

**NSF Summer Institute Short Course on Mechanics of Soft Materials**

Co-sponsored by

**Int. Union of Theoretical & Applied Mechanics and US National Committee of Theoretical and Applied Mechanics**

Organizers: Yonggang Huang and Wing Kim Liu, Northwestern University

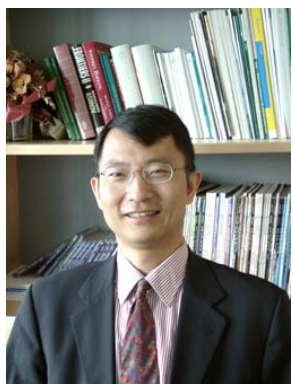
Hilton Garden Inn, 1818 Maple Avenue, Evanston, Illinois, 60201

Dates: **May 10** (Monday) morning to **May 12** (Wednesday) morning **2010**

**Lecturers**



**Zhigang Suo** is Allen E. and Marilyn M. Puckett Professor at Harvard University. He earned a Ph.D. degree in Engineering Science from Harvard University in 1989. His research centers on the mechanical behavior of materials and structures. Basic processes include fracture, deformation, polarization, and diffusion, driven by various thermodynamic forces (e.g., stress, electric field, electron wind, chemical potential). Applications are concerned with microelectronics, large-area electronics, soft materials, and active materials. His work has been highly cited, and has impacted many disciplines in engineering, ranging from mechanics to materials science to microelectronics. He is a co-founder of iMechanica ([www.imechanica.org](http://www.imechanica.org)), the web of mechanics and mechanician, which has more than 10,000 registered members and numerous readers. He is a member of the Executive Committee (2005-2010) of the Applied Mechanics Division, of the American Society of Mechanical Engineers (ASME), and is a member at large of the US National Committee on Theoretical and Applied Mechanics (2006-2010). He is a recipient of the Research Award from the Alexander von Humboldt Foundation (Germany), and Pi Tau Sigma Gold Medal and Young Investigator Medal in Applied Mechanics, both from ASME. He is a member of the US National Academy of Engineering.



**Huajian Gao** is Walter H. Annenberg University Professor at Brown University. He earned a Ph.D. degree in Engineering Science from Harvard University in 1988. His research centers on adhesion mechanisms of hard and soft materials, focusing on the understanding of basic principles that control mechanical properties and behaviors of materials in both engineering and biology. He studies how metallic and semiconductor materials behave in thin film, nanocrystalline and amorphous forms, and how biological materials such as bone, gecko and cell achieve their mechanical functions through structural hierarchy. His research results have been published in top international journals including JPMPS, Nano Letters, Nature, PNAS, PRL and Science. He is one of the two editors-in-chief of the most important mechanics journal, Journal of the Mechanics and Physics of Solids. He is a member of the Executive Committee (2010-2015) of the Applied Mechanics Division, of the American Society of Mechanical Engineers (ASME), is a member of the US National Committee on Theoretical and Applied Mechanics (since 2008), and is on the board of directors for the Society of Engineering Science (SES). He is a recipient of the Research Fellowship from Alexander von Humboldt Foundation, Guggenheim Fellowship from John Simon Guggenheim Foundation, Young Investigator Medal from SES, and Thurston Lecture Award, Melville Medal, and Young Investigator Award in Applied Mechanics, all from ASME.



**John Rogers** is Lee J. Flory Founder Chair in Engineering Innovation, University of Illinois. He earned a Ph.D. degree in Physical Chemistry from Massachusetts Institute of Technology in 1995, and was a Junior Fellow in the Harvard University Society of Fellows from 1995 to 1997. His research includes fundamental and applied aspects of nano and molecular scale fabrication as well as materials and patterning techniques for unusual format electronic and photonic systems. He seeks to understand and exploit interesting characteristics of soft materials, such as polymers, liquid crystals, and biological tissues, as well as hybrid combinations of these with unusual classes of inorganics, such as nanoribbons, wires, and platelets. The aim is to control and induce novel electronic and photonic responses in these materials; he also develops new soft lithographic and biomimetic approaches for patterning them and guiding their growth. His current research focuses on soft materials for flexible macroelectronic circuits, nanophotonic structures, microfluidic devices, and microelectromechanical systems. He is co-inventor on >70 patents and patent applications, more than 40 of which are licensed or in active use by large companies and startups. He has published in top international journals (e.g., Nature, Nature Materials, Nature Nanotechnology, Nature Photonics, PNAS, Science). He is selected as one of the Top 100 Young

Innovators (1999), and twice for one of 10 Technologies That Will Change the World (2004, 2006) by MIT Technology Review magazine, Best of the Best new Technology by R&D Magazine (2001), one of the Top 50 Research Leaders by Scientific American (2005), one of the Top 15 Innovators in Nanotechnology by NASA Technology Briefs (2006), and one of the 10 Coolest Technologies That You've Never Heard Of by PC Magazine (2006). He is a recipient (twice) of the R&D100 Innovation Award (2001,2002), American Chemical Society Award for Team Innovation (2002) and Baekeland Award (2007), National Security Science and Engineering Faculty Fellowship from Department of Defense (2009), and MacArthur Foundation Fellowship (2009). He is Fellow of American Physical Society (2006), the Materials Research Society (2007), the American Association for the Advancement of Science (2008), and the Institute of Electrical and Electronic Engineers (2009).



**Yonggang Huang** is Joseph Cummings Professor at Northwestern University. He earned a Ph.D. degree in Engineering Science from Harvard University in 1990, and was a postdoctoral research fellow from Harvard University from 1990-1991. His research centers on deformation and properties of materials and structures across multiple length scales. His recent research focuses on material systems consisting of both soft and hard materials, which have many applications such as stretchable electronics, flexible silicon-based solar cells, and curvilinear electronics for human health monitoring. His research results have been published in top international journals (e.g., JMPS, Nano Letters, Nature, Nature Materials, Nature Nanotechnology, PNAS, PRL, Science). His collaborative work with John Rogers (University of Illinois) has been widely reported by media (e.g., ABC, BBC, Boston Globe, Chicago Tribune, Discover, MSNBC, New York Times, Newsweek, Reuters, United Press International, and US News & World Report). He is a recipient of the Research Fellowship for US Scientists and Scholars from Alexander von Humboldt Foundation, Guggenheim Fellowship from John Simon Guggenheim Foundation, Young Investigator Medal from SES, IJP Medal, Larson Award and Melville Medal from ASME, and Honorary Professorship from Nanjing University of Posts and Telecommunications, China. He is selected by Thomson-Reuters as an ISI Highly Cited Researcher in Engineering.

## Course Organization

The short course will cover mechanics of soft materials, including soft active materials, adhesion of soft materials including biomaterials and bio-inspired materials, applications of soft materials, and hybrid soft/hard materials. The short course will be divided into 5 blocks of 3 mornings (8:30am-12:00noon, starts at 8:00am the first day) and 2 afternoons (1:00pm-5:30pm).

## Course Description

### Soft Active Materials (4 hours)

Soft materials, such as elastomers and gels, can be made active in that they can undergo large deformation in response to diverse stimuli, including force, voltage, temperature, pH, salinity, and trace amount of enzymes. For example, an elastomer may strain more than 100% under a voltage. As another example, a gel can imbibe a large quantity of solvent and swell thousand times its initial volume. These soft active materials are ubiquitous in tissues of animals and plants, and are exploited in creating familiar commercial products such as contact lenses and superabsorbent diapers. Intense efforts are being devoted to developing these materials for applications such as drug delivery, tissue engineering, soft robots, adaptive optics, self-regulating fluidics, and programmable haptic surfaces.

Professor Suo will teach the theory of soft active materials, relating nonlinear continuum mechanics to thermodynamics of multiple driving forces and kinetics of molecular processes. The theory addresses commonly asked questions. How do non-mechanical stimuli such as pH and salinity generate deformation and force? How do deformation and mass transport couple? What is the maximal energy that a material can convert from one form of energy to another? How might we exploit instabilities associated with large deformation? The theory is related to phenomena in nature and engineering, as well as to ongoing experimental and computational work.

### Adhesion of Soft Materials (4 hours)

Adhesion of soft materials plays a central role in understanding biological functions such as tissue engineering, cell-tissue interactions and cellular functioning, as well as in a broad range of technological applications of soft materials that are emerging in nanotechnology and nanomedicine. Unlike adhesion of hard materials which are commonly described in engineering by JKR and DMT type models, the exact nature and mechanism of adhesion in soft materials are far from understood. Apart from the passive adhesion mechanisms which are still of high interest to various technological applications, a more interesting aspect of adhesion in soft materials is that such adhesion can be highly specific and actively controlled through mechanical activation. For example, cells are known to mechanically probe and feel their surrounding

microenvironment, and respond to the presence of external stresses via localized focal adhesions. The focal adhesions can be dynamically assembled or disassembled through ATP modulated contractile forces in the cytoskeleton. Understanding the mechanical properties, activation of soft materials and control of their interactions with substrate/matrix is a central question not only of importance to biomedical applications from wound healing, muscle growth, tissue assembly, and embryonic development, but also to newly emerging nano- and micro-devices based on soft material assembly. A capability to control adhesion in soft materials, for which a quantitative description of such phenomenon is a critical step, is essential for tissue and cellular engineering as well as nano- and micro-devices engineering.

Professor Gao will teach adhesion in a range of systems involving cells, membranes, biological tissues on substrates, with length scales from molecules to continuum. These include adhesion control at the small scale for a range of systems such as clustering instability in adhesive contact via diffusive molecular bonds, robust and reversible adhesion in biology, mechanics of hierarchical adhesion structures in biology and modeling receptor-mediated uptake and release of viruses and nanoparticles. His lecture will also cover a series of recent studies aimed to probe mechanical principles of focal contacts in cell-substrate adhesion with stochastic-elastic models in which stochastic dynamics of molecular bonds and continuum descriptions of interfacial tractions and separations are unified in the same theoretical framework.

### Applications of Soft Materials (4 hours)

Soft materials can provide solutions to hard challenges in science and technology. Professor Rogers will describe the applications of soft materials in two parts: (1) techniques for 3D and molecular scale nanofabrication and (2) stretchable electronic, optoelectronic and photovoltaic systems.

#### 1) Soft and Fluidic Approaches to Nanomanufacturing

Progress in nanoscience and technology relies critically on the ability to build structures with nanometer dimensions. Established tools, which have their origins in the microelectronics industry, have drawbacks that limit their use in new fields of study: they require expensive facilities; they have difficulty forming features smaller than ~100 nm; they can pattern directly only narrow classes of specialized polymers; and they can only be applied, in a single step, over relatively small areas on ultraflat substrates. These limitations create opportunities for new methods, ranging from adaptations of conceptually old techniques based on printing, molding and writing, to strategies that rely on bottom-up growth, self-assembly, phase separation and others. This talk describes unconventional approaches to nanomanufacturing, including (1) electrohydrodynamic jet printing techniques, (2) molecular scale and three dimensional soft lithographic methods and (3) soft transfer printing schemes for heterogeneous materials integration. The underlying scientific principles of these procedures will be discussed, along with representative engineering aspects of application in plasmonic and photonic systems.

#### 2) Materials for Stretchable Electronics: From Hemispherical Digital Imagers to Devices for Cardiac Electrophysiology

Electronic/optoelectronic systems that involve transistors, solar cells, light emitting diodes (LEDs) and other components on thin plastic or rubber substrates offer mechanical properties (e.g. stretchability) and other features (e.g. curvilinear shapes) that cannot be achieved with conventional approaches. Examples of application possibilities include devices that use biologically inspired designs or those that require intimate integration with the human body. This talk describes the combined use of polymers and inorganics in systems that offer the performance of state-of-the-art, wafer-based technologies but with the mechanical properties of a rubber band. We explain the materials science and mechanics of these approaches, and aspects of their use in various applications. Cardiac and brain monitoring devices provide examples in biomedicine; hemispherical electronic eye imagers illustrate the capacity for bio-inspired device design.

### Hybrid Soft/Hard Materials (4 hours)

Biology is soft, elastic and curved; silicon wafers are not. A future electronics technology that overcomes this fundamental mismatch in mechanics and form will enable applications that are impossible to achieve with hard, planar integrated circuits that exist today. Examples range from surgical and diagnostic implements that seamlessly integrate with the human body to provide advanced therapeutic capabilities, to cameras that use biologically inspired designs to achieve superior performance. Sensory skins for robotics, structural health monitors, wearable communication devices and other systems that require lightweight, rugged construction in thin, conformal formats will also be possible. Establishing the foundations for this future in electronics represents an emerging direction for research, much different than the one dictated by Moore's law, in which transistor dimensions relentlessly decrease over time, but the platforms, i.e. the planar surfaces of rigid, brittle silicon wafers, remain the same.

Work toward mechanically unconventional forms of electronics began ~15 years ago with transistors printed on bendable sheets of plastic, where paperlike displays represented the main target application. Many successes have been achieved since that time; several, including displays, are nearing commercial reality. More recently, the scope of research has expanded dramatically to include more compelling, and more technically challenging, opportunities in soft, bio-integrated devices, in curved, bio-inspired designs and in other areas. Here, the electronics must not only bend, but also stretch,



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compress, twist and deform into complex, curvilinear shapes while maintaining levels of performance, reliability and integration that approach those of well developed wafer-based systems. Research in the last few years is beginning to yield the foundations for a realistic technology of this type, capable of simultaneously providing the electronic capabilities of a silicon chip and the mechanical properties of a rubber band.

These technologies always involve soft and hard materials, and their elastic moduli can be different by 5 orders of magnitude. Professor Huang will teach the mechanics theory of hybrid soft/hard materials.

### Course Website

<http://www.tam.northwestern.edu/summerinstitute/links2/courses4.htm>

### Location

The course will be held at Hilton Garden Inn, 1818 Maple Avenue, Evanston, Illinois, 60201.

### Registration Fee

Status	Registration fee	Deadline
Fellowship Application	Covered by NSF	March 1, 2010
Early Registration	\$1,600	March 15, 2010
Registration	\$2,000	April 15, 2010
Late Registration	\$2,200	May 10, 2010

NSF fellowships are available to faculty members, high-school science teachers, post-doctoral fellows and graduate students from the US (see below). A few fellowships are also available for faculty and postdoctoral fellows outside the US. The deadline for fellowship application is **March 1, 2010**.

### Registration

Please register through the NSF Summer Institute website: <http://www.tam.northwestern.edu/summerinstitute>

### Accommodations

A block of rooms has been reserved at special rates for short course attendees at the **Hilton Garden Inn**. Attendees should contact the hotel directly to make reservations by calling 847-475-6400 or through 1-877-STAY HGI or 1-800-HILTONS, to qualify for special rates guests **must** mention "NSF Summer Institute on Mechanics of Soft Materials". The rooms at the **special rate of \$132 will only be held until April 15, 2010**. The website for hotel online reservation is <http://www.hiltongardeninn.com/en/gi/hotels/index.jhtml?ctyhocn=ORDEVGI>; enter dates of stay, click "go", and enter "Group/Convention Code:" MSM. For participants who are receiving fellowship support (see below), we will make reservations on your behalf at double occupancy. If the fellowship recipient wishes to occupy a single room, he/she will be responsible for the difference.

### Fellowships

U.S. professors, high-school science teachers, post-doctoral fellows and graduate students can apply for the NSF fellowship support through the website noted above. There are a few fellowships for professors and postdoctoral fellows outside U.S. Each fellowship award covers the full registration and three-night stay at the Hilton Garden Inn based on double occupancy.

### For additional information, contact:

**Website:** <http://www.tam.northwestern.edu/summerinstitute/links2/courses4.htm>

**Email :** [summerinstitute@mail.mech.northwestern.edu](mailto:summerinstitute@mail.mech.northwestern.edu)