MRS and SMM organized International Materials Research Congress 2011 held in Cancún

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"If you get a [scientific] result that you believe in, then fight for it," advised Dan Shechtman of the Technion—Israel Institute of Technology and Iowa State University during his plenary address at the **XX International Materials Research Congress (IMRC) 2011**, held in Cancún on August 14–19. Shechtman's tenacity, recognized recently with the honor of the 2011 Nobel Prize in chemistry, paid off in materials advances made since his controversial discovery of quasicrystals in 1982. Shechtman was one of four plenary speakers at the conference chaired by **David Cahen** of the Weizmann Institute of Science, Israel; **Andrea Hodge** of the University of Southern California, USA; **Sergio Mejia Rosales** of the Universidad Autonoma de Nuevo Leon, Mexico; and **Armando Salinas** of CINVESTAV-Saltillo, Mexico. The Materials Research Society (MRS) co-organized with the Sociedad Mexicana de Materiales (SMM) 10 of the 23 symposia and the Brazil-Mexico Nanotechnology Center joined as a co-organizer of a symposium on the Center.

Plenary presentations

The discovery of quasi-periodic materials by **Dan Shechtman** of the Technion (Israel) and Iowa State University (USA) has redefined "crystal." In his plenary address, Shechtman showed the page of his transmission electron microscope logbook from April 8, 1982, when he performed selected area diffraction on a pitch black grain of an Al-25%Mg sample and saw a diffraction pattern that revealed tenfold symmetry, a forbidden crystallographic symmetry state. About five years later, through x-ray diffraction data, Shechtman demonstrated fivefold rotational symmetry. These crystals were not strictly periodic, so they defied the definition of crystallinity that had been accepted for 70 years. Shechtman had discovered quasi-periodic crystalline materials. Instead of a constant distance between each atom in the lattice, the ratio of distances varied in accordance with the Fibonacci series, hence the term "quasi-periodic." This paradigm shift led to a formal redefinition of the word crystal: "By crystal we mean any solid having an essentially discrete diffraction diagram, and by aperiodic crystal we mean any crystal in which three-dimensional lattice periodicity can be considered to be absent." During his talk, Shechtman recounted the challenges he faced proving his discovery. He noted the "soft" wording of the new definition, and said, "suddenly the society of crystallographers became modest. And a good scientist is a modest scientist."

Sumio Iijima of Meijo University in Nagoya, Japan, renowned as one of the major contributors to early work on carbon nanotubes, addressed the science and industrial applications of carbon nanotubes (CNTs) and their associated materials, single-walled carbon nanotubes (SWCNTs), carbon nanohorns, and graphene. "It is okay for scientists to publish their results about carbon nanotubes in *Science* and *Nature*," he said, "but in industry they keep saying, 'Please bring me one kilogram of this material.'"

Though the field has not advanced enough to be able to supply such quantities yet, much progress has been made. Starting with early samples of CNTs grown vertically on a 2 cm × 2 cm Si substrate that needed relatively expensive helium gas to fabricate, laboratory scientists can now produce 50 cm × 50 cm samples of CNTs grown on a stainless-steel foil substrate using the cheaper, more readily available nitrogen gas in place of helium. One 12-m-long reactor system can produce 600 g/day of SWCNTs. The stainless-steel foil substrate is making roll-to-roll continuous processing of SWCNTs a possibility, with the ability to reuse the substrate over and over.

Industrial applications to date include a wafer-based strain sensor made of aligned CNTs on a poly(dimethylsiloxane) polymer substrate; a fully stretchable CNT rubber with 300% strain capacity, from which devices can be made in which every component, including electrodes, is stretchable; and a silicon rubber-like SWCNT that shows no dependence of viscoelasticity on temperature over the range of 96–1000°C.

Chairs of the **IMRC XX** *(left to right):* **David Cahen** (Weizmann Institute of Science, Israel), **Armando Salinas** (CINVESTAV-Saltillo, Mexico), **Andrea Hodge** (University of Southern California, USA), and **Sergio Mejia Rosales** (Universidad Autonoma de Nuevo Leon, Mexico).

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Returning to basic research, Iijima spoke about different methods of modifying SWCNTs by doping. For "nanopeapods," SWCNTs are doped with Er and N trapped inside C_{80} fullerene cages, and photoluminescence mapping of SWCNTs involves inserting the organic molecule coronene into SWCNTs and observing any interaction between the molecules and the nanotubes. Doping carbon nanohorns with aggregate particles might be used for storage of fluorine gas, making fuel cells and supercapacitors, or delivery of anti-cancer drugs to a tumor, according to Iijima.

He also discussed developments in graphene fabrication and carbon nanomaterial analysis. Synthesis of large-area sheets of graphene at low temperatures has been demonstrated by the production of a 30-in. (diagonal) transparent graphene sheet in a roll-to-roll process. In terms of analysis of nanomaterials, spherical aberration-corrected high-resolution transmission electron microscopy instruments are providing unprecedented structural and elemental resolution. Using single atom spectroscopy at low voltages of 30 kV, researchers can distinguish between La and Ce atoms, which are separated by just one atomic number, which Iijima called "the ultimate elemental mapping."

Plenary speaker **Ivan Schuller** of the University of California–San Diego said, "If you make nanohybrids, put them next to each other, and measure them fast, you will find many surprises at the nanoscale." Characterization at the atomic level is important for Schuller because nothing is perfect or as expected at the atomic scale, and small changes in structure can lead to big changes in properties. He focused his talk on three aspects of ultrafast nanoscale technologies: short length scales, the proximity of dissimilar materials, and the fast time response in properties that can occur under these conditions.

Regarding the first of these, Schuller talked about the vortices that can be created when magnetism is confined to small dimensions. The surprising revelation is that the charge can go in one direction and the spin in another. Using magnetic nanodots, researchers have created a magnetic vortex in Ni with a diameter of only 15 nm. Schuller next described how by placing two ferromagnetic materials on top of a normal metal, he obtained what he called the "real Cheshire cat effect—the smile without the cat." In this case, a non-local spin-valve effect produces a situation in which there is no current flow in the circuit, but a voltage still develops—the voltage without the current.

In terms of proximity, Schuller talked about the exchange bias effect that occurs when a ferromagnet (FM) and an antiferromagnet (AFM) are brought together. The hysteresis loop is shifted away from zero, which makes the read heads on magnetic disks possible. On cooling the FM/AFM hybrid, the magnetic moment suddenly goes in the opposite direction of the field, Schuller said.

Measuring things quickly can capture phenomena never seen before, according to Schuller. He described a "pump/probe" analysis, in which he creates an FM/AFM junction, pumps it with a laser, and then probes the sample 60 ps later. "You get a huge change in the magnetic field, which is totally unexpected," Schuller said. If you waited until a couple hundred picoseconds to do the probing, you would miss this "induced phenomenon" entirely, he said.

Eduard Arzt of Saarland University, Germany, gave an unprecedented "live performance" during his plenary address in which he used a small poly(dimethylsiloxane) polymer tube about one inch long to pick up a glass plate measuring a few square inches, using biomimetic properties derived from gecko feet. To release the adhesion, he merely pushed down lightly on the column, effectively creating a pressure switch: the fibers buckled and lost all adhesive properties temporarily.

Arzt has been fabricating biomimetic structures in his laboratory for decades now, and has become particularly well known for his attempts to imitate the gecko's feet. The "adhesion organs" of geckos consist of a hierarchical structure of lamellae—basically hairs 100–300 nm in diameter—that can adapt to any surface. The "pull-off force" increases with the number of mesocontacts made. He and his group have been constructing adhesion design maps that plot fiber

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radius versus Young's modulus; these maps have revealed the importance of the "condensation limit," which is the point at which the hairs are too fine and stick together in clumps, entirely eliminating their ability to adhere to a surface.

Possible applications of a scaled-up production process for polymeric adhesives based on hierarchical structures include tires, band-aids, construction, and robotics. Arzt is particularly excited about work he and his team are doing in collaboration with surgeons to produce a "gecko tape" that can repair ruptured eardrums. The tape would also have to act as a scaffold for tissue growth, and eventually biodegrade. Many challenges remain in this area, including determining the acoustic effects of the tape.

Technical highlights

The experimental realization of isolated sheets of graphene has given rise to numerous questions regarding the study of new physics and the possibility of achieving novel devices, said Gerardo Naumis of the Universidad Nacional Autónoma de México. Due to its two-dimensional character and electronic properties, graphene is the natural candidate to replace silicon in silicon-based technologies. The main problem in considering graphene for this purpose is its non-semiconductor behavior. Intense research has aimed at exploring routes to open a bandgap in this system.

One of the possible routes to opening a gap is through doping. Naumis demonstrated that it is possible to induce a transition from a metallic to a semiconductor state in this way. He also discussed the application of electromagnetic waves and strain to an isolated sheet of graphene. In the first case, he showed that electromagnetic waves induce nonlinear effects in conductivity and optical properties. The application of strain produced a bending of the surface. Here, it was necessary to consider the movement of an electron in a curved space. To understand this, ideas were drawn from relativity. Finally, Naumis discussed the electronic properties of graphene nanoribbons, which show metallic or semiconducting behavior depending on their width.

A principal advantage in using hydrogen to replace gasoline in cars is that hydrogen is abundant and non-contaminating. Only 5–6 kg of hydrogen is needed to run a car for 500 km. However, because hydrogen is a gas, storage problems limit its use as a fuel. One hydrogen storage alternative may be accomplished through use of porous materials. Due to their large specific surface areas and light weights, these materials could fulfill the practical requirements for easy cyclic adsorption and desorption of hydrogen near room temperature. Julio A. Alonso of the Universidad de Valladolid, Spain, has explored the properties of porous carbide-derived carbon materials with molecular dynamics simulations. Nanoporous materials were created by removing metallic atoms in metal carbides, after which the system was allowed to relax. Following the relaxation, the formation of interconnected pores in the compound was observed. One of the main results of this study is that pore size seems to be correlated with hydrogen storage. Another strategy explored the possibility of storing hydrogen by doping carbide-derived materials with metals. In particular, Alonso examined the interaction of hydrogen molecules with Pd-doped nanoporous carbon materials, concluding that the dispersed Pd atoms in the porous material can improve hydrogen storage.

Research work was presented related to recent advances in instrumentation. In one example, Marie-José Casanove of the Université de Toulouse, France, discussed unexpected capabilities of spherical aberration-corrected high-resolution transmission electron microscopy (HRTEM) to localize and quantify atoms in alloys, thereby accounting for composition fluctuations. After first discussing the older methods of digital analysis of lattice images and local composition measured by strain analysis, she said that a new technique was clearly needed.

Using HRTEM at 200 kV, fitted with a spherical aberration corrector, Casanove and her colleagues chose to examine $Si_{0.7}Ge_{0.3}$ because the material has very few defects and the two elements of the alloy are very close in atomic mass. The researchers fabricated a controlled thickness of this alloy on a Si substrate to give them a reference region. In the HRTEM, the Si appeared as white dumbbells. In the Si substrate they observed no speckle formation, but they saw speckled regions—strong variations in brightness—in the alloy region.

To determine the origins of these variations, the researchers ran a Stillinger-Weber semiempirical potential atomic simulation and compared it with the HRTEM images. They found that the standard deviation in the mean peak intensity was much higher (19.4%) in

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the $Si_{0.7}Ge_{0.3}$ region than in the Si region (1.70%). This showed a clear correlation between peak intensity and the fraction of Si in an atomic column. Casanove concluded that spherical aberration-corrected HRTEM images can be sensitive to alloy composition fluctuations, and that there is a clear correlation between the local composition and the image contrast.

Claudiu I. Muntele of Alabama A&M University in the United States showed two case studies of environmental applications in which particle-induced x-ray emission (PIXE) was used for the identification of elements. PIXE is an analytical method which allows the identification of ions based on x-rays. Muntele's first case study concerned an investigation of pollution across Europe.

Pb concentration was highest in large cities, while Zn correlated with automobile traffic. In a second case study, PIXE was used to identify the elements of coal ash from samples of ash released from an accidental spill at a Tennessee Valley Authority power plant in 2008.

Christian Boller of Saarland University, Germany, spoke of work on using electromagnetism to detect defects in bulk structural materials. Magnets have domains separated by Bloch walls. Under an applied field, the Bloch walls move. In moving, they interact with microdefects that occur at the initial onset of structural damage. For instance, Bloch walls become pinned at imperfections in the structure. Boller proposed that researchers could learn a lot about what is happening in the early stages of damage processes by monitoring the Barkhausen noise that is generated when the Bloch walls move. Barkhausen noise is characterized by a series of abrupt changes in the magnetization of a substance when the magnetizing field created in a metal piece is gradually altered. These changes in magnetization can be detected electrically as changes in the signal of a sensing coil placed around the metal sample. There is a correlation between the applied stress and the Barkhausen noise, Boller said. If the amplitude of this noise in two orthogonal directions in a material is measured, something about the structures with which the Bloch walls are interacting can be determined.

For example, in the fatigue of steel specimens, Boller and his colleagues found a correlation between the surface roughness of the fatigued metal and the measured Barkhausen noise. In residual life assessments of coal drag lines, the traditional procedure is to use the Vickers hardness test, which is destructive. Boller achieved the same results nondestructively by monitoring the Barkhausen noise. In analyzing a copper-steel steam pipe that fractured in a coal power plant, the researchers found that Bloch wall movements induced by mechanical load or by magnetism are analogous. This makes it possible to monitor the Barkhausen noise in a pipe and replace it before it bursts. Boller concluded that Barkhausen noise can be used as a means for effective stress and damage monitoring in structural metals.

Along with the technical sessions, IMRC presented poster sessions. As part of the SMM-MRS Poster Award Exchange program, the three first-place winners will travel to San Francisco for the 2012 MRS Spring Meeting, where their winning posters will be on display. The three first-place poster award recipients are Benjamin Portales Martinez, "Synthesis and characterization of Ni-Mo-W carbides produced by catalytic via"; Alvar Paredes-Puerto, "Biocompatibility of polyurethane urea elastomers for cardiac tissue engineering"; and Carlos Andrés Ortiz Cardona, "Optical properties of zinc sulfide thin films doped with rare earths for photovoltaic applications."

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

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