MPA MaterialsMatter

November 2008

Photos: Robb Kramer, ADEPS

Gabriel Montaño

Big-picture nanoscientist

By Tom King
ADEPS Communications

Gabriel Montaño is something of a contradiction. For a young man, he sees the world from an unusually deep and timeless perspective. His specialty is not philosophy, however, it's nanotechnology—the science of building things on an extraordinarily tiny scale.

"My interests in nanotechnology are driven by biological questions. I try to understand a biological process, and then attempt to recreate it."

Montaño, a Los Alamos staff member in MPA-CINT, directs a nanotechnology laboratory at the Center for Integrated Nanotechnologies' (CINT) Core Facility in Albuquerque.

He's fascinated with bio-molecular optical devices. "My interests in nanotechnology are driven by biological questions. I try to understand a biological process, and then attempt to recreate it," he says. He's intent on assembling microscopic mechanisms that convert light into energy. He takes his cue from simple, elegant structures in plants that have been converting the Sun's light into energy for more than 3,000 million years.

Andrew Dattelbaum, his closest collaborator, explains that they are assembling proteins and other substances into photosynthetic membranes an astonishing five nanometers thick—that's 200 billionths of an inch. If you were only five nanometers tall, a strand of spider's web would seem 36 miles thick.

Montaño admits with a grin that his greatest breakthrough could have disintegrated in the laundry.

As a graduate student, he was attempting to isolate a certain protein that had long confounded his peers. After hammering on the problem, he set it aside to gain perspective. While relaxing, he jotted a fresh concept on a

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Los Alamos NATIONAL LABORATORY

From Toni's Desk

Greetings to all of my colleagues in the Materials Physics and Applications Division! I write this as I begin my tenure as MPA Division Leader. I am honored to have been selected for this position and I hope that my actions will demonstrate that I really deserved this privilege. I would like to thank Alex Lacerda for his excellent leadership of MPA Division over the past year. Alex worked hard to manage the various aspects of the Division through a period of change and transition. Alex has now resumed his role as Center Leader for MPA-NHMFL, playing a critical role leading the magnet lab.

In the rest of this note, I would like to share with you my vision for MPA Division.

Given the scientific talent, facilities, and resources in MPA Division, the opportunities for highly impactful science and technology are wide-ranging. To focus this discussion, I will present these opportunities in terms of the Laboratory's recently developed materials strategy, "Science that Matters: Materials for the Future," the purpose of which is to create a materials environment at Los Alamos enabling a materials discovery that enhances and transforms national security, broadly defined. The formulation of this strategy was initially led by Paul Follansbee and is now in the capable hands of David Watkins. The LANL materials strategy is based on capabilities in three focus areas:

- Predictive multi-scale performance—the ability to design materials and manufacturing processes to yield specified objectives.
- Extreme environments—the use of extreme environments and novel diagnostics for the characterization of materials, with the ultimate goal of predicting and controlling behavior.
- Emergent phenomena—the science required to generate new collective forms of matter that exhibit novel functionality and respond in new ways to environmental conditions, enabling the creation of materials with specified functionality.

MPA Division has activities in each of these somewhat overlapping thrusts—ranging from the discovery, characterization, and understanding of exotic phases of materials in high magnetic fields to the design and manufacture of flexible superconducting tapes with high current-carrying capability and to the development of sensor technologies to remotely measure materials properties in the field. As MPA's capabilities and expertise span a range from fundamental materials physics and materials chemistry to the practical application of materials in device technology, I believe the most exciting and compelling science and technology opportunities for MPA will combine elements of all three of these thrusts. In this way, MPA uses its world-leading expertise to create exciting and impactful materials based on concepts of emergent phenomena; uses it range of unique characterization capabilities—including extreme conditions—to develop the understanding required to control the properties of these materials; and, finally, uses its ability to optimize these materials for specific applications in terms of performance, processes, and manufacturing to truly integrate from materials discovery to applications. Successful implementation of such a strategy requires expertise and capabilities available in MPA today, but will also require teaming and coordination across groups in MPA that is not currently in place.

A specific example of a science and technology (S&T) opportunity that would enhance energy security is the discovery and development of a new unconventional superconductor with transformational properties—such as a record high superconducting transition temperature or a significantly higher critical current, via a new approach such as magnetic pinning. The "project" begins as basic research in emergent phenomena, focusing on understanding and controlling competing interactions through a combined synthesis, characterization, and modeling approach. Success requires bulk, thin film, and nanoscale synthesis and expertise resident in MPA-10, STC, MC, and CINT, bulk and nanoscale characterization in MPA-10, STC, CINT, and Lujan, as well as characterization under extreme environments such as high pressures and magnetic fields in MPA-10 and NHMFL, all coupled with theory and simulation resident in T Division. Successful basic research that yields a superconductor with enhanced properties is not the end of the story, as the material must be optimized for applications in terms of its performance, physical properties, and ability to manufacture, ultimately in partnership with industry. Expertise and capabilities, as well as experience in industrial partnerships in MPA-11, MC, and STC will be essential at this stage of optimization of material design, performance, and device integration.

Of course there are many other potential science and technology opportunities for MPA Division that span world-leading basic research to high impact materials applications, and hence, require

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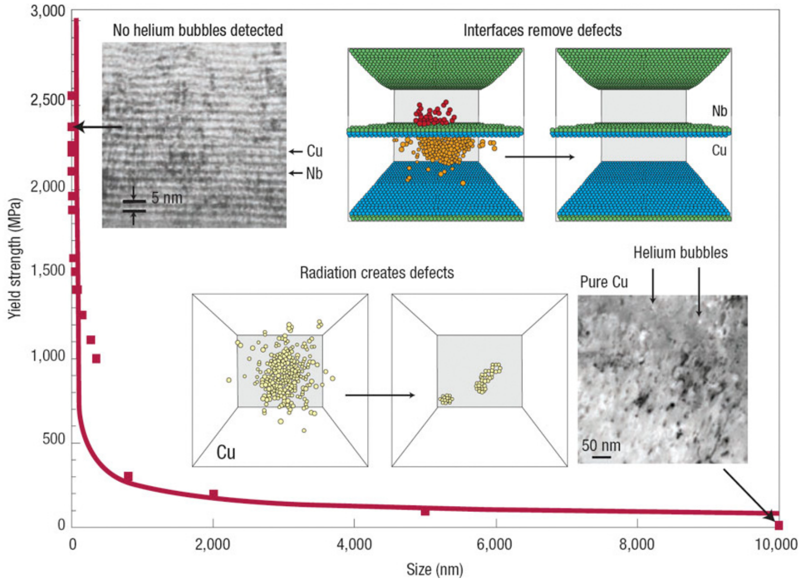
Radiation-tolerant materials research featured in *Nature Materials*

A special issue on nuclear energy was featured in the September issue of *Nature Materials.* A commentary article by R.W. Grimes et al. on materials challenges for future generations of nuclear reactors highlights work from Los Alamos researchers on radiation damage tolerant nanolayered composites via atomic-scale design of interfaces.



▲ *Interfaces act as obstacles to slip and sinks for radiation induced defects. Nanolayered composites such as Cu-Nb provide orders of magnitude increase in strength and enhanced radiation damage tolerance compared to bulk materials. In the example shown, pure Cu and Cu-Nb (5 nm bilayer period) were irradiated at room temperature with He+ ions to a peak concentration of ≈ 5 at.%. While Cu sample showed defect agglomerates, no helium bubbles were resolved in through-focus imaging in a TEM. Atomistic modeling shows that radiation creates point defects that agglomerate in bulk materials but are attracted, absorbed and annihilated at incoherent interfaces in nanolayered composites. The arrows indicate the corresponding strength levels, prior to irradiation, for the pure Cu and Cu-Nb (5 nm bilayer period) samples.*

Nanolayered composites of alternating copper (Cu) and niobium (Nb) layers less than 5 nm thick exhibit remarkable tolerance to radiation damage (provided by helium ion irradiation) and the high strengths characteristic of many nanolayer composites (see figure at right). The structures also suppress helium bubble nucleation and growth of bubbles at elevated temperatures. These materials have a high interfacial area per unit volume, which acts both as obstacles to slip, as well as sinks for radiation-induced defects.

Los Alamos is using an integrated experimental and atomistic modeling approach to investigate the role of the atomic structure of interfaces in providing barriers to slip transmissions and as sinks for radiation-induced defects. The work gives insight on how to tailor the atomistic structures of the interface to enhance material strength and achieve radiation damage tolerance.

Lead scientists for the work cited are A. Misra (MPA-CINT) and M.J. Demkowicz and R.G. Hoagland (MST-8). Key Los Alamos collaborators are J.K. Baldwin, D. Bhattacharyya, M. Nastasi (MPA-CINT), Y.Q. Wang (MST-8); and N.A. Mara (MST-6). The DOE Office of Science, Office of Basic Energy Sciences (A. Misra, PI) supports the research on ultra-high strength nanolayered composites.

Technical contact: A. Misra

Relationships in unconventional superconductivity highlighted at international workshop

The discovery in MPA-10 of a new family of heavy-electron materials, the “Ce115s” ($CeCoIn_5$, $CeRhIn_5$ and $CeIrIn_5$), opened a new window for exploring many of the same scientific problems posed by the high-temperature cuprate superconductors.

One of several similarities between these two seemingly different classes of materials is the ratio of their superconducting transition temperature T_c to the characteristic temperature scale T_F of the electrons that become superconducting. In both families, this ratio T_c/T_F is about 0.2, making the Ce115s also “hightemperature superconductors”, even though T_c and T_F differ by almost two orders of magnitude in these two families. The much smaller temperature scales in the Ce115s have made it possible to study with greater clarity one of the prime issues common to both families, the relationship between unconventional superconductivity and magnetism.

This relationship was discussed at the 2008 International Conference on Strongly Correlated Electron Systems, held in Buzios, Brazil. In a plenary talk, Joe Thompson highlighted MPA-10 discoveries that unconventional superconductivity is necessary for co-existing magnetism in Ce115s. These exciting discoveries were published [Michel Kenzelmann, Th. Strassle, C. Niedermayer, M. Sigrist, B. Padmanabhan, M. Zolliker, Andrea Bianchi, Roman Movshovich, Eric Bauer, John Sarrao and Joe D. Thompson, *Science* **321**, 1652 (2008); Tuson Park, M. J. Graf, L. Boulaevskii, J. L. Sarrao, and J. D. Thompson, *Proceedings of the National Academy of Sciences USA* 105, 6825 (2008)].

Bimetallic actinide complexes enable study of metal-metal interactions

Los Alamos National Laboratory's actinide chemistry research is featured on the cover of *Chemistry: A European Journal*. Research led by Jacqueline Kiplinger (MPA-10) examines preparation routes and physical properties of bimetallic actinide complexes that feature appreciable interactions between metal centers.

The researchers used nitrile insertion chemistry to synthesize bimetallic actinide complexes of thorium Th^{IV}/Th^{IV} and uranium U^{IV}/U^{IV}. These complexes enable the study of electron delocalization and magnetic interactions between actinide ions. The uranium system displays clear signatures of electronic communication between the two metal centers through the π system of the novel dianionic bridging ligand. The results show that these new bimetallic structures are useful platforms to study metal-metal interactions and offer new opportunities to explore the electronic structure and valence delocalization in actinides.

The work, "1, 4-Dicyanobenzene as a Scaffold for the Preparation of Multimetallic Actinide Complexes Exhibiting Metal-Metal Communication," by Eric Schelter (MPA-10), Jacqueline Veauthier (C-IIAC), Christopher Graves (MPA-10), Kevin John (C-IIAC), Brian Scott (MPA-MC), Joe Thompson (MPA-10), Jaime Pool-Davies-Tournear (formerly Los Alamos), David Morris (MPA-CINT), and Jaqueline Kiplinger (MPA-10), appears in *Chemistry A European Journal* **14**, 7782-7790 (2008). The DOE Basic Energy Sciences Heavy-element Chemistry Program, the Seaborg Institute, and the LANL Reines and Directors-Funded postdoctoral programs fund the research.

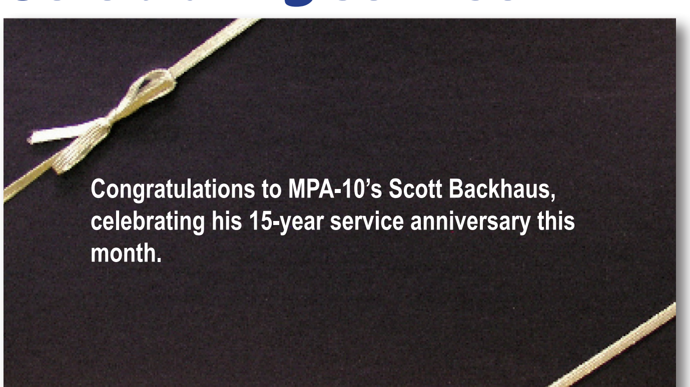
Desk . . *continued from page 2*

expertise and capabilities that span MPA Division. Note that this ability to span fundamental materials research to applications was the premise for the formation of MPA Division. Further, the ability to translate discovery to solutions in pursuit of national security science is the mission of the MaRIE M4 Facility, and therefore, pursuing such a path will enable MPA to define, and ultimately lead, M4 science.

In summary, I believe the most exciting and compelling S&T opportunities for MPA are those where MPA draws upon its world-leading expertise in materials chemistry and physics and its range of unique characterization capabilities to discover and control novel materials with emergent functionality, and then exploits its complementary ability to optimize these materials for specific mission-driven applications in terms of performance, processes, and manufacturing to truly integrate from materials discovery to applications. With its exceptional combination of people, facilities, and capabilities, MPA is uniquely situated to lead the Laboratory, and indeed the nation, in such endeavors. A critical component of this strategy is teaming and coordination across MPA Division, which requires a shared strategic vision across MPA that I hope to develop, in partnership with MPA staff and leaders, over the coming months. Successful implementation of this vision will enable MPA to lead the Laboratory and the nation into a new era of "materials that matter."

— Toni Taylor,
MPA Division Leader

Celebrating service



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To submit news items or for more information, contact Karen Kippen, ADEPS Communications, at 606-1822 or kkippen@lanl.gov.

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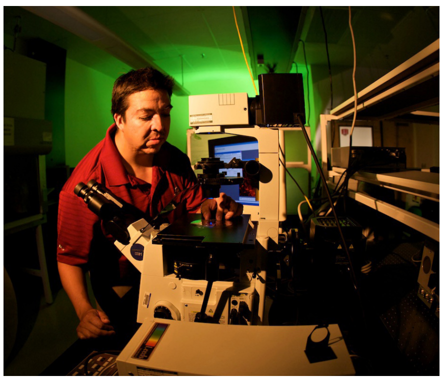
Montaño... *continued from page 1*

cocktail napkin. Thinking the idea might be just another dead end, he stuffed the napkin in a pocket and forgot it. The correct solution, as it turns out, was saved from the laundry. When he realized he had found his breakthrough, Montaño woke his professor in the middle of the night. The professor was first angered, then overjoyed, at the discovery.

Andrew Shreve, soft biological and composite nanomaterials theme leader and Montaño's team leader, sums up his strengths this way, "Gabe is a valuable asset because of his breadth of knowledge across many fields. His experience extends from molecular biology and biophysics to material science and chemistry." Dattelbaum adds, "Gabe's one of the most creative guys we have here."



How does one become such a versatile scientist? It turns out the young Montaño was no "chemistry set kid." As a young man he did well in sports and entered New Mexico State University as an English major. Even after adding chemistry to his undergraduate interests, he still didn't see himself as a scientist. Montaño says the turning point came when Peter Houde, his advisor and mentor at New Mexico State, asked him to perform hands-on research. "Performing experiments—that's when it changed for me, that's where the love of science began," Montaño says.

Montaño later found his niche at Arizona State University with Robert Blankenship, who created a one-of-a-kind program in which small teams were assembled from the various scientific disciplines. At ASU, Montaño discovered the multidisciplinary approach fit him perfectly.

CINT's cross-disciplinary nature also makes it a perfect match for Montaño's versatility. The Department of Energy/Office of Science Nanoscale Science Research Center is a national user facility devoted to establishing the scientific principles that govern the design, performance, and integration of nanoscale materials. Jointly operated by Los Alamos National Laboratory and Sandia National Laboratories, CINT, through its core facility and gateways to both Los Alamos and Sandia provides open access to tools and expertise needed to explore the continuum from scientific discovery to the integration of nanostructures to meet global needs in security, energy, and the environment.

Mentoring is central to Montaño's approach to science. As the child of educators, Montaño says he sees mentoring as the natural progression of science. He takes pride in his work with the Society for the Advancement of Chicanos and Native Americans in Science, where he works to foster under-represented groups. When he mentors young people to discover careers in science, he says he feels he is paying back the valuable lessons he learned from his own mentors. "I owe it to my mentors to pass along the inspiration they gave to me," he says. And in doing so, he helps to create the next generation of scientists. Montaño proudly recalls his first student, Nesia Zurek. He nominated her for a Laboratory award, she won it, and he was there to see here accept the honor. He says, "I watched her grow in my lab as a scientist and as a person…Nesia is a person who will go to grad school and just light it up. I'm so proud."

For a man who deals in a world of the very tiny, Gabriel Montaño sees science as part of a big picture.

My favorite experiment
What: Baseplate photosynthetic complex
Where: Bob Blankenship's laboratory, Arizona State University
When: 1999
The ah-ha moment: While working on a thorny scientific problem, he fished the ultimately correct answer out of the laundry. The breakthrough came when he pushed back and gained perspective. "I found the clarity that comes from free thinking."

Heads UP!

Why recycling is important
As stewards of the environment, we are responsible for preserving and protecting our resources for ourselves and for future generations. To familiarize yourself with the Laboratory's recycle program, see int.lanl.gov/recycle/.

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Drivers need to observe speed limits in the parking garages at TA-3. Employees have reported "cars flying in and out of the parking garage" at a high rate of speed and are concerned that pedestrians could be seriously injured. Please drive safely.

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