2013 Materials Research Society Spring Meeting continues the conversation in materials research

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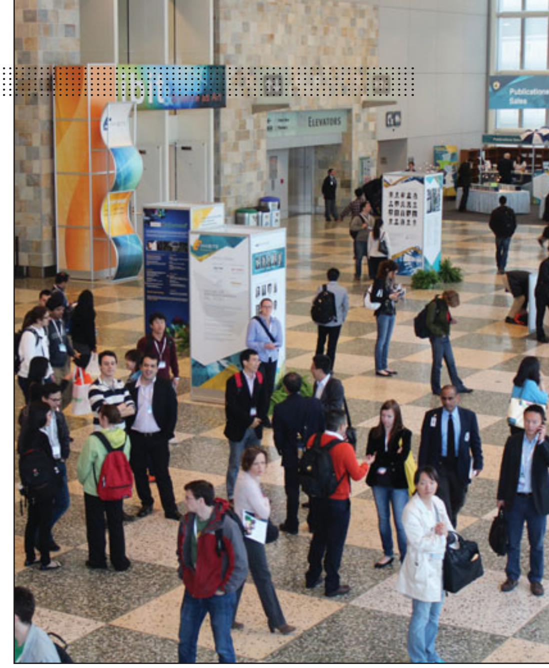

"The biggest change that has happened over the last few years is, as you know, the discovery and production of low-cost shale gas," said plenary speaker Arun Majumdar of Google Inc. at the 2013 Materials Research Society (MRS) Spring Meeting in San Francisco, Calif. While prominent materials researchers at previous MRS Meetings have been warning the materials community for several years of the impending emergency of fulfilling the world's energy needs, this year has witnessed a marked change in this message.

This year's MRS Spring Meeting, boasting over 6400 participants, including exhibitors and virtual attendees, from 60 countries to fill the 56 technical symposia, was held on April 1–5, 2013, in San Francisco, Calif. The Meeting Chairs, **Mark L. Brongersma** (Stanford University), **Vladimir Matias** (iBeam Materials, Inc.), **Rachel Segalman** (University of California–Berkeley), **Lonnie D. Shea** (Northwestern University), and **Heiji Watanabe** (Osaka University) invited Majumdar, former director of the US Advanced Research Projects Agency-Energy (ARPA-E), to give the plenary address concerning challenges the materials community now faces to achieve a sustainable energy future.

Shale oil and gas have changed the game in the last decade or so, Majumdar said. Such deposits are located across the globe, with most of it in China, where it has not begun to be tapped. The permeability of a shale deposit is coupled to pore pressure, but the research community does not yet know enough about how this coupling works, so researchers cannot predict how long shale gas will last. Furthermore, not all shales are the same. Some have a substantial clay component that makes them impossible to fracture, at least so far. This is an opportunity for materials researchers to figure out a way to fracture such difficult shales, Majumdar said. He sees natural gas from shale as a bridge to supply energy until renewable resources can mature enough to become economically viable. Majumdar's talk can be viewed online at www.mrs.org/spring2013, along with a number of symposia and other special talks.

Numerous presentations on materials and energy were given across a number of technical sessions, with one symposium specifically combining the topic with sustainability. Ronny Neumann (Weizmann Institute of Science, Israel) wants to utilize polyoxometalates as molecular analogs of transition-metal oxide materials to catalyze novel reactions. Polyoxometalates offer numerous benefits over traditional catalysis methods such as anionic solubility in water, thermal stability over a range of temperatures, simple aqueous chemistry, and synthetic fidelity. The intense control of structures offers thousands of possibilities for specific applications. Neumann highlighted several specific examples of how using these polyoxometalates could change the way we think about chemistry. Using cobalt polyoxometalates, it is possible to split water in a four-electron reduction reaction. If combined with another specific catalytic compound, this chemistry can be used to reduce CO_2 to CO, which can be used to create liquid fuels compatible with internal-combustion engines. Neumann went on to explain how polyoxometalates can be used to create molecular oxygen, convert methane to methanol, and even directly convert bio-resources to synfuel.

Another area of research that continues to generate much attention at MRS is graphene. Roman Fasel (EMPA/University of Bern) presented research on the bottom-up synthesis of graphene nanoribbons (GNRs), a material of interest because it exhibits many of graphene's appealing electronic properties but is semiconducting rather than metallic. Fasel explained that bottom-up synthetic approaches from small-molecule precursors are preferable for obtaining high-quality ribbons, because top-down lithographic techniques yield ribbons with malformed edges, and cannot produce ribbons narrow enough to have a desirable bandgap. He presented

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several distinct types of GNR synthesized by his group, all having "armchair-type" edges, as compared to "zigzag."

Sreeprasad T. Sreenivasan (Kansas State University) focused on the nanotomy of graphene sheets to give graphene quantum materials. Because pristine graphene has no bandgap and is therefore conducting, it is inappropriate for applications like transistors, but restricting graphene's dimensions opens a bandgap, affording a semiconductor. Sreenivasan accomplished this through nanotomy, a top-down approach that involves cutting graphene sheets with a diamond knife. This automated technique allows for precise control over size and shape of the resulting material, and has produced GNRs as narrow as 5 nm in width. The technique also produced tapered graphene structures, which feature gradual bandgap evolution as the ribbon widens. This property, in that it dictates a direction for the flow of current, allows for the creation of what Sreenivasan called a diodic transistor.

Another rapidly moving field is stretchable electronics. John A. Rogers, who was named a MacArthur Fellow in 2009, has much to show from his research at the University of Illinois at Urbana-Champaign. For his talk upon receiving the MRS Mid-Career Researcher Award, Rogers described what research groups worldwide are doing to create soft, stretchable, and flexible materials that can interface with the soft tissues in our bodies. "What if you want to surround your brain with integrated circuits, or wrap them around your heart, or melt them into your skin?" Rogers asked. Such circuits would be highly valuable for studying and monitoring health conditions and understanding how these regions of the body work, but current Si integrated circuit technology is far from being the answer. The hard, brittle, inflexible circuits that work so well in many areas of technology just do not conform well to soft tissue, in part due to a large modulus mismatch between the materials.

So he and others are trying to design circuits that conform to biological systems—circuits that are soft, flexible, and biocompliant. They are investigating polymers, small molecule organics, carbon-based materials (e.g, nanotubes and graphene), and perhaps surprisingly, silicon. Part of the brittleness of Si is due to its thickness; at a thickness of ~10 nm, Si becomes relatively "floppy and bendable," according to Rogers. This material has the advantage of being able to stick to surfaces through van der Waals forces, so no adhesive is needed. But these materials are only flexible enough to wrap around a cone or cylinder, not the intricate contours of the skin or brain.

The need, Rogers said, is to go from flexile to stretchable Si devices. Putting ultrathin Si devices on a prestrained rubber substrate can create "wavy" silicon nanoribbons that stretch like the bellows of an accordion. Taking this concept a step further, the researchers exploited a buckling mechanism by creating an open spider web structure of filamentary serpentine Si structures bonded to a soft, low modulus silicone surface. This system came close to matching the modulus of skin, and adhered to the skin through van

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Graduate Students Receive Gold and Silver Awards

Graduate Student Awards were announced during an evening ceremony on April 3 at the 2013 Materials Research Society Spring Meeting in San Francisco.

Gold Graduate Student Awards were awarded to (front row, left to right): **William Woodford** (Massachusetts Institute of Technology), **Jingqing Zhang** (Massachusetts Institute of Technology), **Sriharsha Aradhya** (Columbia University), and **Wei Bao** (University of California–Berkeley); (back row, left to right): **Benjamin Chee Keong Tee** (Stanford University), **Zilang Ye** (University of California–Berkeley), and **Matthew McDowell** (Stanford University).

Silver Graduate Student Awards were awarded to (front row, left to right): **Guang Zhu** (Georgia Institute of Technology), **Juanjuan Du** (University of California–Los Angeles), **Runzhe Tao** (University of Illinois at Chicago), and **Le He** (University of California–Riverside); (second row, left to right): **Xiaofeng Feng** (University of California–Berkeley), **Woon Teck Yap** (Northwestern University), and **You Zhou** (Harvard University); (third row, left to right): **Lito de la Rama** (University of Illinois at Urbana-Champaign), **Kedar Hippalgaonkar** (University of California–Berkeley), and **Wei Gao** (University of California–San Diego); (back row, left to right): **Ryan Comes** (University of Virginia), **Jongwoo Lim** (University of California–Berkeley), and **Aaron Rathmell** (Duke University).

der Waals forces, making it mechanically invisible to the person wearing the circuit. The circuit can be made optically invisible, for example, by hiding it in a temporary tattoo with an FDA-approved adhesive.

In a separate talk as part of a symposium, Rogers said that while his group has demonstrated ultrathin conformal electronics both on the surface of and embedded inside skin, there still remains the challenge to deliver power to these devices, to enable applications like sensing. While solar, RF far field (wireless), and inductive power delivery options exist, developing flexible and stretchable batteries is perhaps the ultimate solution, Rogers said. To develop such a battery, his group developed a flexible lithium-ion battery structure with silicone elastomers as substrates comprising arrays of disks containing the cathode and anode active materials, and interconnected these disks by a "self-similar" or spring-within-a-spring interconnect structure. The favorable mechanics imparted by the self-similar structures protect the battery electrode disks during stretching, while silicone spacer disks in between the electrodes provide restoring forces. The resulting flexible and stretchable battery demonstrates biaxial stretching up to 300%, without affecting its energy density.

Work from a group at Stanford University, led by Zhenan Bao, approaches stretchable electronics from a different direction. "Human skin is a great inspiration for us to think about the future of electronics," Bao said. In fact, what her group and many others are investigating is more of a "super skin" that has more functionality than the real thing. These include the possibilities of adding chemical sensing functions to electronic skin, making it stretchable, and even biodegradable. Applications include health monitoring, robotics, and consumer electronics. Current work in Bao's group includes developing organic thin-film transistors (OTFTs) as touch (pressure) sensors. An integrated organic transistor device consisting of a polymer semiconductor and rubber pyramid contact points generates an electrical current when pressure is applied. The device works at pressures as low as a few kilopascals, which Bao describes as equivalent to a "gentle touch," making it more sensitive than previous capacitor-based sensors. The gate and source–drain voltages can be optimized to enhance the sensitivity.

When this sensor is attached to a person's wrist, it can monitor the heartbeat through the pulse point and provide a detailed three-wave peak representing the various stages of blood pumping through a heart, Bao said. Another area of investigation is in flexible temperature sensors that operate around body temperature. Bao said that a flexible wireless body temperature sensor is within reach.

A program closely discussed at recent MRS Meetings is the Materials Genome Initiative (MGI), which President Obama announced nearly two years ago. The goal of this initiative is to double the speed and reduce the cost of discovering, developing, and deploying new advanced materials. Due to the initiative, the materials research community is now beginning to hear about a "shift in paradigm" in the way research as well as education is being done. The initiative receives funding across government agencies, including

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the National Science Foundation (NSF), the National Institute of Standards and Technology (NIST), the Department of Energy (DOE), and the Department of Defense (DOD).

"The invention of silicon circuits and lithium ion batteries made computers and iPods and iPads possible, but it took years to get those technologies from the drawing board to the market place," the President had said at Carnegie Mellon University. "We can do it faster."

At the MRS Spring Meeting, during a Government Agency Forum, James Warren of NIST gave a history of the initiative. Among the changes the research community is seeing since this initiative is the formation of more interdisciplinary teams. For example, MGI has funded research teams consisting of scientists who specialize in computational, experimental, and computer science. Likewise, in the education area, in order to prepare students for the new workforce, Ashley White, who is an AAAS Science and Technology Policy Fellow, said scientists need to start thinking of themselves as part of a network rather than as individuals. White spoke at Symposium EEE on education.

In her talk, White presented recommendations that came from an NSF workshop held in December 2012. Among these recommendations are for universities to hire more faculty with computational expertise, and for students to receive cross and interdisciplinary training. For example, students who specialize in experimental work should learn about the uses and limitations of modeling and vice versa. The workshop also recommends exposing students to interdisciplinary team projects by encouraging the development of centers and common-use research facilities.

Throughout the week, the MRS Spring Meeting was bustling with activities, from the technical sessions and forums to award presentations, an equipment exhibit, and opportunities for professional development and public outreach. The "Best of MRS" can be viewed online at www.mrs.org/spring2013 through video capture of selected symposia and special talks by OnDemand® as well as interviews on MRS TV.

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Congratulations to the 2013 MRS Fellows

Honoring MRS Members who are notable for their distinguished research accomplishments and outstanding contributions to the advancement of materials research worldwide.

John E.E. Baglin
IBM Almaden Research Center

For outstanding achievement in advancing the mission of the materials community through service; pioneering ion-beam materials research of industrial importance; championing materials education globally.

Leonard J. Brillson
The Ohio State University

For seminal contributions to the understanding and control of semiconductor interfaces, metallurgical reactions, native point defects and electronic properties.

David Cahen
Weizmann Institute, Israel

For fundamental contributions to thin-film photovoltaics, photoelectrochemical energy conversion and biomaterial/inorganic interfaces; scientific leadership and service to the Materials Research Society.

Long-Qing Chen
The Pennsylvania State University

For contributions to development of the phase-field method and its innovative application to predicting mesoscale microstructural evolution and properties of metallic alloys, oxides and ferroelectrics.

Yang-Tse Cheng
University of Kentucky

For enduring research contributions to ion-solid interactions, shape-memory surfaces, superhydrophobicity, tribology, instrumented indentation and high capacity durable lithium ion batteries; distinguished leadership and service in the materials community.

Paul K. Chu
City University of Hong Kong

For outstanding contributions to the development of plasma immersion ion implantation for modifying materials surfaces to improve functional properties and obtain novel structures for industrial and biomedical applications.

Antonio Facchetti
Polyera Corporation and Northwestern University

For seminal contributions to materials research, from the design, synthesis and characterization of novel organic and hybrid materials to development of unconventional fabrication strategies and commercially viable electronic devices.

Joseph E. Greene
University of Illinois at Urbana-Champaign

For foundational contributions to the understanding of thin film and nanostructure synthesis, particularly for pioneering work in thin-film nitrides; distinguished leadership in the materials community.

Naomi J. Halas
Rice University

For fostering plasmonics within materials research; pioneering the study of nanoparticles with tunable optical properties and their applications in sensing, biotechnology and biomedicine.

Richard G. Hoagland
Los Alamos National Laboratory

For outstanding contributions in fracture mechanics and atomistic modeling of dislocation mechanisms of deformation and fracture of metals, ceramics and nanolayered composites.

Andrew B. Holmes
University of Melbourne, Australia, and Commonwealth Scientific Industrial Research Organization (CSIRO)

For distinguished contributions to materials science in the design and applications of conjugated organic materials for electronics; leadership and outreach in polymer materials.

Taeghwan Hyeon
Seoul National University, Republic of Korea

For outstanding contributions in scalable synthesis of nanomaterials with precisely controlled compositions and dimensions; pioneering research in the design of metal oxide nanocrystals for biomedical applications.

Ram S. Katiyar
University of Puerto Rico

For pioneering contributions in bulk and thin-film oxide ceramics for energy efficient electronics and energy-storage applications.

Enrique J. Lavernia
University of California, Davis

For outstanding contributions to the development of novel metal processing techniques; service and leadership in education.

Chad A. Mirkin
Northwestern University

For pioneering contributions to nanochemistry that have led to materials and devices which have dramatically increased our scientific understanding and capabilities.

Patricia M. Mooney
Simon Fraser University, Canada

For leadership in the understanding and control of point and extended defect structures in both compound and elemental semiconductors enabling new device technologies.

Daniel E. Morse
University of California, Santa Barbara

For seminal contributions to understanding the molecular mechanisms of biomineralization; development of novel bioinspired routes to kinetically controlled, low-temperature synthesis of nanostructured inorganic materials.

John H. Perepezko
University of Wisconsin–Madison

For seminal scholarly contributions to the fundamental understanding of structural synthesis, kinetics and alloy phase stability during materials processing, especially during the nucleation stage of reaction.

Pradeep K. Rohatgi
University of Wisconsin–Milwaukee

For sustained leadership in research on solidification synthesis and characterization of metal-matrix composites; pioneering initiatives in technology and product development, education, materials policy and institution building.

Rodney S. Ruoff
University of Texas at Austin

For fundamental and pioneering studies of novel carbon nanostructures, including graphene, chemically modified graphenes, nanotubes, nanofoams and fullerenes.

M. Stanley Whittingham
Binghamton University

For fundamental contributions to materials research leading to the discovery that provided the foundation for the Li-ion battery; leadership in materials education at all levels.

Karen I. Winey
University of Pennsylvania

For outstanding contributions to the understanding of polymer nanocomposites and ion-containing polymers through rigorous and insightful experiments; distinguished leadership in the materials community.

Jackie Y. Ying
Institute of Bioengineering and Nanotechnology, Singapore

For distinguished contributions to the synthesis of advanced nanostructured materials with unique functionalities for catalytic and biomaterial applications; distinguished service to the materials community.

Steven J. Zinkle
Oak Ridge National Laboratory

For pioneering contributions to the understanding of radiation effects in materials; advancing the scientific basis of performance limits for structural materials in advanced nuclear energy systems.

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