SENSING INNOVATION

MEMS TECHNOLOGY BRINGS NJIT AND INDUSTRY TOGETHER ON A SMALL SCALE

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MEMS — MICROELECTROMECHANICAL SYSTEMS — are now basic to products ranging from inkjet printers to automobile air bags, and work continues to develop this technology for many new uses. Scientists and engineers at NJIT and American Sensor Technologies (AST) have pooled their talents for one such effort — commercializing a superior MEMS-based sensor for monitoring the flow of gases and liquids. Their work is a matter of microns; a critical component of the new sensor is just a single micron in thickness. At one millionth of a meter, it would take some 1000 microns to stack up to the thickness of a dime.

Essentially, this joint effort involved creating a micron-thick layer of silicon semiconductor material on a flexible substrate by means of a process known as plasma enhanced chemical vapor deposition. The substrate, some 50 microns thick in the prototype sensor, flexes when pressure is applied from below, which in turn causes the electrical resistance of the semiconductor layer to vary. The variations in resistance can be correlated with even minute changes in the pressure exerted by a stream of liquid or gas.

The design originated by NJIT and licensed to AST offers several advantages for many applications, most notably the sensitivity to detect and measure pressures from 0 to 2 pounds per square inch gauge (psig). It is difficult to monitor pressure below 2 psig with other types of comparably sized sensors now on the market. In addition, the combination of semiconductor material on an inert polymer substrate makes the new sensor suitable for operation in corrosive and electromagnetically active environments.

Technology, talent and timing

The development of this unique sensor is much more than the story of a technological breakthrough. It's a saga of entrepreneurial foresight and good timing as well. It also demonstrates how creative research can point the way to other applications as a new technology evolves.

The key players at NJIT include Hee Lim, assistant research professor, and Roumiana Petrova, assistant director of the undergraduate program and special lecturer in the Department of Physics. Petrova and Lim, who earned his PhD at the university, are co-inventors of the new thin-film pressure sensor. A patent covering their innovation is now pending.

But no matter how brilliant a technological concept may be, it won't move far from experimentation in the lab without adequate funding. This is where Gordon Thomas and John Federici, professors of physics, were of assistance. Thomas was interested in thin-film technology for biomedical applications prior to joining the NJIT faculty. Earlier, while he was at Massachusetts Institute of Technology, he had also looked into the fabrication

PHOTOS: BILL WITTKOP

The 16 experimental sensor elements deposited on the flexible substrate shown are only a micron in thickness.

capabilities that Princeton University could provide with respect to chemical vapor deposition.

When Thomas came to NJIT several years ago, he brought his interest in thin-film applications and teamed up with Federici to establish a relationship with the fabrication facility at Princeton. They also secured additional funding from the New Jersey Commission on Science and Technology for the research already under way in Newark. That funding amounted to nearly a million dollars for NJIT. However, one piece was still needed to complete the thin-film sensor picture.

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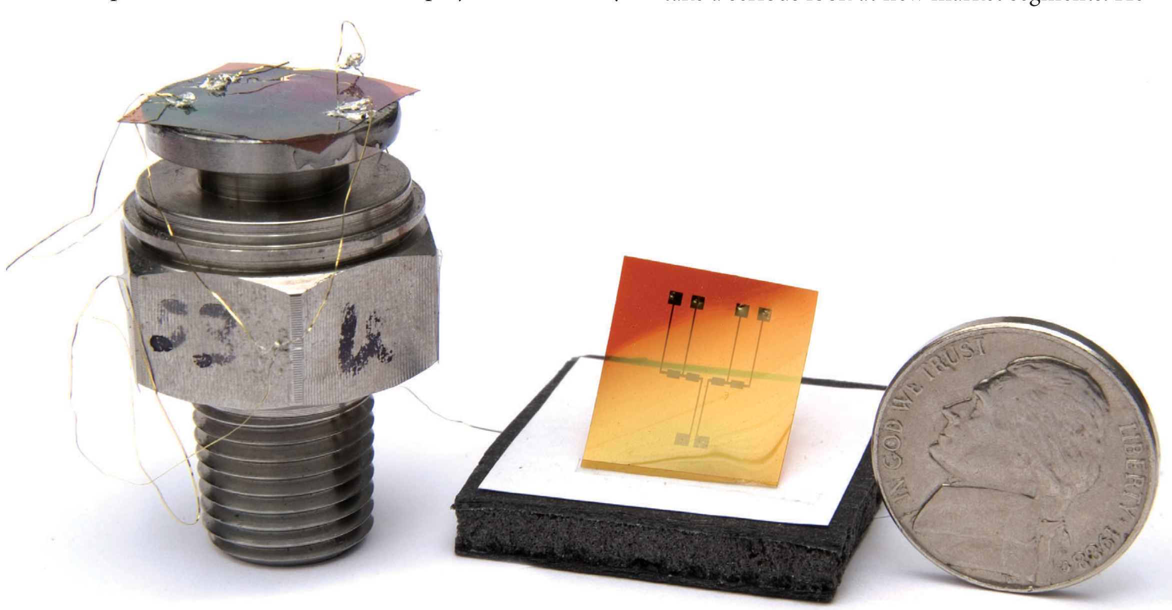
Some very significant classwork

The New Jersey Commission on Science and Technology is charged with promoting economic development in the state along with encouraging technological innovation. To achieve this commercial objective, NJIT needed to find an appropriate partner for the thin-film sensor project. Fortuitously, as the thin-film work advanced toward the point where a patent application was warranted, Petrova was also teaching two graduate courses — Fundamentals of Engineering Materials and Mechanical Behavior of Materials. One of her students, a PhD candidate, was Karmjit Sidhu. He also happened to be AST's vice president of business development.

Petrova says that her classes require completion of a project, which can be related to work a student is currently doing for an employer. As she and Sidhu discussed the possibilities, they realized that a project based on NJIT's thin-film research could be of considerable benefit to everyone involved, including AST.

Sidhu's class project was the starting point for adding an important new product to AST's offerings. Located in Landing, New Jersey, the company is a leading manufacturer of MEMS-based pressure sensors and related process-control components. Incorporated in 1997, AST specializes in supplying products customized for a growing number of clients, including firms that need such technology for hydraulics, water treatment, energy management, and oil and gas processing. In 2004, AST received one of the Finest Private Companies awards given each year by *NJBIZ* magazine to honor the state's 25 fastest-growing privately held companies.

From Sidhu's perspective, the collaboration between AST and NJIT will enable his company to take a serious look at new market segments. He



Mounted in a prototype test unit such as the one on the left, the innovative sensing element on the substrate in the center can detect the slightest variation in the pressure of a gas or liquid.

says, "Working with NJIT significantly extends our reach in terms of research and development. It gives us access to the intellectual and developmental resources of a major research university." These resources, Sidhu adds, could help AST enter especially challenging commercial areas, such as the biomedical market.

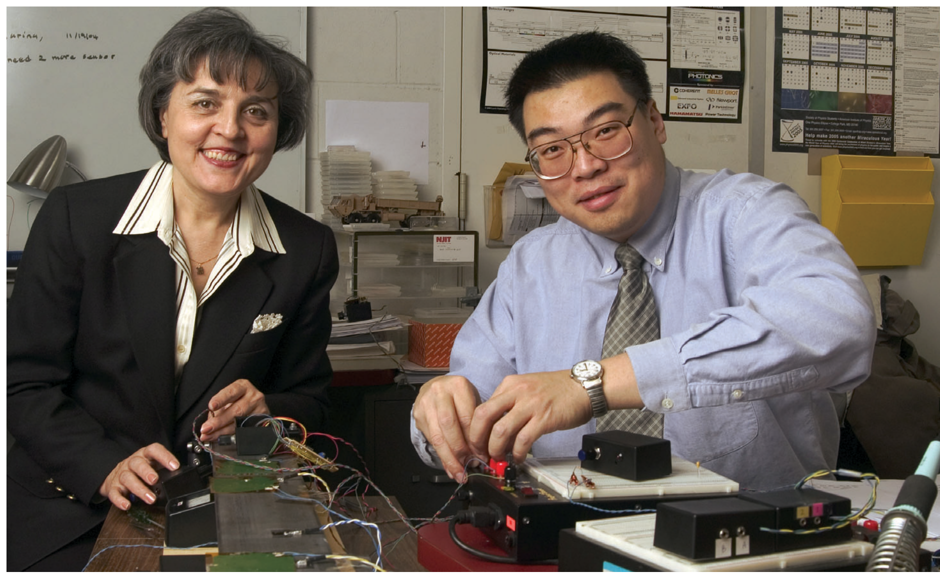
Michael Eldredge, AST's executive vice president, cites the benefits that linkage with the private sector can hold for NJIT. He says that teaming up with a successful company is a much faster track to the commercialization of intellectual property than attempting to acquire the requisite business savvy without an experienced partner. "We've already opened doors to the real world of the marketplace, and we know what to expect when you go through them. It's definitely to the advantage of both NJIT and our company that we work together to explore what lies beyond those doors."

Smart next steps

The genesis of the technology that NJIT has licensed to AST is to be found in the multidisciplinary "smart coatings" research initiated under the leadership of Daniel Watts, Panasonic Chair in Sustainability and executive director of the Otto H. York Center for Environmental Engineering and Science. This work was funded initially by the U.S. Department of Defense, which was interested in coatings for use on vehicles and weapons systems that could sense deterioration and make repairs in surface breaks without human intervention. The department also wanted to investigate the possibility that such coatings could change color and pattern in a chameleon-like manner for camouflage purposes.

Federici, who has contributed to the work with AST, explains that the thin-film concepts basic to creating smart coatings for large pieces of military hardware can also be adapted for use on a much smaller scale and for very different applications — such as the pressure sensor invented by Lim and Petrova. As an example of another application, Federici says that it's possible to develop a "smart decal" just a few square inches in size that might be used to monitor corrosion and metal fatigue in key automotive components. Installed throughout a fleet of trucks, for example, such a device could warn of deterioration by turning on an indicator light or other visible display.

Thomas, along with colleagues at NJIT, the University of Medicine and Dentistry of New Jersey and Harvard Medical School, is continuing to develop thin-film sensor technology on a very small scale in the biomedical field. One project involves incorporating a minute sensor in an implantable shunt that can be used to relieve the abnormal accumulation of cerebrospinal fluid (CSF) within the brain that afflicts individuals with hydrocephalus.



NJIT faculty members Roumiana Petrova and Hee Lim, co-inventors of the MEMS-based pressure sensor licensed to American Sensor Technologies for commercial development

Current shunt designs do not allow for monitoring CSF pressure and flow. Enhancing a shunt with a highly sensitive thin-film sensor would provide this capability. Further, as in the larger AST-licensed version, the shunt sensor's semiconductor layer is deposited on a non-metallic substrate, which minimizes problems that could be caused by ambient magnetic fields.

"This is certainly a versatile technology," Thomas says. "On one scale, you can use it to monitor industrial processes or environmental conditions more effectively, and on another to help people suffering from a condition like hydrocephalus. That's an impressive range of possibilities." ■

Department of Physics: http://physics.njit.edu
Department of Biomedical Engineering: www.njit.edu/bme

For more on smart coatings, see the homeland security section in the *2003 Annual Report*, online in the Publications Library at www.njit.edu.