ICMAT 2011 conference held in Singapore

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The sixth International Conference on Materials for Advanced Technologies (ICMAT-2011), organized by the Materials Research Society of Singapore (MRS-S), was held on June 26 to July 1, 2011 in Singapore. The program covered various aspects of materials science, engineering, and technology, including the science and technology of graphene; topological insulators; nanostructures of various materials; metamaterials; photovoltaics, including dye-sensitized solar cells; and lithium-ion battery materials for electric vehicles (EVs). A few of the research highlights follow.

Nobel laureate Andre Geim (University of Manchester, UK), in a plenary talk, enumerated the unique physical and chemical properties of graphene (a single layer of carbon atoms) and why scientists and engineers throughout the world are excited about exploiting it for potential applications. Geim said that during the last two years the quality of synthetic graphene has improved greatly. Eventually, manufacturers will have the ability to make graphene in ton quantities and kilometer lengths. A transparent, flexible, rectangular sheet of graphene with a diagonal of 30 inches has already been made, he said. Low-temperature charge-carrier mobilities of a few million cm^2/Vs have been demonstrated. Geim said that when exposed to fluorine, graphene becomes a wide-bandgap semiconductor and the fluorographene also acts as "two-dimensional Teflon."

Kicking off the symposium on Advanced Materials for Energy Storage Systems (symposium N), Keynote Speaker Gebrand Ceder of the Massachusetts Institute of Technology, USA (MIT) showed recent results on the Li-ion battery cathode material $LiFePO_4$. His group studied the system with a combination of first-principles calculations and molecular dynamics simulations and calculated the mixing energy as a function of Li concentration. They find that 30 meV of overpotential is required to access the solid solution, and furthermore that neighboring nanoparticles of $LiFePO_4$ go through the solid solution sequentially during cycling, one giving up all of its Li before its neighbor begins to de-lithify. He said that the absence of nucleation in this model is much more compatible with the observed high transformation rates and posed the question of whether this model can be extended to other fast two-phase systems, like $LiMnPO_4$ and $Li_4Ti_5O_{12}$. Furthermore, he showed a sampling of data from the Materials Genome Project, a database project he founded in order to help researchers data-mine scientific trends in materials properties. The project has thus far generated and compiled data for over 15,000 compounds, focusing on potential electrode materials for Li-ion batteries. To demonstrate the power of the approach, Ceder discussed some of the results comparing the stability of a range of oxides and phosphates. Though conventional wisdom holds that phosphates are much safer than oxides, his data mining found that oxides are only moderately less stable than their phosphate counterparts at a given voltage.

In symposium S on Metamaterials, Nikolay Zheludev (University of Southampton, UK) reported that his group's goal is the development of nonlinear, switchable metamaterials for all-optical data processing, storage, and telecom switching. He defined the ultimate nonlinear medium as one in which "all atoms within the light absorption length absorb a photon." Zheludev described four possible paths toward the goal: (1) hybrid metamaterials consisting of a nonlinear medium plus a plasmonic metamaterial; (2) a phase-change material plus a plasmonic metamaterial; (3) a reconfigurable metamaterial that can change size mechanically; and (4) a flux quantization metamaterial. Various materials his group has considered and investigated are carbon nanotubes (CNTs) and graphene coupled with a metamaterial (gold) or with nonlinear metamaterials and superconducting metamaterials (e.g., yttrium barium copper oxide and Nb). The latter two are interesting because of their extraordinary transmission capabilities and Fano resonances (a type of resonant scattering phenomena that gives rise to an asymmetric line-shape), Zheludev said.

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Masafumi Yamaguchi (Toyota Technological Institute, Japan), in symposium O (Photovoltaic Materials and Devices), presented Japan's roadmap, up to 2025, for photovoltaic (PV) cells. Their mid- to long-term plan slates nearly 30 billion yen (~USD$385 million) to reach a target of 14 yen (~USD$0.18) per kilowatt-hour by 2020, with a module production cost of 75 yen (~USD$1) per watt. Target module conversion efficiencies for that period range from 20% for wafer-based Si technologies to 10% for dye-sensitized solar cells. Yamaguchi particularly highlighted the push in multijunction cells, as demonstrated by his research group, which seeks to aim for efficiencies of 45% for a cell and 35% for a module.

In the same symposium, Andreas Bett (Fraunhofer Institute for Solar Energy Systems, Germany) made the case for

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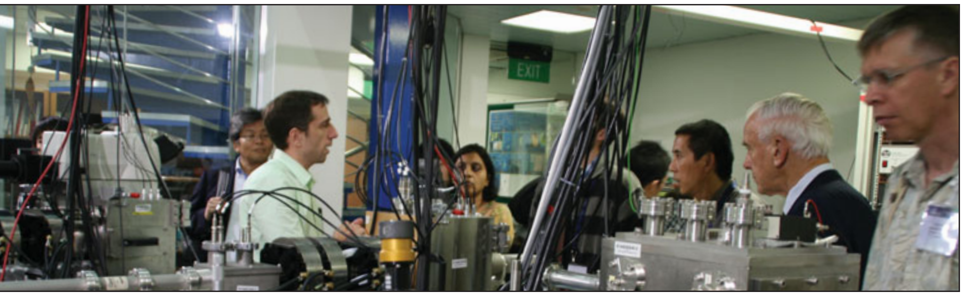

large-scale development and deployment of III–V multijunction solar PV cells. The current industry standard is an efficiency of 38–40%, reached with GaInP/GaInAs/Ge multijunction cells. Bett said that the high cost can be brought down by shrinking the cells and implementing onboard solar concentrators that provide a 500- to 1000-times concentration. The resulting cells are fabricated at high densities, for example, 1200 on a single 4-in. Ge wafer, and have been deployed in centralized power stations in the United States. He cited 25% efficiencies and an energy payback time of less than 10 months as motivators for the technology. Bett outlined three thrusts of their work at Fraunhofer, aiming to exceed the industry standard: First, tackle the lattice mismatch of III–V semiconductors with Ge, using buffer layers to “marry” layers with differing lattice constants. The second thrust is using additional layers to capture more of the solar spectrum, and third is the development of III–V solar cells on Si substrates by direct wafer bonding.

Stuart Parkin (IBM Research, USA), in symposium A (Nanostructured Oxides, Interfaces, Heterostructures, and Devices), described results for vanadium oxides, VO_2 and V_2O_3, well-known low-valent oxides that exhibit a semiconductor-to-metal transition upon heating and which are used as temperature sensors. For films grown by pulsed laser deposition and molecular beam epitaxy, his group measured the resistivity as a function of applied electric field and observed a shift in the transition temperature relative to the bulk materials. The critical field strength for the transition can be varied by oxygen pressure during growth, which adjusts the film stoichiometry. They found that, as the electric field is turned on, the resulting current through the films initially decreases. Once critical potential is reached, the current shoots up like a regular Mott insulator. This unusual “incubation period” before the transition is not consistent with the usual theoretical models for metal–insulator transitions. They describe it with a new model: Highly localized *d* electrons undergo Zener-tunneling as the field is applied, becoming localized in a now-filled *d*-band of a neighboring atom rather than contributing to a current. Thus, a higher field is required before critical carrier densities are reached for metallic behavior. He added that the model is consistent with their computational investigations.

In symposium II on Computational Science of Transport Phenomena in Materials, Su Ying Quek (Institute of High Performance Computing, Singapore) showed that first-principles calculations can deliver quantitative trends for electronic charge and heat transport through single-molecule junctions. In understanding molecular-level electronics, she said that two of the key challenges are developing a physical understanding of transport and of the structure-conductivity relationship. Quek and co-workers calculated the electronic structure of organic molecules on metallic surfaces, compensating for the shortcomings of density functional theory, resulting in remarkably good agreement between theory and experiment. The method has proven successful for studies of amine- and bypyridine-Au single-molecule junctions. For the latter, Quek’s group found that the bonding angle of the molecule on the surface heavily influences transport due to the different symmetry of the molecule and surface bonding states. From the calculations, they rationalized the observation of two distinct conductive states seen in the molecular break junction experiments performed by their collaborators.

Control over surface plasmon resonance wavelengths of conductive nanoparticles by the use of semiconductors has been described and discussed by Toshiharu Teranishi (Tsukuba University, Japan) in symposium B (Synthesis and Architecture of Nanomaterials). In a metal nanoparticle, absorbed light can collectively oscillate the electrons on the metal surface, a phenomenon called “localized surface plasmon resonance” (LSPR). In the local area of the excitation on the metal surface, and the surrounding area, the electric fields increase by several orders of magnitude, which can lead to enhanced electric, optical, and chemical properties. Teranishi said that it is possible to selectively tune the LSPR across a broad light spectrum by many different methods: The first and most obvious way is to change nanoparticle size and/or shape, since LSPR is an inherent surface effect. Also, changing the surrounding solvent, or bringing two nanoparticles in close proximity during synthesis, will achieve enhanced LSPR. The third method that Teranishi promotes is changing the charge-carrier density. Gold and silver nanoparticles have charge-carrier densities on the order of 10^{23} per cm^3, whereas the carrier density in conductive metal oxides/sulfides like, for example, indium tin oxide (ITO) and copper sulfide (Cu_7S_4), is two orders of magnitude less ($\sim 10^{21}$ per cm^3). These can be used to tune LSPR in the near-infrared region. Furthermore, introducing defects as charge carriers lead to a fine tunability of the LSPR in this newly accessible region.

Plenary speaker Yin Chang Boey (Nanyang Technological University,

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Singapore) discussed the design, development, and testing of polymeric materials for biodegradable cardiovascular implants. His group's goal is to replace the presently used metallic stents with a polymeric stent that self-expands at body temperature, maintains its structural integrity for three to six months, fully degrades after nine months, and releases multiple drugs at controlled rates over the lifetime of the stent. They experimented and succeeded with double-layered hollow tubes, with the interior layer made of the polymer poly-(L-lactic acid) (PLLA) and the outer layer of poly-(lactic-glycolic acid) (PLGA), both biodegradable polymers. By varying the thickness of the layers, the rate of degradation in the body could be controlled. Boey said that their polymers have the benefit of incorporating drugs into their structures, which is an improvement over metal stents that can only support drugs on their surfaces. This allows an infusion of a higher concentration of drugs into a layer, and to vary the drug type from layer to layer, if desired.

Boey reported great success with this approach in tests carried out on animals. The polymer stents self-expand in 3–10 min to open the clogged blood vessel; they degrade layer-by-layer at rates controlled by the thickness and composition of the layers; they deliver high concentrations of drugs over a long period of time; they encourage overgrowth of a protective epithelial layer; and they biodegrade inside this epithelial pocket, so that the degradation by-products do not enter the bloodstream, where they might cause a stroke. Cross sections of removed blood vessels revealed an open artery and good blood flow in the region of the degraded stent after 60 days. Boey said that much more testing needs be performed before these biodegradable polymer stents might be ready for use in humans.

In symposium F (Toxicology of Engineered Nanomaterials), Suresh Balasubramanian of the National University of Singapore (NUS), reported results of studies on the effects of nanoparticles of gold, with diameters of 20 nm and 7 nm, introduced into rats through inhalation and injection. Their group found that inhaled particles tend to accumulate primarily in the lungs and olfactory bulb (nasal pathway), although some were transported through the bloodstream to the aorta, spleen, and kidneys, for example. Injected particles tended to follow the bloodstream and deposit in organs across the body, although some made it back to the lungs. Surprisingly, Balasubramanian said, very few nanoparticles were found in the urine of the animals, which means that they are not passing through the animal at all. Such studies are of relevance, since there is growing concern over the toxicity of handling and use of nanoparticles to humans and the environment. It was pointed out that detailed studies of various systems of nanoparticles are urgently needed.

Other plenary talks of ICMAT 2011 were delivered by Nobel laureates Albert Fert (Unité Mixte de Physique CNRS/Thales and the Univ. Paris-Sud, France), Ada Yonath (Weizmann Institute, Israel), and Klaus von Klitzing (Max-Planck-Institut für Festkörperforschung, Germany), as well as Joachim Luther (Solar Energy Renewable Initiative of Singapore and NUS), Susumu Kitagawa (Kyoto University, Japan), Charles Lieber (Harvard University, USA), and Jean M.J. Frechet (King Abdullah University of Science and Technology, Saudi Arabia). Fert and Yonath also delivered Public Lectures at the NUS Cultural Center, which were open to the conference attendees as well as the general public, high school and junior college students. Three "Theme lectures" were given by Jonathan Adams (Thomson-Reuters, UK), Qi-Kun Xue (Tsinghua University, China), and D.D. Sarma (Indian Institute of Science, Bangalore, India).

The conference was inaugurated by the Minister for Trade and Industry, Lim Hng Kiang, Government of Singapore. Tan Chorh Chuan, President of NUS, and B.V.R. Chowdari, Organizing Chair of the ICMAT 2011 Conference, also from the NUS, welcomed the gathering on the first day of the weeklong conference. The Ambassador of France and the Indian High Commissioner also addressed the conference.

More reports can be found online at www.mrs.org/meeting-scene/.

Conference on Stress and Vibration Analysis to be held in Glasgow

http://mpsva2012.iopconfs.org

The Modern Practice in Stress and Vibration Analysis Conference will be held in Glasgow, UK, on August 29–31, 2012. The conference will present international research in the fields of vibration analysis and stress analysis and technical areas where they intersect.

Among the confirmed speakers are J.R. Barber (University of Michigan, USA) who will present a talk on "Frictional systems under periodic loads"; W. Lacarbonara (La Sapienza University, Rome, Italy), "Nonlinear dynamics enabled systems design and control"; F. Pierron (Arts et Métiers, Paris Tech, France), "A novel photomechanical approach to dynamic testing of materials"; W. Ostachowicz (Polish Academy of Sciences, Gdansk, Poland), "Structural health monitoring by means of elastic wave propagation"; and J. Warminski (Lublin University of Technology, Poland), "Nonlinear phenomena in mechanical systems dynamics."

The abstract deadline is March 14, 2012.

The conference is organized by the Institute of Physics Applied Mechanics Group and co-sponsored by NAFEMS. It is endorsed by the Materials Research Society.

For further information, visit http://mpsva2012.iopconfs.org. □

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