

# Materials Science and Engineering

Robert R. McCormick School of  
Engineering and Applied Science  
Northwestern University

SUMMER 2010

## Greg Olson Elected to National Academy of Engineering



*Greg Olson holds a "Dragonslayer bullet-proof" drive gear used to win the Baja 1000 1600-class event. The top five finishers all used commercial Questek-designed steel gears.*

stainless steel alloy for aircraft landing gears that replaces the cadmium-plated steel, which poses an environmental hazard.

Olson is a fellow of ASM and TMS-AIME, and he has authored more than 200 publications. He received a BS and MS in 1970 and ScD in 1974 in materials science from MIT and remained there in a series of senior research positions before joining the faculty of Northwestern in 1988. Beyond materials design, his research interests include phase transformations, structure/property relationships, and applications of high resolution microanalysis. Recent awards include the ASM Campbell Memorial Lectureship, the TMS-SMD Distinguished Scientist/Engineer Award, and the Cambridge University Kelly Lectureship.

**G**reg Olson, Walter P. Murphy Professor of Materials Science and Engineering, has been elected a member of the National Academy of Engineering. He is cited for his contribution to research, development, implementation and teaching of science-based materials by design.

Olson is considered one of the founders of computational materials design. He developed a systematic science-based approach for designing alloys that takes the desired properties and calculates the optimum composition and processing route.

He directs the Materials Technology Laboratory/Steel Research Group at McCormick, and in 1997, he founded QuesTek Innovations LLC, a materials design company that was selected for Fortune magazine's list of the 25 breakthrough companies of 2005. QuesTek's first creation was a high-performance gear steel that was designed at Northwestern and licensed to the company. That steel has found an unusual market: Baja 1000 racing, where QuesTek's materials have led to better final drive gears for off-road racers, as demonstrated by the top five finishers of the 1600 class for the past several years. The company recently developed a

In addition to Olson, McCormick alumnus Sang Yup Lee was elected to NAE as a foreign member. Lee, currently dean of the College of Life Sciences and Bioengineering at the Korea Advanced Institute of Science and Technology (KAIST), received both his MS ('87) and PhD ('91) from the Department of Chemical and Biological

*Olson developed a systematic science-based approach for designing alloys that takes the desired properties and calculates the optimum composition and processing route.*

Engineering at Northwestern. Lee was cited for leadership in bacterial biotechnology and metabolic engineering, including development of fermentation processes for biodegradable polymers and organic acids.

## New Faculty Profile: Ramille Shah

When Ramille Shah came to the McCormick School of Engineering as an undergraduate in the late 1990s, the civil engineering major got a work study position under Hamlin Jennings, professor of civil and materials science and engineering.

Working in his lab on experiments involving cement, Shah had two thoughts that would shape the rest of her life: she loved research, and she loved working with materials.

“I loved trying to answer questions that no one knew the answers to,” she says. So she switched her major to materials science and engineering and took a class with Samuel Stupp, Board of Trustees Professor of Chemistry, Materials Science and Engineering, and Medicine. That set her on a decade-long trajectory — from McCormick to graduate school at MIT to a postdoctoral fellowship in Stupp’s lab — that landed her back in the Department of Materials Science and Engineering in the fall of 2009 as an assistant professor.

“It’s been a great transition to go from student to professor,” she says. “I know the people here, I know the system — the facilities are state of the art, and the reputation of the MSE department at Northwestern is one of the best. It was an ideal situation for me to have the opportunity to be here.”

Shah is now beginning to establish a lab at the Institute for BioNanotechnology in Medicine at Northwestern (IBNAM) while soliciting teaching advice from other young faculty — “I’m trying to make a fun and effective learning experience for undergrad and grad students,” she says.

Shah’s work in materials science began as an undergraduate, when she worked in Stupp’s lab in tissue engineering. “That was my first taste of biomaterials research,” she says. “The potential to create materials and therapies that can improve the quality of life of patients

*“I was very fortunate to have such wonderful mentors that are now my colleagues,” Shah says. “It’s a cool transition and a real reward for me.”*

really sparked an interest in me.” After graduating from McCormick in 2000, Shah went on to graduate school at MIT, where her research in Myron Spector’s laboratory involved cartilage tissue engineering and delivering genes through collagen scaffolds to stimulate cells into regenerating cartilage.

After earning her PhD in 2006, the Chicago native wanted to return to her hometown. Stupp’s group was working with peptide systems that can self-assemble into nanostructures, and Shah wanted to get a taste of how nanotechnology could contribute to regenerative medicine, so she joined his group as a postdoctoral fellow.

“I was very fortunate to have such wonderful mentors that are now my colleagues,” Shah says. “It’s a cool transition and a real reward for me.”

Now with her own lab, Shah is creating new biomaterials for tissue engineering that target orthopedic tissues like bone, cartilage, meniscus and ligaments. She’s interested in examining plant-based biomaterials for tissue engineering implants because plants, particularly soy, are a sustainable and renewable resource with very interesting thermoplastic qualities.



Shah is also interested in creating hybrid systems that take self-assembling peptide-based materials — materials made up of natural amino acids — and combining them with polymers to create hybrid materials that have specific mechanical and bioactive properties. While working in Stupp’s lab, Shah helped discover a system in which a highly ordered membrane formed at the interface of these two solutions.

“By combining these two different systems, you can change the chemistry and processing variables to alter the resulting hybrid properties,” she says. “My goal is to strengthen the properties of the membrane to create more robust materials for its potential use in more load bearing applications.”

Shah is also interested in mechanically stimulating tissue engineering scaffolds to promote cell and tissue growth. Low-intensity ultrasound has been used as a clinical therapy to accelerate healing (i.e. fractures, tendonitis, and damaged ligaments), and Shah is trying to determine if this treatment can also be used to stimulate the regenerative response of cells in biomaterial scaffolds.

With a joint appointment in the Department of Orthopaedic Surgery in the Feinberg School of Medicine, Shah has the opportunity to work with surgeons, clinicians, and medical students — a collaboration she says is a must in her field.

“In order to create biomaterials and therapies that will work in the clinic, it’s important to have conversations with the surgeons who will implement the technology in surgery,” she says. Her number one collaborator is her husband, Nirav A. Shah, MD, who graduated from McCormick with a biomedical engineering degree and is now a practicing orthopedic surgeon in Palos Heights.

“Through his clinical work and my research experience we continually learn from each other and discuss where new biomaterial technologies can have an impact on current clinical procedures,” she says. “We talk about it over dinner. Not many people can have the type of dialogue we can have on a daily basis. It’s an exciting dynamic that can hopefully lead to new innovations in orthopaedic surgery and tissue engineering.”

## Growing Cartilage — No Easy Task

Northwestern University researchers are the first to design a bioactive nanomaterial that promotes the growth of new cartilage in vivo and without the use of expensive growth factors. Minimally invasive, the therapy activates the bone marrow stem cells and produces natural cartilage. No conventional therapy can do this.

The results were published by the *Proceedings of the National Academy of Sciences (PNAS)*.

“Unlike bone, cartilage does not grow back, and therefore clinical strategies to regenerate this tissue are of great interest,” said Samuel I. Stupp, the paper’s senior author, Board of Trustees Professor of Chemistry, Materials Science and Engineering, and Medicine, and director of the Institute for BioNanotechnology in Medicine (IBNAM).

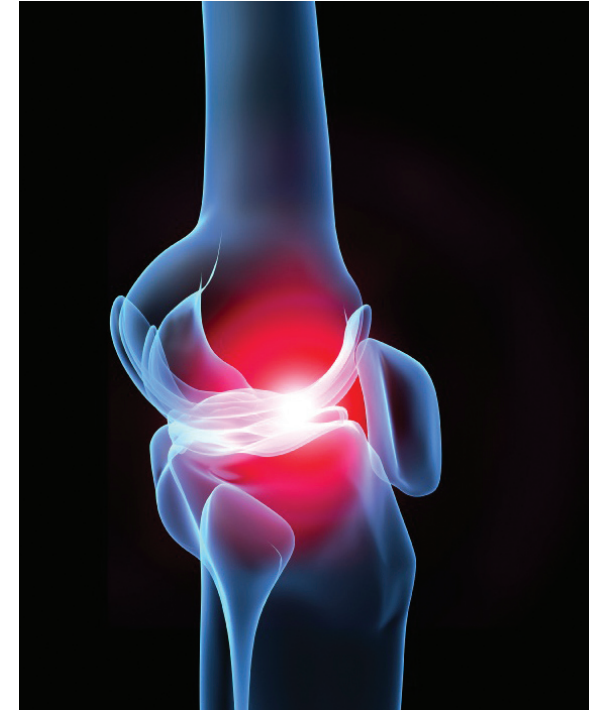
Countless people — amateur athletes, professional athletes and people whose joints have just worn out — learn this all too well when they bring their bad knees, shoulders and elbows to an orthopaedic surgeon.

Damaged cartilage can lead to joint pain and loss of physical function and eventually to osteoarthritis, a disorder with an estimated economic impact approaching \$65 billion in the United States. With an aging and increasingly active population, this figure is expected to grow.

“Cartilage does not regenerate in adults. Once you are fully grown you have all the cartilage you’ll ever have,” said first author Ramille N. Shah, assistant professor of materials science and engineering at McCormick and assistant professor of orthopaedic surgery at the Feinberg School of Medicine. Shah is also a resident faculty member at IBNAM.

Type II collagen is the major protein in articular cartilage, the smooth, white connective tissue that covers the ends of bones where they come together to form joints.

“Our material of nanoscopic fibers stimulates stem cells present in bone marrow to produce cartilage containing type II collagen and repair the damaged joint,” Shah said. “A procedure called microfracture is the most common technique currently used by doctors, but it tends to produce a cartilage having predominantly type I collagen which is more like scar tissue.”



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The Northwestern gel is injected as a liquid to the area of the damaged joint, where it then self-assembles and forms a solid. This extracellular matrix, which mimics what cells usually see, binds by molecular design one of the most important growth factors for the repair and regeneration of cartilage. By keeping the growth factor concentrated and localized, the cartilage cells have the opportunity to regenerate.

In collaboration with Nirav A. Shah, M.D., a sports medicine orthopaedic surgeon who treats athletes of all levels and ages and is a former orthopaedic resident at Northwestern, the researchers implanted their nanofiber gel in an animal model with cartilage defects.

The animals were treated with microfracture, where tiny holes are made in the bone beneath the damaged cartilage to create a new blood supply to stimulate the growth of new cartilage. The researchers tested various combinations: microfracture alone; microfracture and the nanofiber gel with growth factor added; and microfracture and the nanofiber gel without growth factor added.

They found their technique produced much better results than the microfracture procedure alone and, more importantly, found that addition of the expensive growth

factor was not required to get the best results. Instead, because of the molecular design of the gel material, growth factor already present in the body is enough to regenerate cartilage.

The matrix only needed to be present for a month to produce cartilage growth. The matrix, based on self-assembling molecules known as peptide amphiphiles, biodegrades into nutrients and is replaced by natural cartilage.

“The greatest clinical utility of this matrix would be as an adjunct to current minimally invasive surgical techniques,” said Nirav Shah, whose practice is based in Palos Heights, Ill. “Our study illustrates the nanofiber gel’s excellent potential for accelerating rehabilitation and return to function, improving clinical outcomes, and hopefully delaying, if not stopping, the progression of cartilage lesions into painful degeneration and arthritis.”

Further evaluation of the nanomaterial is under way in a larger preclinical study; pending that study’s results, clinical trials would be the next step.

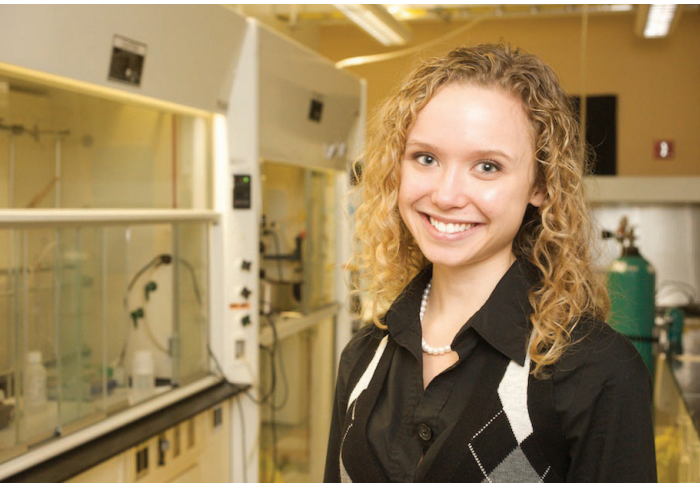
# Materials Science Student Awarded Churchill Scholarship

The Winston Churchill Foundation has awarded Northwestern University senior Kelsey Stoerzinger a Churchill Scholarship to pursue graduate studies at the University of Cambridge. Stoerzinger, the seventh Churchill Scholar from Northwestern, was selected from among 81 nominees for the 14 scholarships available. Eligible universities, consisting of the top schools in the nation, are allowed to nominate only two qualified applicants. Nominees must display high academic achievement and the capacity to contribute to the advancement of knowledge in their field.

“I am beyond ecstatic,” said Stoerzinger, a senior in materials science and engineering in the McCormick School of Engineering and Applied Science and a native of Inver Grove Heights, Minn. “This is a once-in-a-lifetime opportunity on so many fronts. I am looking forward to being part of an international community of scientists at an 800-year-old institution with so much history in physics.”

The Churchill Scholarship provides one year of support for a postgraduate degree in engineering, mathematics or the sciences at Cambridge, including all tuition and fees, airfare and a living allowance. Stoerzinger will be based in the physics department, working toward a research-based Master of Philosophy degree.

For the last two years, since her sophomore year, Stoerzinger has conducted nanoscience research in the lab of Teri W. Odom, Dow Chemical Company Research Professor of chemistry and materials science and engineering. In her work with nanopyramids, Stoerzinger has investigated ways to assemble them in a controlled



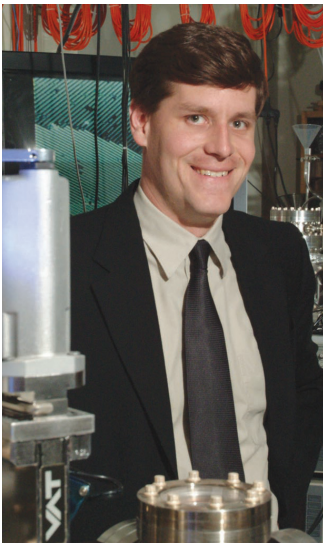
manner and studied how they behave when irradiated with light. She has studied using nanopyramids irradiated with near-infrared light as localized therapeutic agents to help kill breast cancer cells.

“Kelsey is spectacular,” Odom said. “She has been one of the most effective undergraduate students I’ve had in my lab. She is very conscientious and pays attention to details, which is extremely important. Kelsey makes the natural leaps or connections necessary to make progress in research.”

After Cambridge, Stoerzinger plans to return to the United States to pursue a doctoral degree in materials science.

Last summer she interned at Dow Corning Corp. doing research and development work on photovoltaic encapsulants, and she also has interned at General Motors. Stoerzinger plays oboe in Northwestern’s Philharmonia Orchestra and is section leader.

# Mark Hersam Receives Outstanding Young Investigator Award



Northwestern University’s Mark Hersam has been selected to receive the Outstanding Young Investigator Award from the Materials Research Society (MRS). The award was presented in April during the 2010 MRS Spring Meeting in San Francisco.

Hersam is professor of materials science and engineering in the McCormick School of Engineering and Applied Science and professor of chemistry in the Weinberg College of Arts and Sciences.

The award recognizes outstanding, interdisciplinary scientific work in materials research by a young scientist or engineer. The award recipient must also show exceptional promise as a developing leader in the materials area.

Hersam’s citation states that he is being honored for “pioneering research on the physics, chemistry, and engineering of nanoelectronic materials and devices, including solution phase techniques for sorting

carbon nanotubes and graphene, and for organic functionalization and nanopatterning of semiconductor surfaces.”

Hersam and his research group apply the fundamental paradigm of materials science and engineering to hybrid materials at the nanometer level. The research has far-reaching impact in fields such as information technology, biotechnology and alternative energy.

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Hersam’s award marks the third time a Northwestern professor has won the MRS Outstanding Young Investigator Award. Teri Odom, associate professor of chemistry and Dow Chemical Company Research Professor, was honored with the award last year, and Chad Mirkin, George B. Rathmann Professor of Chemistry, was honored in 1999.

# Monica Olvera de la Cruz Honored by Department of Defense, Named NSSEFF Fellow



Monica Olvera de la Cruz has been selected by the U.S. Department of Defense as a fellow in its National Security Science and Engineering Faculty Fellowship (NSSEFF) program.

She is the Lawyer Taylor Professor, professor of materials science and engineering and director of the University’s Materials Research Science and Engineering Center.

Olvera de la Cruz is one of only 11 distinguished university faculty scientists and engineers from across the nation forming the program’s 2010 class. The selection process was rigorous; only 1.4 percent of nominees received the honor.

She will receive up to \$4.25 million of support for up to five consecutive years for her research project, “Paradigms for Emergence of Shape and Function in Biomolecular Electrolytes for the Design of Biomimetic Materials.”

The grants awarded to the new fellows support unclassified, basic research that may transform the Department of Defense’s capabilities in the long term.

Olvera de la Cruz is the second Northwestern faculty member to be named an NSSEFF fellow. Chad Mirkin, George B. Rathmann Professor of Chemistry in the Weinberg College of Arts and Sciences, was named an inaugural fellow in 2008.

In her work, Olvera de la Cruz has developed theoretical models to determine the thermodynamics, statistics and dynamics of macromolecules in complex environments, including multicomponent solutions of heterogeneous synthetic and biological molecules.

# Morris Fine Honored with Lecture and Award

The inaugural Morris E. Fine Lecture in the Department of Materials Science and Engineering took place Oct. 16 and featured Subra Suresh, the Vannevar Bush Professor of Engineering and dean of the School of Engineering at the Massachusetts Institute of Technology.

Suresh gave a lecture titled, “Materials Science at the Intersections of Nanotechnology, Life Sciences and Human Health.”

Suresh holds faculty appointments in materials science and engineering, mechanical engineering, biological engineering, and health sciences and technology at MIT, and served as head of the Department of Materials Science and Engineering from January 2000 to January 2006. He began his tenure as dean of the School of Engineering in July 2007.

The lecture is named in honor of Morris E. Fine, Walter P. Murphy and Technological Institute Professor Emeritus of Materials Science and Engineering in Service.

In August 2009, Fine received the Outstanding Achievement Award from the University of Minnesota.

The award recognizes graduates who have attained unusual distinction in their chosen fields or in public service, and who have demonstrated outstanding achievement and leadership on a community, state, national, or international level.

Fine received his PhD in physical metallurgy from the University of Minnesota in 1943. After working on the Manhattan Project in Chicago and Los Alamos, Fine worked for Bell Labs until 1954, when he came to Northwestern to help start the first materials science department in the world.



Since then he has published more than 300 papers and continues to publish today. He has received numerous awards; most recently he was chosen as recipient of the TMS 2009 Application to Practice Award for research that led to a new steel with better corrosion resistance, toughness, and welding properties. This steel was selected for a new bridge in northern Illinois. He is a member of the National Academy of Engineering and the American Academy of Arts and Sciences. He is a fellow of the Metals, Minerals and Materials Society (TMS), ASM International, the American Ceramic Society and the American Physical Society. He is an honorary member of AIME and the Japan Institute of Metals.

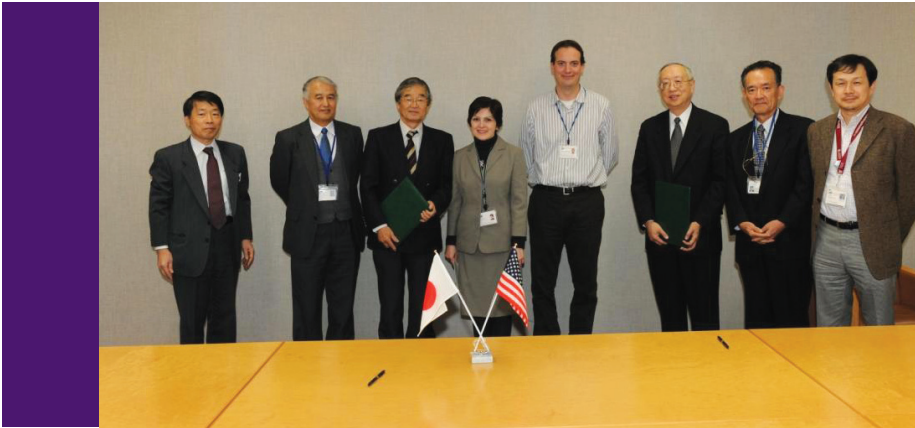
# Agreement Established Between NU and NIMS, Japan

In December, Northwestern University signed a comprehensive collaborative agreement with the National Institute of Materials Science (NIMS), headquartered in Tsukuba, Ibaraki Prefecture, Japan. This agreement will reinforce existing collaborations between Northwestern and NIMS in the fields of 3-D structural analysis and semiconductor nanowires and should facilitate new collaborations and exchanges. The agreement was signed by NIMS President, Professor Sukekatsu Ushioda and Northwestern Provost Daniel Linzer. Robert P. H. Chang, director of the Materials Research Institute and professor of materials science

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and engineering at Northwestern, was on-hand at the signing ceremony following the MRS-Japan 20th Anniversary Symposium. Also present were Larry Aageson, a member of the materials science and engineering professor Peter Voorhees' research group who spent three months at NIMS, Susan

Farjami, former Voorhees post-doc, now on the staff at NIMS, and Koichi Tsuchiya, a Northwestern materials science and engineering alumnus (JR Weertman) now at the NIMS Innovative Materials Engineering Laboratory. Professors Hans and Julia Weertman visited NIMS in February.



From left to right: Takao Kitamura (IAO, NIMS), NIMS Vice-President Tetsuji Noda (Vice-President, NIMS), Professor Sukekatsu Ushioda (President, NIMS), Susan Fajarmi (NIMS; former NU post-doc), Larry Aageson (visiting NU researcher at NIMS), Professor R.P.H. Chang (NU), Masaki Kitagawa (Senior Advisor, NIMS), Koichi Tsuchiya (NIMS; NU alumnus)

# Solar Energy Institute established at McCormick

The International Materials Institute for Solar Energy Conversion, funded by a \$4 million grant from the National Science Foundation, is being established at Northwestern. The institute, led by Bob Chang, professor of materials science and engineering and director of the Materials Research Institute, will develop a network of global materials researchers and train young U.S. researchers for positions of leadership in the field. “Solar cell research has a large potential impact on sustainable energy usage, the environment, and economic development worldwide,” says Chang. “This program will build U.S. capacity in solar energy research by linking U.S.

expertise with best international practices, building collaborative partnerships abroad, and preparing the next generation of U.S. researchers to enter the global workforce as leaders.” Key to the institute is a partnership with Tsinghua University in China in organic/inorganic photovoltaic cells. The institute also features collaborations with researchers from Louisiana State University and Argonne National Laboratory. In addition to research, participating organizations will develop educational content for college and precollege students and the public, including undergraduate courses on energy topics and modules for K–12 math and science classes.

# A Lost Picasso? Uncovering Old Secrets to Identify Modern Sculptures

How do you tell when, where and how a Picasso or a Matisse sculpture was cast? Could bronze sculptures have their very own DNA?

Researchers from Northwestern University, together with collaborators from the Art Institute of Chicago, have completed the first comprehensive survey of the alloy composition of a large number of cast bronze sculptures by major European artists from the first half of the 20th century.

The researchers classified the unique composition profiles of 62 modern sculptures by linking data from the alloy composition of these sculptures with parameters from art history, including artist, foundry, casting methods and casting date.

These profiles — where a sculpture's metal composition is akin to DNA's genetic information — could be used as another method to identify, date and even authenticate sculptures.

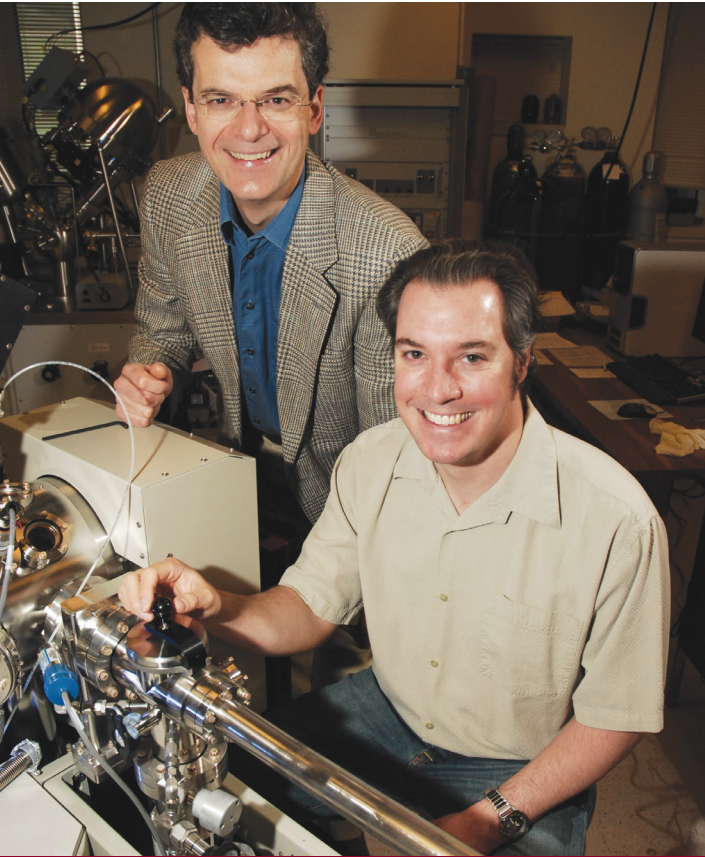
The study was published in the journal *Analytical & Bioanalytical Chemistry*.

The foundries of the early 20th century were quite secretive about the bronze composition they used, to prevent other foundries from producing a superior product. This suggests that alloy composition may be sufficient to identify which foundry cast a particular sculpture.

Bronzes are copper alloys containing various amounts of tin, zinc and other metals whose presence alter the alloy's melting temperature and fluidity, the strength and hardness of the sculpture, its resistance to corrosion, and its color and patination (the chemical process by which a patina forms).

Not all sculptures carry a foundry mark or have documentary evidence to identify where and when they were cast. In some cases, the same sculpture was cast at various dates, with gaps spanning years or even decades. An in-depth knowledge of bronze composition is therefore important to the art historian and connoisseur studying 20th century sculptures and trying to address questions of authenticity, origin and artist intention.

The research team, led by Marcus Young while a postdoctoral fellow in the lab of David Dunand, James N. and Margie M. Krebs Professor of Materials Science and



Professor David Dunand and Marcus Young

Engineering, used a form of optical emission spectroscopy called ICP-OES to determine the metal composition of 62 bronze sculptures cast in Paris during the first half of the 20th century.

The sculptures studied, from the collections of the Art Institute of Chicago and the Philadelphia Museum of Art, included works by Matisse, Picasso, Renoir and Rodin, among other masters.

The researchers showed that the sculptures consist of copper, with zinc and tin as major alloying elements, varying over a broad range of compositions. They were able to group the sculptures into three distinct types: high-zinc brass, low-zinc brass and copper-tin bronze.

These three groups show good correlations with the artist, the foundry, the casting date and the casting method. For example, the high-zinc brass alloys correspond to most of the Picasso sculptures cast in lost-wax at the Valsuani foundry after World War II.

“By expanding the ICP-OES database of objects studied, these material correlations may become useful for identifying, dating or possibly even authenticating other bronzes that do not bear foundry marks,” the authors concluded.

In addition to Young (now at Ruhr-University Bochum in Germany) and Dunand, James N. and Margie M. Krebs Professor of Materials Science, other authors of the paper are Joseph Lambert, professor of chemistry at Northwestern, and Francesca Casadio, A.W. Mellon Conservation Scientist, and Susie Schnepf, associate conservator of objects, both of the Art Institute.

The research is part of the McCormick School's ongoing collaboration with the Art Institute of Chicago, which is led by Katherine T. Faber, Walter P. Murphy Professor of Materials Science and Engineering, for Northwestern, and Casadio, for the Art Institute.

## EVENTS

### Hilliard Symposium, May 20, 2010

Transportation Center, 600 Foster St., Evanston

Keynote: Making Cyber Steels Fly, Charles Kuehmann, President & CEO, Questek Innovations LLC

*Multi-scale tomographic analysis of toughness and fatigue strength in UHS steels* — Stephanie Chan (Adviser: Prof. Olson)

*Strain-stiffening in synthetic and biopolymer networks* — Kendra Erk (Adviser: Prof. Shull)

*Analysis of anisotropy, topology, and kinetics of grain growth* — Ian McKenna (Adviser: Prof. Voorhees)

*Monodisperse carbon nanomaterials for thin-film electronics* — Alex Green (Adviser: Prof. Hersam)

*A path to eliminating costly crystal substrates: biaxially oriented ZnO on glass* — Blake Stevens (Adviser: Prof. Barnett)

*Three-dimensional imaging of porous microstructures for advanced energy applications* — Noah Shanti (Adviser: Prof. Faber)

*Understanding Au impurity incorporation in Si nanowires grown via the VLS mechanism* — Eric Hemeseth (Adviser: Prof. Lauhon)

*Chemical functionalization of epitaxial graphene surfaces* — Qing Hua Wang (Adviser: Prof. Hersam)

*In situ atomic-scale study of redox-induced cation dynamics for oxide-supported monolayer catalysts* — Zhenxing Feng (Adviser: Prof. Bedzyk)

*Interfacial and mechanical properties of self-assembling systems* — Daniel Carvajal (Adviser: Prof. Shull)



Hilliard Symposium speakers (left-to-right): Eric Hemeseth (1st place), Blake Stevens (honorable mention), Daniel Carvajal (2nd place), Noah Shanti, Qing Hua Wang, Ian McKenna, Stephanie Chan, Alex Green (3rd place), Zhenxing Feng, and Kendra Erk (honorable mention).

### Dow, Cohen and Dorn Lectures, 2009-2010

March 30: Dow Lecture Joseph DeSimone, “Top-down Nano-fabrication Technologies for the Production of Uniform, Shape-Specific Carriers for Vaccines, Biologics and Small Molecule Drugs”

May 12-14: Jerome B. Cohen Distinguished Lecturer Joanna Aizenberg (Harvard University) gave three talks:

- Actuated “Spiny” Surfaces à la Echinoderms: En Route to Adaptive Materials
- Creatures that See through Their Bones and Illuminated Glass Houses of the Deep: Lessons in Optics and Mechanics from Marine Organisms
- Bio-Inspired Approaches to Crystal Design

## FACULTY NEWS

**Vinayak Dravid** was named to the Associated Student Government Faculty Honor Roll for 2010.

**Katherine T. Faber’s** group results on improved gelcasting techniques for laminate manufacturing were featured in *International Journal of Applied Ceramic Technology* volume 6 number 5 (2009) and highlighted in the ACerS Ceramic Materials, Applications & Business Blog in October 2009.

**Tobin Marks, Mark Hersam** and **Lincoln Lauhon** received a Nanoelectronics Research Initiative grant from the Semiconductor Research Corporation. NRI is a university-based research consortium cooperatively funded by industry and federal and state governments; the primary goal is to discover the next switch, a new mechanism for computing that goes beyond simply improving today’s transistor. The funds, provided as a supplement to NU’s NSF-funded Materials Research Science and Engineering Center, will be used to study excitons in carbon-based nanomaterials.

**Mark C. Hersam** was chosen to receive the 2010 SES Research Young Investigator Award from the Fullerenes, Nanotubes, and Carbon Nano-structures Division of the Electrochemical Society.

**Tom Mason** won the 2009 American Ceramic Society Edward C. Henry Award for the best paper in the Journal of the American Ceramic Society on a subject related to electronic ceramics. He will receive the award at the upcoming American Ceramic Society meeting this October.

**Phil Messersmith** was named fellow of the Royal Society of Chemistry.

**Amanda K. Petford-Long** was named division director of the Center for Nanoscale Materials at Argonne National Laboratory.

**David Seidman** will give the Minerals, Metals & Materials Society (TMS) Institute of Metals Lecture and receive the Robert Franklin Mehl Award for 2011 at the 140th TMS meeting in San Diego.

**David Seidman** and **Vinayak Dravid** were named to the 2010 class of fellows of the Materials Research Society. The number of new fellows selected each year for this lifetime honor is capped at 0.2 percent of the total MRS membership. Dravid was recognized for his “sustained seminal contributions to the science and technology of advanced materials using the power of electron and scanned probes, and for passionate commitment to facility infrastructure development.” Seidman was recognized for his “pioneering achievements, involving experiments and simulations, for understanding internal interfaces associated with precipitates, dispersoids, and grain- or heterophase- boundaries in a wide range of hard materials.”

**David Seidman** and **Monica Olvera de la Cruz** were among five Northwestern faculty, including University President Morton Shapiro, named as fellows of the American Academy of Arts and Sciences, one of the nation’s oldest and most prestigious honorary societies. They are among the 229 leaders in the sciences, social sciences, the humanities, the arts, business and public affairs who have been elected to the academy this year for their pathbreaking work and will be inducted at a ceremony Oct. 9 at the academy’s headquarters in Cambridge, Mass.

## STUDENT NEWS

PhD student **Laura Cote** (Huang group) was selected as a MRS graduate student award finalist and presented with a Silver Award at the April MRS meeting. MSE alum James Rondinelli (Marks group) was a Gold Award winner.

PhD student **Karen Chen** was awarded a two-year “Studying Abroad Scholarship” from the Ministry of Education in Taiwan.

PhD student **Marie Cox** will receive an American fellowship from AAUW for 2010-11.

PhD student **Mark Huntington** has been awarded a 2010 NDSEG fellowship.

PhD student **Harold Hsiung** was one of a seven-member interdisciplinary team of graduate students who won first place (\$7,000) in the 2010 Social Entrepreneurship in Health & Wellness Challenge. Teams were required to submit sustainable business plans for diabetes management.

Two MSE students were recently selected as winners of the 2010 Dow Sustainability Innovation Student Challenge. The winners of the \$10,000 prize were **Philip Brunner** (Torkelson) and **Jonathan Servaites** (Tobin Marks and Mark Ratner). Servaites was selected for his work to enhance the efficiency of organic photovoltaic solar cells by addressing existing limitations in light absorption and electron transfer that inhibit the commercial viability of OPVs. His proposal was the highest scoring in this year’s challenge. He will represent Northwestern University at Dow’s annual event at Tufts later this year. Brunner was selected for his work “Novel Green Hybrids of Poly(lactic acid) with Microcrystalline Cellulose and Polyethylene Glycol Created via Solid-State Shear Pulverization.” The citation states that “...his work...to enhance the physical properties of the green polymer, poly(lactic acid) demonstrates the kind of innovative multi-disciplinary approach to solving sustainability problems that we were seeking. We firmly believe that such integrated approaches are essential to addressing the global challenge of sustainability.” Phil is the second student from the Torkelson group to be selected as a winner for this award; alumna Cynthia Pierre was a winner of the 2009 challenge.

**Danielle Proffit** (Mason) and senior Kelsey Stoerzinger have received Department of Energy Office of Science 2010 Graduate Fellowships.

An SEM image of graphitized wood by **Matt Johnson** (Faber) will grace the October 2010 cover of *Materials Today*, an issue devoted to carbon-based materials.

**Michelle Mok** (Torkelson) won the 2009 Akzo-Nobel Student Award in Applied Polymer Science. Earlier Torkelson group winners included David Hall (1998) and Chris Ellison (2004). Mok and Torkelson together won another award related to her gradient copolymer research, a 2009 Best Paper Award from the Engineering Properties and Structures Division of the Society of Plastics Engineers.

NSF Graduate Research Fellowships for 2010 have been awarded to five MSE students: graduate students **Anthony Johnson, Tyson Moyer** and **Martin McBriarty** and seniors **Kelsey Stoerzinger** and **Wenhao Sun**. Graduate students Evelyn Auyeung, Mark Huntington, Catherine Tupper and alum Derek Hsu received honorable mention.

**Kelsey Stoerzinger** won the TMS Technical Division Student Poster contest for her research, done with Teri Odom’s group, focusing on the assembly of a new class of three-dimensional nanomaterials. Stoerzinger was also awarded the Lucille and Charles A. Wert Scholarship from ASM Materials Education foundation, the J. Keith Brimacombe Presidential Scholarship from TMS, and a 2010 Illinois Technology Foundation 50 for the Future award.

The Titaniator design team, MSE seniors **Allison Weil, Kelsey Stoerzinger, Pitichon Klomjit, Tian Zhou, Wenhao Sun**, led by Professor **Greg Olson** and project adviser **Jamie Tran**, placed second in the 2009 ASM Undergraduate Design Competition. The project, Ti5111: Trip Titanium, explored new directions in Ti-alloy design for naval and automotive applications for clients General Motors and the Office of Naval Research. The group combined first principles quantum mechanical calculations with available atomic volume data to model the composition dependence of the transformation volume change. They redesigned the 5111 composition to meet the transformation stability requirement while increasing the transformation volume change by a factor of three for efficient toughening.

**Alvin Tan**, a MSE sophomore, won the first prize in the Material Advantage Undergraduate Student Speaking Contest at the TMS meeting at Pittsburgh for a talk based on his work with Professor Jiaxing Huang.

## ALUMNI NEWS

**Josh Jacobs** has been appointed an adjunct professor of materials science and engineering. Jacobs, the William A. Hark, MD/Susanne G. Swift Professor and chairman, Department of Orthopaedic Surgery at Rush University Medical Center presented “Biological Implications of Wear and Corrosion of Orthopaedic Implants” at the MSE colloquium on May 4.

**Daniel Harrington** (BS ’96; PhD ’04, Stupp) accepted a position at Rice University in Houston, TX, where he will be helping to build an interdisciplinary research center. Dan was previously a research assistant professor in the Feinberg School of Medicine (Department of Urology) and Children’s Memorial Hospital.

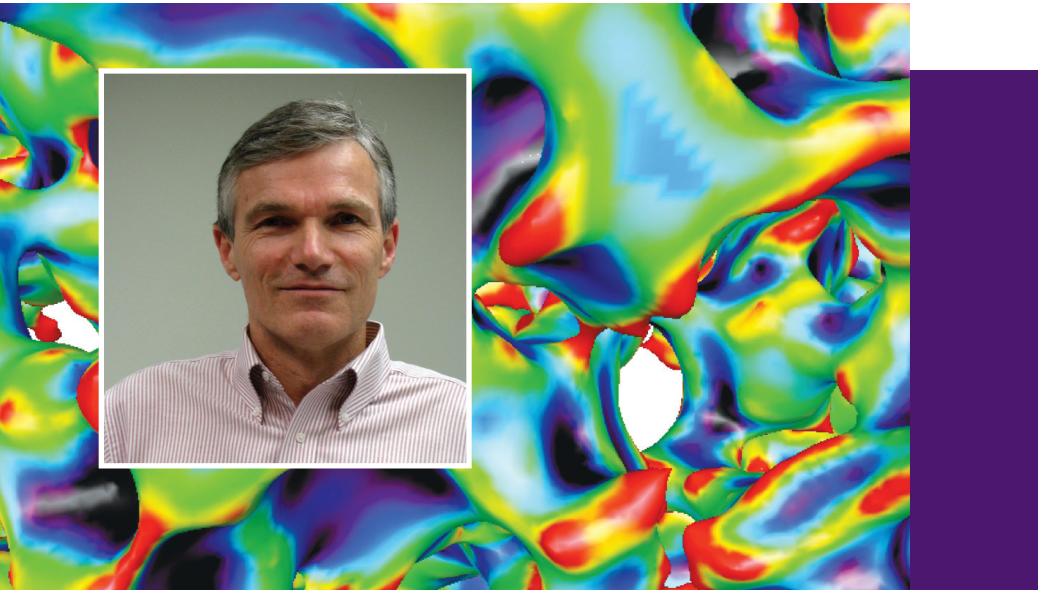
**Chantal K. Sudbrack** (PhD ’04, Seidman) has taken a position with NASA John H. Glenn Research Center in the turbine disk superalloy group.

**Bryan Harder**, (PhD ’04, Faber) has taken a position with NASA John H. Glenn Research Center.

## IN MEMORIUM

A symposium in memory of Professor **Toshio Mura** was held on the Northwestern campus on May 24 and 25. Mura, who passed away in August 2009, came to the United States in 1958 to work in the Department of Materials Science and Engineering at Northwestern. He became a professor of civil engineering in 1966 and also held an appointment in mechanical engineering. Among the many accolades for his work, he was elected to the National Academy of Engineering for his contributions to the field of micromechanics. He retired from Northwestern in 1996.

# Scott Barnett Researches Fuel Cells to Make Fossil Fuels More Efficient



The future of energy could lie in harnessing the energy of solar and wind to power our homes and reduce CO2 emissions. But technology has not yet reached the point where we can rely solely on renewable energy — the vast majority of our energy still comes from fossil fuels.

So how can we make those fossil fuels more efficient and better for the environment now? One answer is fuel cells — specifically, solid oxide fuel cells (SOFCs), which use an electrochemical conversion device to produce electricity directly from the fuel. Research happening at the McCormick aims to better understand just how these fuel cells work — and to find better materials to create them.

Fuel cells work by using two electrodes and an electrolyte to exploit the reaction between oxygen and hydrogen. By combining hydrogen from a fossil fuel directly with oxygen (instead of burning it, like in a coal power plant) we can harness the electricity from the

*We're trying to get a handle on how fuel cells degrade over time, and we can do that with this technique."*

reaction with an efficiency of 40 to 60 percent, compared to less than 30 percent for conventional power plants. The result is a highly efficient, low-emission energy source.

So why aren't fuel cells used more often? NASA has used them on its space shuttles, and Google uses fuel cells to power part of their private headquarters. But cells are still relatively high-cost and can't yet be used directly with fossil fuels — they work best with hydrogen, which is found in most fossil fuels but needs to be processed out. Some also question fuel cells durability and lifespan, and whether the cost can be reduced enough for broad commercial markets.

Scott Barnett, professor of materials science and engineering, is working on two SOFC research projects — both funded by the National Science Foundation through the American Reinvestment and Recovery Act — that will address these challenges. Barnett

Image shows a three-dimensional reconstruction of a portion of a porous fuel cell. Inset: Scott Barnett

is an expert in SOFCs — he's been working in the field for more than 20 years — and says fuel cells are currently the best bet for producing greener energy.

"The technology has come a long way," he says. "Fossil fuels like coal are going to be in use for a long time to come, until renewable energy sources take over, and SOFCs provide a means for using them more efficiently and reducing our production of CO2."

Over the last five years, Barnett and his research group have been using a Focused Ion Beam Scanning Electron Microscope to peer inside SOFCs to see just how they work.

Barnett's team, working with Peter Voorhees, Frank C. Engelhart Professor of Materials Science and Engineering, spent several years trying to figure out the process for imaging the fuel cells — no one had ever done it before — and process works similar to an MRI: the microscope produces 3D images that show the insides of fuel cells. These images show both the electrochemical processes and how the fuel cells degrade over time.

"Being able to accurately measure these structures is useful in figuring out how they actually work," Barnett says. "We're trying to get a handle on how fuel cells degrade over time, and we can do that with this technique. That will allow manufacturers to make better fuel cells in the future."

Barnett is also researching how to use fuel cells for energy storage. Solar and wind power are intermittent — solar power is produced only during the day, for example, and yet we still need electricity during the night. By running solar or wind-produced energy backwards through a fuel cell, you could use it to make fuels like hydrogen or natural gas, and store that fuel until you need it.

"We've started publishing papers on this, and we're getting good results," Barnett says. "It looks very feasible."

Part of Barnett's research projects include looking for new materials to use in fuel cells. Right now, fuel cells run best on hydrogen, but that hydrogen has to be processed out of fuel. Fuel cannot be used directly with fuel cells because, as is the case with natural gas, the methane deposits carbon on the nickel that is used as a key material in the fuel cell. Natural gas also contains impurities like sulfur, which glom onto the nickel and render it inoperable.

"We're trying to find alternative materials to nickel to overcome these problems," Barnett says.

To conduct this research, Barnett uses a cadre of both graduate and undergraduate students in his lab.

"It's fun to have undergraduates around," he says. "A lot of them do meaningful research and are getting their names on publications. We invest a little time initially, and pretty soon they are giving back."

# Surface Science Goes Inorganic

A collaboration between researchers at Northwestern University's Center for Catalysis and Surface Science and scientists at the University of Oxford has produced a new approach for understanding surfaces, particularly metal oxide surfaces, widely used in industry as supports for catalysts.

This knowledge of the surface layer of atoms is critical to understanding a material's overall properties. The findings were published online Feb. 14 by the journal *Nature Materials*.

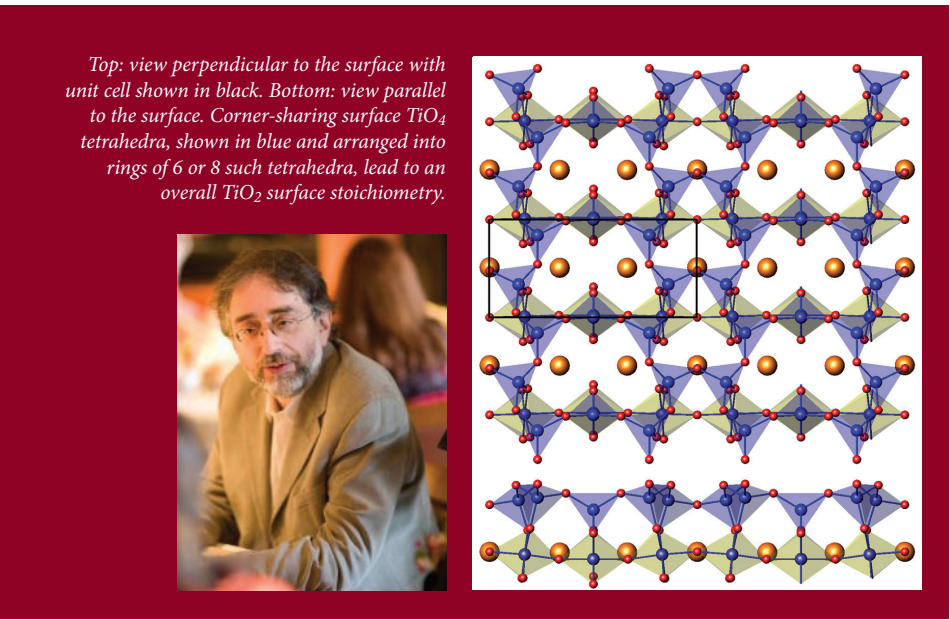
Using a combination of advanced experimental tools coupled with theoretical calculations, the research team has shown how, using methods commonly taught to undergraduate chemistry students, one can understand how atoms are arranged on a material's surface. (These methods date back to the pioneering work of Linus Pauling and others to understand the chemical bond.)

"For a long time we have not understood oxide surfaces," said Laurence Marks, professor of materials science and engineering. "We only have had relatively simple models constructed from crystal planes of the bulk structure, and these have not enabled us to predict where the atoms should be on a surface."

"Now we have something that seems to work," Marks said. "It's the bond-valence-sum method, which has been used for many years to understand bulk materials. The way to understand oxide surfaces turns out to be to look at the bonding patterns and how the atoms are arranged and then to follow this method."

Marks, together with Kenneth Poepelmeier, professor of chemistry in Northwestern's Weinberg College of Arts and Sciences, and Martin Castell, university lecturer in the department of materials at Oxford, led the research.

In the study, Northwestern graduate student James Enterkin analyzed electron diffraction patterns from a strontium titanate surface to work out the atomic structure. He combined the patterns with scanning-tunnelling microscopy images obtained



Top: view perpendicular to the surface with unit cell shown in black. Bottom: view parallel to the surface. Corner-sharing surface TiO4 tetrahedra, shown in blue and arranged into rings of 6 or 8 such tetrahedra, lead to an overall TiO2 surface stoichiometry.

by Bruce Russell at Oxford. Enterkin then combined them with density functional calculations and bond-valence sums, showing that those that had bonding similar to that found in bulk oxides were those with the lowest energy.

Writing in a "News and Views" article from the same issue of *Nature Materials*, Ulrike Diebold from the Institute of Applied

Physics in Vienna, Austria, said, "This simple and intuitive, yet powerful concept [the bond-valence-sum method] is widely used to analyze and predict structures in inorganic chemistry. Its successful description of the surface reconstruction of SrTiO3 (110) shows that this approach could be relevant for similar phenomena in other materials."

# Chad Mirkin Elected to NAS and Honored by Chinese Academy of Sciences

Chad A. Mirkin, a world-renowned leader in nanotechnology research and its application, has been elected to the prestigious U.S. National Academy of Sciences (NAS) and has been elected an Einstein Professor of the Chinese Academy of Sciences.

Membership in the NAS is one of the highest honors given to a scientist or engineer in the United States. The Einstein Professorship Program is a key initiative of the academy, with professorships awarded each year to up to 20 distinguished scientists working around the world at the frontiers of science and technology. Mirkin will visit China this year for a lecture tour organized by the Chinese Academy of Sciences.

Mirkin is the George B. Rathmann Professor of Chemistry in the Weinberg College of Arts and Sciences and professor of medicine, chemical and biological engineering, biomedical engineering and materials science and engineering and director of Northwestern's International Institute for Nanotechnology.

A member of President Obama's Council of Advisors on Science and Technology, Mirkin is known for invention and development of biological and chemical diagnostic systems based upon nanomaterials. He also is the inventor and chief developer of Dip-Pen Nanolithography, a groundbreaking nanoscale fabrication and analytical tool, and is the founder of three Chicago-based companies: Aurasense, Nanosphere and Nanolink.


# 100 Years of MSE

On October 26, the department celebrated a combined century of dedication to the department: Jerry Carsello, manager of the J. B. Cohen X-Ray Diffraction Facility, and Mark Seniw, manager of the Central Laboratory for Materials Mechanical Properties (CLAMMP), each celebrated a 25th anniversary with MSE. Professor Hans Weertman celebrated his 50th anniversary at Northwestern.



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Editors: Emily Aysford, Kathleen Stair  
Photographer: Andrew Campbell  
Design: Amy Charlson Design