micro tech nology

TECHNOLOGY

Microtechnology

Changing the world little by little

The Nomad System allows its user to view plans, diagrams, and procedures while keeping hands completely free to manipulate tools. Photo: Microvision

In 1959, theoretical physicist Richard Feynman was the first to explain the potential of small-scale technology.

"I would like to describe a field, in which little has been done, but in which an enormous amount can be done in principle," said the Caltech professor in a now famous talk entitled "There's Plenty of Room at the Bottom."

"What I want to talk about is the problem of manipulating and controlling things on a small scale," he said to members of the American Physical Society. "In the year 2000, when they look back at this age, they will wonder why it was not until the year 1960 that anybody began seriously to move in this direction."

Fast-forward to 2004, and devices dependent on small-scale technologies are firmly embedded in our lives. Though Feynman didn't use the terms "microtechnology" or "nanotechnology" in his talk, they are the small-scale technologies of which he spoke.

The idea of nanotechnology—engineering devices on the scale of atoms and molecules— has captured the imagination of scientists, engineers, and the public.

But for all of its high-tech promise, nanotechnology is still far from practical implementation. Rather, it is microtechnology that is having an immediate effect on our lives through new products and processes, from air bag sensors to computers.

Researchers throughout the Northwest at universities, government labs, and companies are actively involved in developing new microtechnologies and pushing back the frontiers of the field. And they are exploring the interface where micro meets nano.

by Jeff Wolfe

Two Microvision researchers use equipment in the WTC's Microfabrication Laboratory to develop a MEMS device. Photo: WTC

Microtechnology involves the use of objects at the micron level, or one-millionth of a meter. Nanotechnology entails the use of objects a thousand times smaller, or one-billionth of a meter. While microns are used to measure biological cells, like red blood cells, nanometers are used to measure molecules. It's like comparing the distance of a trip across the country to a trip to the local grocery store.

Microtechnologies are built using a top-down approach that uses techniques developed mostly in the semiconductor industry, explains Keith Ritala, manager of laboratories and new technologies at the Washington Technology Center.

"It's called a top-down approach because a solid block of something, usually silicon, is selectively etched or built up into the needed structures," says Ritala. "The process goes from large to small."

The Washington Technology Center (WTC) is a science and technology organization funded by the State of Washington and headquartered on the University of Washington (UW) campus. Its mission is to stimulate growth in the state by helping Washington companies develop commercially viable technology. The center provides companies with access to technical expertise, funding for company projects jointly with universities, and access to microfabrication facilities, among other services.

The most common examples of microtechnology can be found in microelectronics, which include computer chips and most modern electronic components. However, a type of microtechnology that combines micron-sized electrical and mechanical parts is now experiencing growing commercial use. Called microelectromechanical systems (MEMS), they have already enjoyed success as air bag sensors, inkjet print heads, and the read/write heads of hard drives over the last ten years, says Ritala.

A MEMS accelerometer developed by Albert Leung, engineering professor at Simon Fraser University (SFU), Burnaby, B. C., is garnering increasing commercial attention due to its numerous applications and low production cost. The thumbnail-sized accelerometer is said to be more robust than competitive devices and can be manufactured cheaply using techniques developed in the semiconductor industry. Currently, MEMSIC, Inc. of Andover, Mass., is commercializing Leung's invention and has built a facility in China capable of producing 20 million accelerometers per month. Leung says the accelerometer could be used in a variety of products, such as car alarms, earthquake monitors, vehicle rollover sensors, and toys. A Harry Potter wand that utilizes the accelerometer is expected to hit stores in 2004.

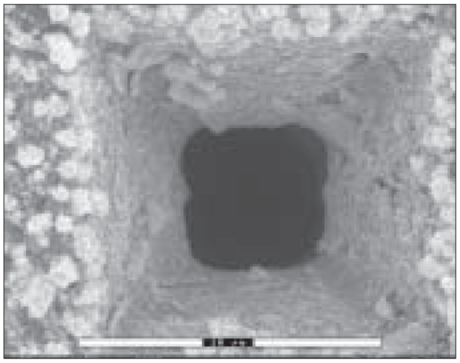
The WTC's Microfabrication Laboratory has been used by a number of companies conducting microtechnology research. One such company is Neah Power Systems of Bothell, Wash.

An emerging leader in micro fuel cell technology, Neah Power is developing a silicon-based micro fuel cell that is nearing the marketplace and has the potential to replace the batteries used in consumer devices such as laptops and cell phones. Because of this potential, the company received a $2-million grant from the Advanced Technology Program of the National Institute of Standards and Technology in September of 2003 to further the development of the fuel cell.

Using techniques developed in the semiconductor industry, researchers at Neah Power etch millions of microscopic pores into a piece of silicon 400 microns thick. It is in these millions of pores where the chemical reaction between oxygen and a hydrogen-based fuel, such as methanol, takes place to generate electricity.

Neah Power officials believe the micro fuel cell will be able to provide more energy for longer periods of time than conventional batteries while taking up the equivalent space. And while batteries take time to recharge, Neah Power's fuel cell can be instantly "recharged" by simply replenishing the fuel cartridge.

Another WTC client is Microvision, a leader in the photonics industry that is also based in Bothell, Wash. [*NWS&T*, Autumn 2003, p.20]. Microvision's patented MEMS devices, in which optical surfaces and small hinges are formed on a silicon chip roughly one fourth the size of a dime, have enabled the development of a number of products with mobile display and imaging applications.



Less than 10 microns wide, this pore and the millions around it enclose the chemical reaction that generates electricity in Neah Power's silicon-based micro fuel cell. Photo: Neah Power

Microvision's Nomad Augmented Vision System is able to project an image from a source, such as a computer or video camera, through the viewer's pupil onto the retina. The image is created as the MEMS device paints as many as 30 million pixels per second onto the retina using a low-intensity light beam. In this way, the Nomad System superimposes high-contrast, high-resolution images on its user's view of the surrounding environment.

In October of 2003, the American Honda Motor Company announced plans to supply their dealers and technicians with Nomad Systems as early as 2004. Because the system can overlay automobile diagnostics and repair instructions directly on a technician's vision, Honda believes it will increase the efficiency and accuracy of technicians performing complex repairs.

Other applications reported by Microvision for the Nomad Augmented Vision System include the positioning and alignment of surgical tools for surgeons, navigation and mapping for security personnel and military troops, and wearable displays for pilots.

The 18-ounce Nomad System uses a MEMS device to superimpose high-contrast, high-resolution images on its user's view of the surrounding environment. Photo: Microvision

Microtechnology's alphabet soup: MEMS, MICROCATS, and MECS

A considerable portion of the work in microtechnology is aimed at computers or MEMS devices, says Kevin Drost, associate professor at Oregon State University (OSU), Corvallis. Many of these devices are sensors, one way or another collecting and processing information, says Drost.

In contrast, two other applications of microtechnology, abbreviated MECS and MICROCATS, process mass and energy. These devices may be used, for example, as biosensors, chemical reactors, fuel processors, or cooling systems.

In January 2003, the Pacific Northwest National Laboratory (PNNL) in Richland, Wash., and OSU teamed up to create the Microproducts Breakthrough Institute (MBI), of which Drost serves as co-director.

The Institute combines PNNL's research in microchemical and thermal systems (MICROCATS) with OSU's micro energy chemical and biological systems (MECS) research.

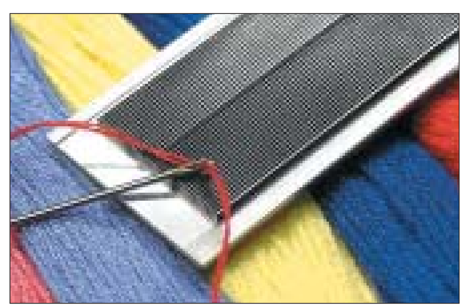
"What we're trying to do at the MBI is process mass and energy in large enough volumes that we in the macro world care about it," says Drost. "The idea of MECS and MICROCATS is to extend microscale devices out of the electronics world."

The extension of microtechnology into processing mass and energy has required some fundamental changes in the way microtechnologies are manufactured. Ever since the semiconductor industry started using silicon instead of germanium 50 years ago, silicon has been the foundation on which most microtechnologies are built.

However, because energy and chemical systems can have potentially high temperatures or chemically aggressive environments, silicon often can't be used, says Landis Kannberg, co-director of the MBI and senior program manager at PNNL.

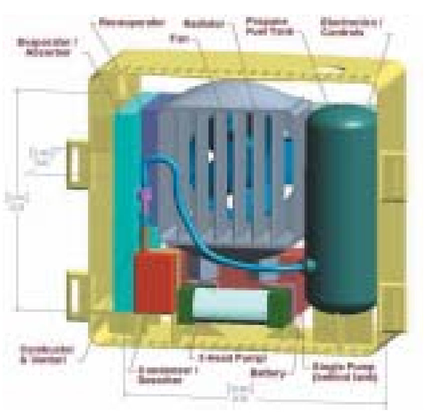
"Silicon is just too brittle and cracks too easily," says Drost.

As a result, plastics, ceramics, glasses, intermetallics, and metals such as aluminum and stainless steel are used to manufacture MECS and MICROCATS. But because the fabrication technologies for these materials haven't been around as long as those for silicon, they are not as well developed. "Con-


Because they produce very high rates of heat and mass transfer, microchannels 10-100 microns thick are the key to a number of technologies being developed by the Microproducts Breakthrough Institute. Photo: PNNL

sequently, the costs are relatively high for some of these devices right now," says Kannberg. However, he believes manufacturing costs will lower with continued research and economies of scale.

"The MBI will be undoubtedly the national leader in the U.S. in the development of this class of devices," says Drost. "We will have some competition from Germany, but there isn't anything else in the U.S. that would even come close to the capabilities that we will have."



This prototype of a compact personal cooling system developed by the Microproducts Breakthrough Institute will weigh 3 or 4 pounds and cool an individual up to four hours. Image: PNNL

A recent product that has resulted from PNNL's and OSU's collaboration in the MBI is a compact personal cooling system. Funded by a three-year, $7 million, Department of Defense grant, the portable cooling system could be used by soldiers wearing chemical and biological warfare gear in combat.

"We think we can produce a cooling system about the size of a paperback book that weighs 3 or 4 pounds," says Drost. "The next best system would weigh 11 or 12 pounds, and when you're already carrying 100 pounds of gear, which soldiers can do, that makes an enormous difference."

Capable of cooling an individual for up to four hours, the cooling system might also be invaluable to firefighters or other professionals who have to do critical work in extraordinarily hot conditions.

Other projects either under way, or being considered by the MBI include:

- A biosensor the size of a lapel pin currently under development to detect chemical and biological warfare agents;
- Chemical reactors being created for new environmental applications, such as pen-sized reactors capable of cleaning up underground toxic waste onsite by converting it into inert components;
- Water-cooled micro-chips with tiny "veins" etched into the surface to transfer heat and allow for even faster computer chips;
- Microprocessing fuel plants sent to Mars to provide astronauts the necessary fuel for a return trip to Earth; and
- Small systems to produce hydrogen for fuel cells in automobiles, changing a power plant that now fills the back of a pickup truck into a unit the size of a briefcase.

"The MBI's focus is to accelerate the development of the science and fundamental understanding of micro chemical and physical systems in order to translate that into viable products," says Kannberg.

"Some of the research we're doing is between a year or two from being commercialized," says Drost. "Some of our stuff is probably ten years away, but I truly believe we are just barely scratching the surface of what MECS can do."

Small in the spotlight

While microtechnologies are built using a top-down approach developed mostly by the semiconductor industry, says Ritala, nanotechnologies are built quite differently.

"At the nano level," he explains, "single atoms can be manipulated to build complex structures one atom or molecule at a time. They're grown from the bottom-up to form complex structures."

In the process, the properties of nano-sized structures could be controlled to make lighter but stronger materials for aircraft, smaller yet faster computer chips, or more effective therapeutic drugs.

The promise of nanotechnology has captured attention nationally and in Northwest states, which have launched new initiatives recently.

In 2000, President Clinton created the National Nanotechnology Initiative and nearly doubled the federal funding of nanotechnology research to almost $500 million. In 2003, President Bush requested that nearly $900 million be spent on nanotechnology research.

"Nanotechnology really started getting people's attention with President Clinton's National Nanotechnology Initiative," says Charles Campbell, professor and director of the Center for Nanotechnology at the UW. "It seemed like once the initiative was announced, nanotechnology received much more media attention."

In the Northwest, the WTC is working to foster the development of a nanotechnology industry through its Washington Nanotechnology Initiative. By inventorying the state's technological assets, identifying market applications for nanotechnology, and forming a communication network of nanotechnology professionals, the initiative aims to develop a strategy to strengthen Washington state's national position in nanotechnology.

And in Oregon, the state legislature allocated $21 million in September 2003 to build the National Center for Multiscale Materials and Devices (MMD) in Corvallis.

The MMD combines OSU's microtechnology research and the University of Oregon's nanotechnology research with the semiconductor manufacturing capabilities of Intel and the printer technologies of Hewlett-Packard (HP) and Xerox, all of which are largely based in Oregon.

The MMD represents the best possible overlap of research and industry capability in the state, says Skip Rung, a consultant and former research and development executive with HP who co-authored the MMD's business plan.

"Together they make a very complementary research program," says Rung, "The MMD will hatch all kinds of interesting ideas that will create jobs and attract federal funding to Oregon."

Microtechnology advancing nanotechnology

Microtechnologies are playing a role in nanotechnology by providing an enabling technology for what's being done at the molecular level, says Ritala. "Most nanotechnology research begins by first fabricating a platform or structure at the micron scale." Many of the researchers working in nanotechnology come to the WTC to fabricate features on the micron scale, which become enabling technologies for their nanotechnology research, he says.

UI Chip Goes into Space with NASA

NASA has approved for use in space a microchip designed by researchers at the University of Idaho's (UI) Center for Advanced Microelectronics and Biomolecular Research (CAMBR).

Consuming less than 15 milliwatts of power, UI's Reed-Solomon microchip uses 100 times less energy than chips currently used by NASA and is more than twice as fast. The chip uses so little energy than it is eight years ahead of the commercial semiconductor industry's roadmap for operating voltage.

However, the primary difference between the microchips used in space and the microchips used in your home computer is the need to operate in a radiation-filled environment, says Jody Gambles, associate director of CAMBR. In space, radiation belts, galactic cosmic rays, and super-charged solar particles can damage chips unless they are radiation-tolerant. The Reed-Solomon chip is designed to be both radiation-tolerant and low-power.

"The ability to perform complex tasks using only small amounts of power is critical in space," says Gambles.

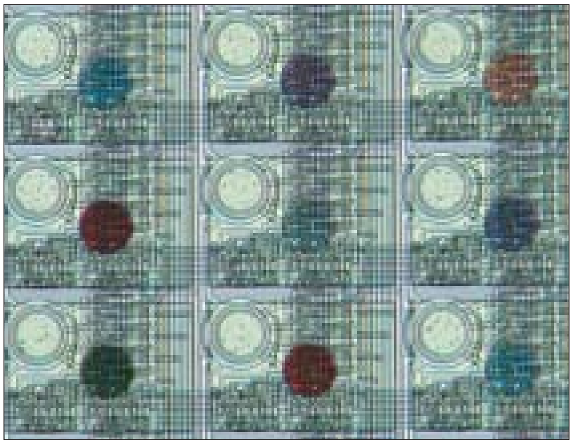
"It creates a domino effect." If a satellite uses less power, he explains, the size of the satellite's batteries and solar panels can be reduced, which reduces the total size of the satellite. And if satellites can become smaller, more can be launched into space on a single launch vehicle.

CAMBR's chips will be used in NASA's New Millennium Program's Space Technology 5 Project (ST5), which is scheduled for launch in 2004. Composed of three satellites, each weighing less than 50 pounds, ST5 will test the satellites' innovative concepts and technologies in the harsh environment of space while measuring charged particles in the Earth's magnetosphere.

CAMBR is located at the UI's technology park in Post Falls. CAMBR's core research team, including the center's director, Gary Maki, moved to CAMBR from the University of New Mexico (UNM) in June of 2002. While at UNM, the research team developed chips used in the Hubble Space Telescope, Landsat 7, and the Mars Odyssey.

Two companies that are using microtechnology to advance nanotechnology are CombiMatrix and MicroEnergy Technologies, both of which conducted much of their initial research at the WTC.

At CombiMatrix, based in Mukilteo, Wash., microtechnology is being used to create nano-structured materials. At the heart of this effort is CombiMatrix's lab-on-a-chip technology. By using thousands of microelectrodes patterned on an integrated circuit and capable of controlling chemical reactions, researchers are able to simultaneously mix and match different chemicals side by side.



A small section of a lab-on-a-chip is shown above. Each nano-structured material is a different color and is synthesized at a microelectrode with a diameter of 92 microns. The underlying circuitry and the underlying microelectrodes (the larger circles of uniform color) are also visible. Photo: CombiMatrix

Because CombiMatrix's chip designs can exceed 500,000 microelectrodes per square centimeter, hundreds or thousands of different nano-structured materials with varying properties can be created on a single chip.

"Our initial commercial products are based on microtechnology," says Sho Fuji, CombiMatrix's director of microarray technology, "but we see tremendous opportunity to utilize our technology platform in the area of nanomaterials discovery."

The lab-on-a-chip process is valuable because it drastically reduces the cost and time of synthesizing a large number of nano-structured materials. The chip also allows each material to be tested for properties useful for applications in electronics, video displays, and energy storage, among others.

Aligned in series, MicroEnergy's nanoparticle sorter (8 x 6 x 5 cm) can precisely sort large quantities of nanoparticles into different sizes, ranging from tens of microns to several nanometers in diameter. Photo: MicroEnergy

MicroEnergy Technologies of Vancouver, Wash. has developed a device capable of sorting large quantities of nanoparticles into different sizes, ranging from tens of microns to several nanometers in diameter.

Currently, nano-sized particles have many emerging applications in microbiology, medicine, and aerospace. In these applications, however, it has been shown that a nanoparticle's size can greatly affect its properties. Consequently, many of these applications require nanoparticles to be very uniform in size, not varying by more than a few nanometers.

MicroEnergy's method of providing nanoparticles of consistent size has the possibility of creating new applications for nanoparticles, including coatings, polymer additives, and suntan lotions.

The use of nanoparticles as additives or coatings are viable applications of nanotechnology, says Mehdy Khotan, vice president of business development at MicroEnergy. "To achieve commercial success for these applications, high volumes, quality control, and low cost are necessary requirements," he says. "MicroEnergy's technology adds quality control to some of the low cost nanoparticle production processes." ■

Jeff Wolfe received a B.A. in communication from Washington State University in May 2003. Currently, he is pursuing a master's degree in technical communication at the University of Washington.