



MRS Meeting Scene...




Presented by the Materials Research Society

2011 MRS Fall Meeting

A Publication of the
Materials Research Society

Advancing materials. Improving the quality of life.

Boston, MA
November 27 - December 2

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Meeting Scene Day 3, Tuesday, November 29

Tuesday at the 2011 MRS Fall Meeting in Boston featured an intriguing David Turnbull Lectureship Award talk on the practical aspects of graphene by Phaedon Avouris of IBM, and an equally fascinating look at the extremes of thermal conductivity in materials by David Cahill of the University of Illinois at Urbana-Champaign in his Symposium X lecture. As usual, hundreds of other interesting technical talks and poster presentations filled in the time before, between, and after these events--just a normal day at an MRS Meeting.

Another exciting event was the opening of the exhibit today, with 250 exhibitors eager to show their products and offer scientific solutions to the materials scientists gathered in Boston. Be sure to check it out!

Rounding out the schedule was a successful Town Hall Meeting in which MRS solicited ideas for the look and feel of "Meetings of the Future," with "virtual meetings" figuring prominently in the discussions. Also, officials from DOE, Darpa, and ONR spoke about funding focus areas and opportunities for materials scientists in evening sessions. Another poster session resulted in awards for four outstanding scientists.

Thanks to all of you for helping to make this day such a success!



MRS President Jim DeYoreo presents an award plaque to Jennifer Nekuda Malik, the 2011-2012 MRS/TMS Congressional Science and Engineering Fellow.



2011 MRS
FALL MEETING
November 28-December 2 - Boston, MA



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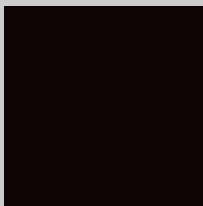
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MEETING HIGHLIGHTS

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Other Links of Interest

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This online survey will help us to learn what you are looking for in a scientific meeting, and get your ideas on what future meetings should look like. Please take a few minutes to let us know what you think.

[MRS Meetings Blog](#)



The MRS Meeting Experience

View the MRS Fall Meeting through the eyes of our student bloggers and reporters. A glimpse of the Meeting as you have never seen it before!

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A collage of photos taken at the *MRS Communications* Reception to celebrate the publication of the first volume of our new, rapid communications, letters journal. Learn more about *MRS Communications* and how to submit your papers [here](#).



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David Turnbull Lectureship Award



Phaedon Avouris
IBM T.J. Watson Research Center

Graphene--Applications in electronics and optoelectronics

While graphene has been touted for its exceptional electronic and optical properties, Phaedon Avouris warned that most of the research on graphene isolates the material from its environment. While he does not dispute the extremely high carrier mobility, the excellent heat conduction, and the wide range of optical absorbance of graphene, he carefully pointed out that graphene “is all surface. In contact with other materials, its properties are perturbed.” For instance, he noted that you can get both elastic and inelastic scattering of graphene phonons when it is in contact with a polar substrate. “The end results depend on the strength of interactions, and that depends on conditions,” he said

Avouris urged researchers to take these conditions into consideration when performing research on graphene. Graphene field-effect transistors can never have zero current flow, so they would make leaky switches in digital devices, he said. However, the finite current I_{on}/I_{off} ratio, the high carrier mobility, and the high drive current make graphene ideal for analog radio frequency applications, specifically for high frequency/low noise devices.

Getting electronic carriers in and out of graphene circuits is “a tricky subject,” according to Avouris. Contacts are necessary, and contact resistance depends on the applied bias voltage and temperature. Taking Pd contacts as an example, he noted that the metal and the graphene have different work functions, so the graphene will become doped with Pd. At positive gate voltage, a p-n-p junction will be



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formed, raising the resistance, with the effect being stronger in shorter channels. “Going to small sizes in small devices, contact effects eventually become dominant,” Avouris said.

Avouris is very positive on the use of graphene in optoelectronics because it absorbs at least 22% of any wavelength in the spectrum. Also, its Fermi level can be tuned using an electric field, and has high speed photoresponse. His research has shown no decrease in this photoresponse up to 40 GHz, the limit of his measurement system, in a single-contact graphene photodetector. He believes graphene will have its biggest impact in optoelectronics in the terahertz frequencies.

The critical issues for graphene, according to Avouris, are producing high quality, large area, low price materials; controlling doping; developing low resistance contacts and gates; and producing ultrathin, high dielectric constant insulators that are compatible with graphene. He concluded his talk by urging researchers once again to “work in real world conditions with graphene, not just at microkelvins.”

Symposium X: eXtremes of Heat Conduction

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David G. Cahill
University of Illinois at Urbana-Champaign

eXtremes of Heat Conduction--Pushing the Boundaries of the Thermal Conductivity of Materials

In a talk that investigated both extremes of thermal conductivity in materials—the highs and the lows—David Cahill described how his team’s investigations using time domain thermal reflectance (TDTR) have enabled them to study materials across the conductivity spectrum. The technique uses thermal waves to measure transport properties, but because they are usually examining nanoscale materials the measurement must be ultrafast. Fully understanding thermal conductivity is difficult because the solution “involves an integral over all thermally excited states in a material,” Cahill said.

Diamond has long been at the high end of the thermal conductivity scale, but evidence exists that carbon nanotubes or graphene may replace it at the top. Some question exists as to whether this high conductivity can be put to practical use, however, since graphene in contact with other materials experiences a significant reduction in thermal conductivity.

At the other end of the scale, disordered layered crystals typically have ultralow conductivity. In fact, the lowest heat carrying capability of a material is called the “amorphous limit.” However, because heat is lost at interfaces, carefully constructed multilayered materials containing both crystalline and amorphous elements are pushing the lower boundaries of thermal conductivity.

The case in point is a multilayered, 60-nm-thick sample of WSe_2 . Cahill’s group built this structure by depositing W and Se in layers at room temperature on an Si substrate. An annealing step removed excess Se and improved the crystallinity. The resulting structure showed some crystalline order parallel to the planes of the layer, but none normal to these planes. Also, each layer was relatively incoherent in relation to the one below it. TDTR measurements showed that this 60-nm film of WSe_2 has the lowest thermal conductivity ever observed in a fully dense solid, having only twice the thermal conductivity of



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air. This is a factor of six less than the calculated amorphous limit for this material. Cahill noted that there is a “compelling race to the bottom to find even lower conductivity solids.”

Being an optical technique, TDTR also allows them to study thermal conductivity of materials under extreme conditions, such as ice VII at 20 GPa. Ice VII initially forms at pressures of 2 GPa. Its structure is cubic with interpenetrating but not interconnected bcc sublattices. The Liebfried-Schlomann (L-S) equation says that acoustic phonons are the dominant heat carriers under these conditions. TDTR analysis showed ice VII at 20 GPa agreed well with the predictions of the L-S equation. When compressed to 2/3 of its normal volume, ice VII had a high thermal conductivity, close to that of sapphire.

Cahill’s group is now investigating what he calls “extraordinary spin-wave thermal conductivity in $\text{Ca}_9\text{La}_5\text{Cu}_{24}\text{O}_{41}$.” The copper oxide spin ladders are believed to carry the heat, but this is still a work in progress. They plan to use TDTR’s frequency dependence to probe magnon-phonon coupling in this material. “Time domain thermal reflectance enables experiments that were not possible a decade ago,” Cahill concluded.

Town Hall Event--MRS Meetings, the Next Generation



We at MRS are proud of our reputation for hosting outstanding meetings, but we don't want to rest on our laurels. Rapid technology advances are making "virtual meetings" and other experiences a reality, and some companies and organizations are pursuing these opportunities.

But what is the right path for MRS? We held a Town Hall Event last night to allow MRS members to voice their opinions about what the "Meetings of the Future" should look like, and many of you helped us by attending and sharing your viewpoints. We thank you all for taking the time to talk to us on this important topic.

For those of you who could not attend the Town Hall, don't despair! You can still give us your input by filling out the online survey available [here](#). Please take a few minutes to let us know what your vision of the future is for scientific meetings. We can offer you our gratitude as a reward.

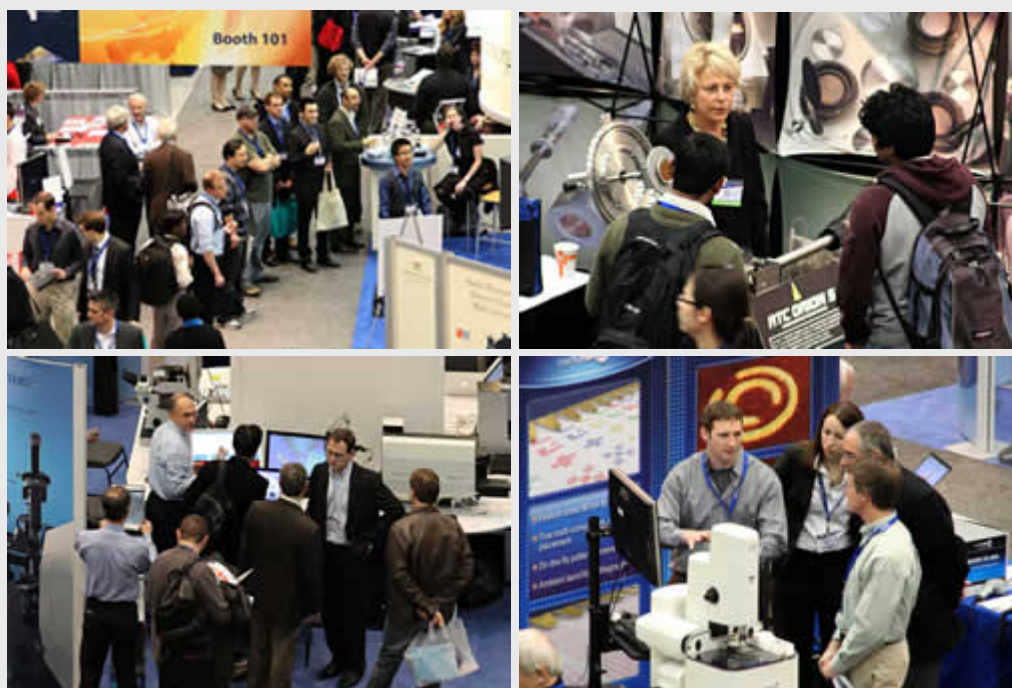
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THE EXHIBIT



Two hundred and fifty companies are showing off their products at this meeting, and one of them just might have the solution to that nagging experimental problem you've been trying to solve. Instrumentation is evolving rapidly, and you might not be aware of the latest developments that could make your research life easier and more successful. Scientific publishers are also on hand with the latest in technical books and journals that might contain information that that you need.

Our exhibitors play a large role in making our MRS Meetings successful. Please repay their efforts by taking a stroll through the Exhibit Hall and perusing their products. It could be to your great benefit.



GOVERNMENT AGENCY SESSIONS

Department of Energy (DOE)

Linda Horton, director of the Materials Sciences and Engineering Division of the Office of Basic Energy Sciences (BES) in the Department of Energy returned to the MRS Meeting to discuss DOE's mission and the opportunities in 2012 for materials funding. Her division's research focus areas are condensed matter and materials physics, materials discovery design and synthesis, and scattering and instrumentation sciences. DOE supports single investigators and small group projects, the Energy Frontier Research Centers, and the Energy Innovation Hubs. New in 2012, DOE will add three Energy Innovation Hubs, including one on Batteries and Energy Storage. Also new in 2012 are four federal programs in support of the president's recently announced Materials Genome Initiative, including a call for proposals by DOE. The Initiative is a multi-agency endeavor. Horton said that DOE will use the Initiative to build on its current programs. For example, the Initiative will fund teams of theorists and

experimentalists with the purpose of accelerating development of multiscale computational modeling systems.

Elaine Ulrich, DOE's Photovoltaic Technology Manager, also spoke during the DOE seminar. Ulrich illustrated opportunities in the department's solar program known as the SunShot Initiative. The goal of the program is to accelerate research, development, and deployment of solar energy at reduced costs. Ulrich noted that 13 of the 46 Energy Frontier Research Centers across the country are focused on solar. Opportunities are available at the centers for collaborations as well as positions for postdoctoral fellows and graduate students.

Office of Naval Research (ONR)

Shawn Thorne, associate director of functional materials at the Office of Naval Research, UK, discussed the funding of integrated computational materials science and engineering and energy storage and power generation science (architectures to increase power density; materials and structures for increased efficiencies; surface chemical and electrochemical reactions; organic, polymeric, and hybrid materials; and high throughput quantum computing). ONR Global provides worldwide science- and technology-based solutions for current and future naval challenges.

Research and development trends are focusing on industry as a driver. Funding from ONR comes down to, "Is Industry going to develop this anyway?" said Thorne. ONR S&T investments fall into four technologies: Off-the-shelf: 1--2 years; component: 3-5 years; disruptive: 5-10 years; and undiscovered and emerging: 10+ years.

Three programs address the needs of the U.S. Navy and the Marine Corps: the Visiting Scientists Program, which supports short-term travel opportunities for foreign/international scientists to the United States; the Conference Support Program, which supports foreign or international workshops, conferences, and seminars of naval interest; and the Naval International Cooperative Opportunities in Science and Technology Program, which provides direct research support to international scientists to help address naval S&T challenges.

Defense Advanced Research Projects Agency (DARPA)

The Defense Advanced Research Projects Agency (DARPA) takes a different approach to funding, where the focus is on the idea or the program. "The golden nugget is the program. It gets you the resources to make the progress you want to make," said Brian Holloway, program manager for DARPA. "You cannot achieve technological surprise with science. We do exploitable science."

The Defense Sciences Office Materials Program seeks to advance materials science on many technology fronts. Programs range from developing physics- and chemistry-based models that allow for the design of novel materials possessing radically improved or new properties, to innovative processing methods that dramatically reduce the cost of producing titanium metal and its alloys.

"Getting involved early helps you to be effective to get the programmatic money," said Holloway.

More information is available at
<http://science.energy.gov/bes/>
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VIDEO

Attendees discuss their experiences at the 2011 MRS Fall Meeting. All interviews in this video were taken at the Student Mixer.



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TECHNICAL PROGRAM

Symposium E: Solar Fuel Generation

Invited Speaker: Daniel Nocera, MIT

E4.1: The artificial leaf

Long before the talk began, the projector screen displayed what looked like a black rectangular piece of silicon (artificial leaf) placed on top of a bright green real leaf. This unassuming device was what the audience had come to see. The artificial leaf uses a silicon based p-n junction to replace the photosynthetic membrane of real leaves. On either side of this junction are selective gas evolving catalysts that split water under sunlight to form oxygen and hydrogen. The self-healing, highly stable catalyst is a molecule of 7 cobalt atoms that form a “cobaltate cluster.” The cobalt atoms cycle between different oxidation states during the device operation. The “leaf” is designed to work under simple conditions, and “can even operate inside a glass of water put on a window sill,” Nocera said. The talk showed exciting videos of the leaf doing exactly this. There are no expensive noble metal catalysts involved, and the selectivity of the cobaltate clusters eliminates the need for complicated membranes. This low cost device is now being promoted by the Tata Industrial group as a kind of “fast food energy in developing countries like India,” Nocera said.



Symposium H/I: Organic Photovoltaic Devices and Processing

Invited Speaker: A. J. Heeger, University of California, Santa Barbara (UCSB). Heeger's postdoc Y. Sun actually gave the talk.

H/I 5.1: High performance solution processed bulk heterojunction solar cells fabricated from small molecules

Starting from 1% in 1995, the solar energy conversion efficiencies of bulk heterojunction organic (polymer-fullerene blend based) solar cells have steadily increased, reaching 9.3 % in 2011. As the race

towards 10% efficiency continues, many groups are now replacing the light absorbing donor polymers typically used in these solar cells with small molecules. Problems associated with the polymer, like batch to batch variations in solubility; molecular weight; polydispersity and purity; and processing difficulties do not apply to these solution-processed small molecules. The Heeger group recently demonstrated a champion 7% efficient small molecule based organic solar cell incorporating a PC70BM acceptor and a donor-acceptor small molecule (DTS(PTTh₂)₂) as a polymer replacement. Typically fill factors are the limiting factor in small molecule based organic solar cells, but here they obtain excellent fill factor values exceeding 60 %. The efficiencies were also enhanced by adding the right amount of an additive, and by carefully removing all impurities after the small molecule synthesis. The speaker cautioned the audience to pay special attention to the role of impurities in these types of solar cells. Less than 1% impurity content can cause efficiency values to drop from the remarkable 7% to an average 3%. The reason for this degradation is that impurities lead to trap assisted recombinations which lower photovoltaic parameters.



A meeting of the subcommittee for Strange Matter International, MRS's traveling exhibition that has introduced the wonders of materials science to audiences at museums and science centers in Canada, Mexico, and the United States. Learn more about the Strange Matter exhibit [here](#).

Symposium J: Photonic and plasmonic materials for enhanced photovoltaic performance

Invited Speaker: Yi Cui, Stanford University

J3.6: Nanoscale photon management for solar cells and transparent electrodes

Yi Cui's group has led the way to design a variety of nanostructures for photon management inside solar cells. They have borrowed heavily from the laser community in designing exotic nanoscale structures like nanocones, nanodomes, nanocavities and hollow structures, and in determining how these structures interact with light. In simple terms, they deposit these structures by Langmuir Blodgett (LB) film deposition followed by a reactive ion etch to get the desired shapes. Using this approach they have demonstrated amorphous silica nanocone structures with a graded refractive index that exhibit enhanced wideband anti-reflection and wide-angle absorption compared to traditional flat films. In fact, Cui promotes these pitch black films as "the perfect anti-reflection coating." They have also extended this approach to fabricate nanodome and nanocavity structures that generate significant improvements in light harvesting efficiencies in amorphous silicon solar cells. Inspired by the dome of St. Paul's Cathedral, they now demonstrate hollow nanocrystalline silicon nanospheres that manipulate the whispering gallery modes commonly seen in lasers.

Speaker: Supriya Pillai, University of New South Wales (UNSW), Australia

J3.9: Effect of surface plasmon resonance on the photoluminescence from Si quantum dot structures for third generation solar cell applications

The main focus of this talk was how third generation photovoltaic solutions based on surface plasmon resonance can address the high cost and low efficiency problems associated with earlier generations of solar cells. The UNSW research demonstrated how quantum dots, which are quantum confined structures with tunable band gaps, can be used to realize high efficiency tandem solar cells with efficiencies that exceed the Shockley-Queisser limit. Their tandem cells use band gap engineered silicon quantum dots. The sizes of these quantum dots are varied to tune the plasmon resonance position so as to enhance absorption within each layer of the tandem cell, thereby obtaining tremendous enhancements in efficiency.



Symposium M: Oxide Semiconductors--Defects, Growth, and Device Fabrication

Invited Speaker: Anderson Janotti, University of California, Santa Barbara

M5.1: Doping and Defects in Wide-Band-Gap Oxide Semiconductors

The speaker started by comparing the band gaps of various oxide semiconductor materials like ZnO, SnO₂, and TiO₂, which have band gaps around 3.0eV. These materials are used in many applications like transparent contacts, LEDs, laser diodes, transistors, photocatalysts, and gas sensors. The challenges that these oxide semiconductors pose include control of conductivity, band-gap engineering, heterostructures, epitaxial growth, and nanostructures. They are highly dispersive with wide band-gaps. The main goal of the group's research is to understand the role of doping in oxides using first principles. They experimented with different ways to study unintentional defects in these oxides. Hydrogen in ZnO can occupy interstitial and substitutional sites; in both forms H is an acceptor and a donor, so it can cause n-type conductivity. In conclusion, some progress has been observed in understanding unintentional n-type conductivity in ZnO. Also nitrogen can act as a deep acceptor when substituted for some of the oxygen in TiO₂.



Symposium DD: Transport Properties in Polymer Nanocomposites II

Invited Speaker: Choongho Yu, Texas A&M University

DD8.3: Organic Nano-composites for Thermoelectric Energy Conversion

Yu considers carbon-based organic composites to be excellent for thermo-electric energy harvesting. Current thermoelectric devices with semiconductors connected in series are used for both cooling and energy harvesting. These state-of-the-art thermoelectric devices contain a Bi-Te-Pb-Sb alloy, which exhibits good properties but is very inexpensive and toxic.

So Yu and colleagues decided to try harvesting energy using polymers, which are inexpensive, light, flexible, and non-toxic. However, polymers tend to be poor electrical conductors, while thermoelectric conversion requires high electrical conductivity and low thermal conductivity. The researchers achieved these parameters using single-walled carbon nanotubes (SWCNTs) and decoupling conductivities. They controlled the junctions and surfaces by coating the SWCNTs, which caused the transfer property to decrease dramatically. Also by introducing PEDOT connections between SWCNTs it is possible to tailor the device for a specific application.

ABOUT THE MEETING SCENE

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