajian Gao, John Rogers, Ellen Arruda, and Yonggang Huang

Tuesday, November 1, 2022

9:15–10:00 am	Materials Division Plenary #1 (Julia Greer, Caltech) Room A212/213, Columbus Convention Center
3–4:45 pm	**Materials Division Awards Event and Reception** Gina Knee Fourth Fl., Hilton Hotel
3:00–3:05 pm	Presentation of Materials Division Journal of Engineering Materials and Technology Orr Best Paper Award (Ala Qattawi et al., University of Toledo)
3:05-3:35 pm	Sia Nemat-Nasser Early Career Award Lecture (Ankit Srivastava, TAMU)
3:35–4:05 pm	Centennial Mid-Career Award Lecture (Samantha Daly, UCSB)
4:05–4:50 pm	Nadai Medal Lecture (George Voyiadjis, LSU)
5:00-6:30 pm	**Materials Division Reception** Gina Knee Fourth Fl., Hilton Hotel (Light cold and hot appetizers, drink tickets will be distributed)

Wednesday, November 2, 2022

9:45–10:30 am	Materials Division Plenary #2 (Cate Brinson, Duke University) Room A212/213, Columbus Convention Center
2–3:30 pm	Materials Division General Meeting (open) Charles Massey B Third Fl., Hilton Hotel

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Material Division Centennial Celebration Symposium – Materials Past, Present, and Future (MD-CCS)

4:00–6:30 pm, Monday October 31, 2022
Pheoris West BC Third Fl., Hilton Hotel

- 4:00-4:05: Introduction (Min Zhou)
- 4:05-4:10: Presentation of Honorary Member Award
  Tsu-Wei Chou, University of Delaware
- 4:10-4:45: From Mechanics of Materials to Mechanomaterials: A Perspective
  Huajian Gao, Nanyang Technological University
- 4:45-5:20: Mechanics, Materials and the Metaverse
  John Rogers, Northwestern University
- 5:20-5:55: Full-field methods for characterizing soft tissues
  Ellen Arruda, University of Michigan
- 5:55-6:30: Mechanics-guided 3D assembly of complex mesostructures and functional devices
  Yonggang Huang, Northwestern University
- 6:30 Conclusion

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100th Anniversary

ASME Materials Division Technical Committee Meetings at IMECE 2022

- Monday 10/31 3-4 pm, Charlie Owens Third Fl., Hilton Hotel
  Nanomaterials for Biology and Medicine Technical Committee Meeting

- Monday 10/31, 7-8 pm, Kimpton Boardroom Fourth Fl., Hilton Hotel
  Nano Materials for Energy Technical Committee Meeting

- Monday 10/31 7-8:30 pm, Charlie Owens Third Fl., Hilton Hotel
  Composites and Heterogeneous Materials Technical Committee Meeting

- *Monday 10/31, 8-9 pm, Dorothy Barnes Fifth Fl., Hilton Hotel*
  Multifunctional Materials Technical Committee Meeting

- Tuesday 11/1, 2-3 pm, Dorothy Gil Barnes Fifth Fl., Hilton Hotel
  AMD/MD Joint Committee on Constitutive Equations Technical Committee Meeting

- Tuesday 11/1, 6-7:30 pm, Charlie Owens Third Fl., Hilton Hotel
  Design of Engineering Materials Technical Committee Meeting

- Tuesday 11/1, 6:30-7:30 pm, William Hawkins Tower 1 Lobby Level, Hilton Hotel
  Materials Processing Technical Committee Meeting

- Tuesday 11/1, 6:30-7:30 pm, Edward Parker Hayden Tower 1 Lobby Level, Hilton Hotel
  Electronic Materials Technical Committee Meeting

- Wednesday 11/2. 3:45-5:15 pm, Amy Kimpton Fourth Fl., Hilton Hotel
  Materials Division Executive Committee Meeting (closed)