Nice Work, Fellows

Each year, the American Physical Society (APS) honors a select group of its members from industry, academia, and government by electing them APS Fellows. This year, the society bestowed the title on 12 members of its Forum on Industrial and Applied Physics whose work, as these examples show, is especially relevant to industry.

Donald P. Monroe has spent his career exploring the physical mechanisms underlying electronic-device performance and reliability, first at AT&T Bell Laboratories and now at Agere Systems (Murray Hill, NJ). "Don is a fundamentalist physicist who has been involved in application issues of virtually all the electronic devices you buy today," says colleague Steven Hillenius, a department director in Agere's Silicon Research Laboratory. "Early on, for example, he used some very fundamental physics to understand how electrons scatter and how doping and surface characteristics affect this mobility."

Fundamental understandings of electron behavior have driven the scaling of semiconductor-device performance and size. Monroe's research, like that of many industrial scientists, spans the spectrum from basic to applied. For users, his insights have led to new ways to increase electron mobility and, thus to faster devices with lower power demands.

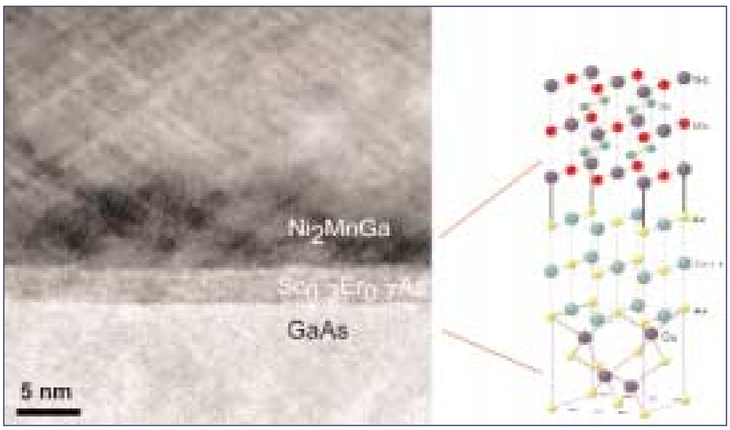


Image of a three-dimensional integrated circuit interconnect based on data acquired using scanning X-ray microscopy at Argonne's Advanced Photon Source (Zachary Levine).

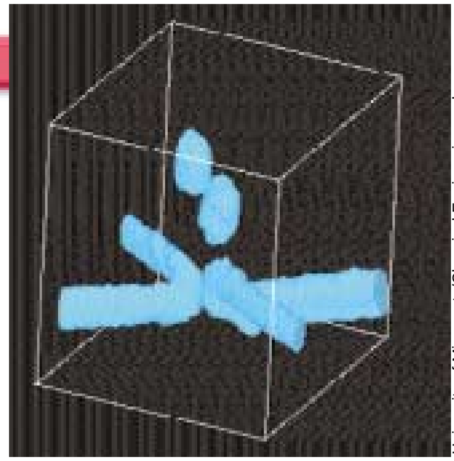
"The way people share information in the semiconductor industry, particularly about fundamental phenomena, has always been very open," Hillenius says. "It is Don's fundamental understandings that have been incorporated into the things we buy."

Bruce David Terris was named an APS Fellow for his novel approaches to high-density data storage. Since joining IBM's Almaden Research Center in 1985, Terris has made several significant contributions to the field.

He and his IBM colleagues pioneered the application of scanning probes in high-density storage using the tips of atomic-force microscopes to record data. In particular, Terris showed that one could achieve read-only data storage using replicated polymer disks with 50-nm features. He also invented a way to keep the probe's tip on a single, 50-nm-wide track for hundreds of hours, which allowed the measurement of wear rates.

Next, Terris's IBM team and Gordon Kino of Stanford University applied a new form of near-field optics called the supersphere solid immersion lens (SIL) to high-density data storage. They fabricated a flying SIL recording head and used it to demonstrate 2.5 gigabits/in.^{2} recording density on a spinning disk at a rate of 3.3 megabits/s.

Since 1998, Terris has focused his research on nanoscale magnetism and the potential use of lithographic-patterned nanoscale magnetic islands for high-density data storage. He initiated this project as a potential approach to delaying the onset of superparamagnetism, the point at which the stability of small written bits is reduced because their magnetic-orientation energy



University of Minnesota/Chemical Engineering and Materials Science

Transmission electron micrograph and ball-and-stick model of a ferromagnetic shape memory alloy atop a single crystal semiconductor with a diffusion barrier interlayer (Christopher Palmstrøm).

is equal to the surrounding thermal energy. Terris and his group recently demonstrated writing and reading of patterned media at 100 gigabits/in.^{2} with a recording head.

For nearly 20 years, **E. Fred Schubert** of Boston University has made innovative contributions to the doping of semiconductors. "His many original and important contributions have had a strong impact on semiconductor technology, and they are employed in a number of devices manufactured today," says H. Walter Yao of Advanced Micro Devices (Sunnyvale, CA).

Starting as a graduate student in Germany, Schubert pioneered delta doping, the confinement of dopants to thin sheets in a semiconductor, and applied it to improve homojunction and heterojunction field-effect transistors and light-emitting diodes (LEDs). At AT&T Bell Laboratories, he showed that compositional grading, combined with modulation doping of interfaces, completely eliminated band discontinuities at heterojunctions.

After joining the Boston University faculty in 1995, he and his collaborators pioneered superlattice doping, which increased by more than an order of magnitude the conductivity in p-type gallium nitrite semiconductors and enabled their greater use in products. "Those superlattices are now a part of the majority of p-type gallium nitrite devices, including lasers, LEDs, and bipolar resistors," Schubert says. He continues the search for improved placement of dopants in superlattices to further increase the hole concentration, mobility, and conductivity.

Zachary Howard Levine of the National Institute of Standards and Technology (Gaithersburg, MD) was cited for using X-ray tomography to demonstrate sub-micrometer resolution of integrated-circuit interconnects. In the mid-1990s, Levine became interested in the quality-control problem of the semiconductor industry as it created features on chips with increasingly higher aspect ratios. Both scanning-electron and transmission-electron microscopy appeared inadequate as chip features became deeper and narrower.

"The ultimate goal was to provide an analytic tool for the semiconductor industry," Levine says. "The major issues were: What is the resolution attainable? What kind of reconstruction algorithms do we need? How do you align the chips?"

He and his colleagues obtained chip samples from Digital Equipment Corp., IBM, and Intel. Using the Advanced Photon Source, a synchrotron-radiation facility at Argonne National Laboratory, the team focused soft X-rays to spot sizes as small as 60 nm. In a series of experiments that demonstrated the usefulness of X-ray tomography, their best resolution was 140 nm in three dimensions.

The challenge now is to develop an X-ray tomography instrument of a size suitable for industrial use. "Such an instrument is under development in the private sector," says Levine.

APS cited **Christopher J. Palmstrøm** "for his original work on metallic compound/compound semiconductor heterostructures and thin film interfacial analysis." The University of Minnesota researcher seeks to create novel materials that have a ferromagnetic metal atop a single-crystal semiconductor. He envisions products derived from this work entering the marketplace in 10 or 20 years.

In today's magnetic random-access memories, magnetic metals and semiconductors "are layered and they communicate with each other, but they are not integral to each other," says Palmstrøm. The ideal situation would be to transfer electrons and holes from the magnetic metal to

FIAP's New APS Fellows

Francesco Cerrina
University of Wisconsin–Madison
For innovative physics applications in the domains of lithography, X-ray optics, and microscopy.

Henry Frederick Dylla
Thomas Jefferson National Accelerator Facility
For sustained contributions to the surface science of materials and the design of ultrahigh-vacuum systems that have enabled a new generation of particle accelerators, plasma devices, and materials processing systems.

Lester Fuess Eastman
Cornell University
For pioneering contributions to the concepts of ballistic transport and piezoelectric doping in ultrasmall III–IV heterojunction transistors for applications in high-speed and microwave power devices and circuits, and for leadership in transitioning electron device technology from university to industrial laboratories.

Lewis S. Edelheit
General Electric Company
For outstanding technical contributions to projection radiography and fast-scan, "fan-beam" computed X-ray tomography systems, and for leadership in bringing world-class commercial medical-imaging systems to the market.

Daniel Mark Fleetwood
Vanderbilt University
For important and broad-based contributions to the understanding of radiation effects and low-frequency noise in microelectronic materials and devices.

Zachary Howard Levine
National Institute of Standards and Technology
For leadership in demonstrating X-ray tomography in integrated circuit interconnects with submicrometer resolution.

Jerry Richard Meyer
Naval Research Laboratory
For fundamental and applied contributions to the physics of semiconductor optical and electronic processes and devices, including new classes of midwave-infrared quantum-well lasers.

Donald Paul Monroe
Agere Systems
For contributions to the understanding of physical mechanisms underlying electronic device performance and reliability.

Christopher J. Palmstrøm
University of Minnesota
For his original work done on metallic compound/compound semiconductor heterostructures and thin film interfacial analysis.

Frances Mary Ross
IBM T. J. Watson Research Center
For her pioneering contributions to in situ studies of materials processes in the electron microscope.

E. Fred Schubert
Boston University
For pioneering contributions to the doping of semiconductors, including delta doping of compositionally graded structures resulting in the elimination of band discontinuities and superlattice doping to enhance acceptor activation.

Bruce David Terris
IBM Almaden Research Center
For the exploration of novel approaches to high-density data storage.

the semiconductor with the electron spin intact. His team is striving to make single-crystal ferromagnetic–semiconductor combinations that interface flawlessly and eliminate spin scattering. "This work goes toward spintronics and the quantum computer," he says.

Another goal is to develop thin films of ferromagnetic shape-memory materials that alter their form in the presence of an electromagnetic field. "Shape-memory materials have a clear advantage in MEMS [microelectromechanical systems] because their work output is greater than piezoelectric materials," says Palmstrøm. "We are now trying to add the ferromagnetic part to actuate the shape changes." Ω

The Forum department is initiated by the American Physical Society's Forum on Industrial and Applied Physics. For more information about the Forum, please visit the FIAP Web site (http://www.aps.org/FIAP/index.html) or contact the chair, Gordon A. Thomas (thomasg@adm.njit.edu).