October 2006 • A publication of the Michigan Small Tech Association

Michigan Small Tech Journal

Growing the micro and nano industry

In this Issue

Computer-Aided Design: Modeling Nanostructures

By Robert Frederick
Michigan Small Tech Correspondent

At present, there is no way to make a nano-sized gearbox. Assembling atoms or molecules into such complicated nanostructures as gears, cranes, or other machines, admits Mark Sims -- president and founder of Nanorex -- is still the stuff of dreams: "But when that day comes, then there's going to be a big demand for software like ours."

So the short-term market plan for NanoEngineer-1, a Computer-Aided Design (CAD) software package for modeling nano-scale machines, includes free distribution of its beta version this fall. The aim is to help educators and researchers teach nanotechnology and, in return, get feedback that will help Nanorex improve the software until -- said Sims –the day when such software-designed nano machines might become a reality.

For example, in January, Fouad Khoury was searching the Internet for a modeling program to help graduate students understand the principles and applications of chemical nanotechnology for a course he's planning for this fall at the University of Houston. Khoury, an adjunct professor of chemical engineering, contacted Nanorex to get an alpha-version of the software.

"The role of the program [in the course] will be to demonstrate what can be done, like maybe build nano clusters, and try to see if we can predict some of the nano clusters' properties based on simulation," Khoury said. Because nanotechnology is an interdisciplinary field, "We have to introduce it based on the basics of nanotechnology, including intermolecular forces, a little bit of quantum mechanics, and then introduce the techniques of nanotechnology applications."

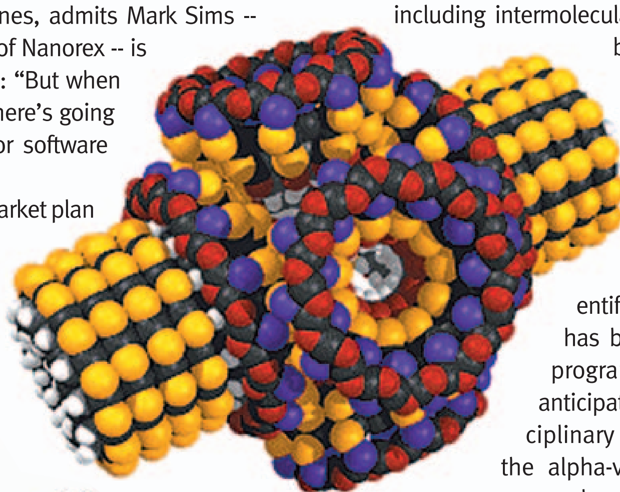

Image courtesy of Nanorex

Motion is just one feature of NanoEngineer-1, this Drexler-Merkle Differential Gear can be viewed in the Nanorex online gallery.

Nanorex's scientific advisory board has been helping the programming team anticipate those interdisciplinary requirements; the alpha-version software has been under development for two years with chief technical advisor, K. Eric Drexler, providing thought leadership.

"He is the guru," said Sims, "and he's making sure that we get critical features into the program that are necessary for rapidly designing and analyzing molecular machine systems." But Sims happily acknowledges that the back-and-forth communication with educators and academics is key to ongoing software development.

"I've been communicating with them," said Khoury, "and they did mention that the program has the ability to predict some properties such as

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Wayne State's SSIM to expand

By Kimberlee Roth
Michigan Small Tech Correspondent

As part of the Wayne State University College of Engineering expansion, the Smart Sensors and Integrated Microsystems (SSIM) program will expand its facilities.

The SSIM, directed by Gregory Auner, professor of electrical and computer and biomedical engineering, is devoted to the research and development of MEMS, microsystems, microsensors and nano and micro integration technologies. Its current facilities, located in the college, occupy more than 12,000 square feet of laboratories overall, as well as containing class 10 and class 100 clean room space.

The expansion will double the clean room space. When completed, the SSIM will have more than 9,000 square-feet of clean room space, including one for specialized packaging and laser micromachining, explained Auner. Expansion plans also call for a new design center, which will include a large computational simulation room for electronics sensors and microsystems – "everything from materials research to systems-integration-type design," he said.

Driving the growth in facilities is the strong growth of several SSIM research programs, including one in robotics and the integration of new fixtures, sensing systems and augmented reality capabilities. In collaboration with the Children's Hospital of Michigan, SSIM investigators provide surgical robots with 3-D overlays of MRI and CT images along with specialized Raman spectroscopy sensing in order to help doctors distinguish cancerous from non-cancerous tissue during surgery. This work is "synergistic with work we're doing with NASA and the Department of Defense, where we're adding these systems onto robots where none existed before," Auner said.

Also driving the need for expansion is the enhanced efficiency and collaboration that comes from having all design and simulation work done under one roof rather than in various labs and offices around the college. Additional clean room space is needed for the SSIM's rapidly growing Excimer and other laser capabilities. The new clean room will enable specialized packaging for high-frequency, high-power and biological devices, including nano-embossing systems for fluidic and other structures.

More than two dozen full-time staff scientists and engineers work on SSIM projects and programs. Currently 37 faculty from across the university participate, including surgeons, physicists, chemists and engineers, said Auner.

Auner founded the SSIM about eight years ago with two colleagues. "We expanded from one small lab to five major labs and a new clean room," he said. Today he is the principal investigator or co-PI on several projects, including the Raman spectroscopy work as well as the development of a "smart pixel" sensing array for early-stage breast cancer detection. The technology, which incorporates advanced materials, uses ultrasound to generate highly-defined images of tissue. The high-sensitivity, ultra-fast, piezoelectric array communicates with an integrated silicon processing chip. It has been tested in animals and, more recently, Auner has been applying it to pancreatic cancer detection.

He is also the PI on a neural implant program to develop treatments for vision and hearing loss and Parkinson's disease. The program includes work on controlled neuronal growth on implantable devices so that the body doesn't reject them and so sensing capabilities are not forfeited. The research is novel, he said, "and really shows the integration of nanoscience with microsystems."

Early funding for the SSIM came in part from an NSF grant for smart sensors and integrated devices. Over the years additional funds have come from research contracts with the Department of Defense, the National Institutes of Health, National

Continued on page 7

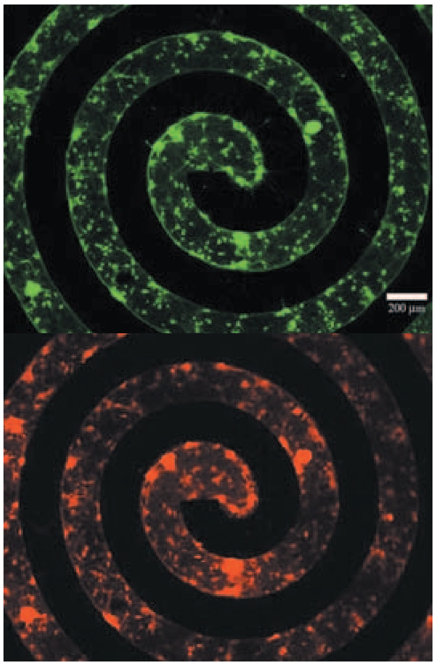


photo courtesy of WSU

SSIM researchers have controlled the growth of neurons using nanotechnology.

Dr. Greg Auner is the Director of SSIM and ECE, BME Professor at Wayne State University.

> "Delphi is a technology driven company, and SSIM allows us to test a lot of 'what if' scenarios so that we can get to market fast with a good product."
>
> *Joseph Mantese, Delphi Research Laboratories*

What should I be willing to give up?

Mark Lundquist, CEO of Fulcrum Edge, held senior leadership positions within the aerospace and defense industries before shifting to executive roles in the automotive and industrial marketplace.

One of the biggest worries for companies considering private financing options is what they will be asked to give up in exchange for funding. During this contemplation time entrepreneurs balance the need for money against an imagined loss of control. Frequently, business owners choose to self-fund their company with limited finances rather than risk losing control by accepting large cash infusions. Is this a good plan? Let's examine a few of the most common myths that companies face when seeking investment.

Myth 1: You will lose control of your company

It depends. In order to properly determine the correct response to this myth, one must insert the missing adjective: some control, no control or all control. The good news is that virtually no investor takes complete control of a company. Therefore, the remaining choices range from no control to some control.

Investors invest in companies because the reward outweighs the risk and, ultimately, the reward will hopefully pay off better than traditional investments. These rewards typically take the form of interest on the investment (usually deferred for some period of time) and some percentage of ownership in the company that will hopefully accrue in value as the company grows. The payback for investment comes when the investor cashes out, is bought out or the company goes public.

Business owners should expect private financiers to demand a percentage ownership in the company. The level of ownership reflects the level of investment compared to the realistic investment by the original founders. Cash helps companies grow. The ultimate question is: Would you rather have ten percent ownership in a $200 million company or one hundred percent in a $200,000 company?

Myth 2: You must have an exit strategy

Wrong. The answer depends on the type of investor and their expectations for pay back.

Angel investors range from very hands off to those that want direct involvement in the direction of the company. Matching the needs of the angel investor and the business owner is just as critical as the money. Find the right partner and the relationship works well for everyone.

Venture capitalists on the other hand earn their money by investing wisely, growing a company quickly and effectively, and then nearly always exiting the market through merger, sale or initial public offering (IPO). If a business owner is searching for venture capital they should expect to sell off their company in four to seven years. The business plan should reflect potential exit strategies and anticipated timing.

> Cash helps companies grow. The ultimate question is: Would you rather have ten percent ownership in a $200 million company or one hundred percent in a $200,000 company?

Myth 3: I'll never have another great idea, so I must make this one count

This is one of the hardest myths to crack. Most people believe they have only a single chance to write one great book, create one great masterpiece or invent one great product. The reality I see contradicts this myth. Most business owners I have interviewed admit an entirely new problem: too many new ideas and not enough time. Starting a company frees the mind. Quickly new ideas appear: spin-offs, new applications, related products, different markets.

Don't let myths rule your decisions

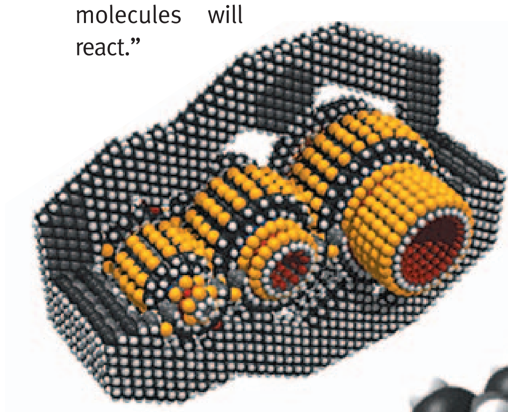
Myths abound in the investment world because most people have never lived in it. Before you allow fear of the unknown rule your decisions, seek out professional help, meet with government-sponsored advisement organizations, or talk to other business people with real experience in starting companies. Then launch your company. Be willing to give up something to get the financing to make it grow. You can decide on the future of your company if you choose the right investor partner. Keep the faith that this will not be your only invention.

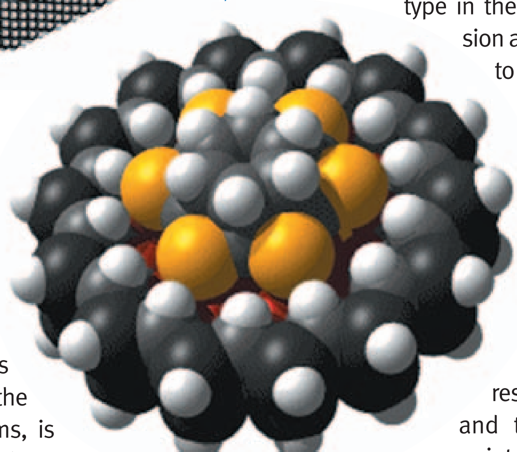
Mark Lundquist, Founder, President & CEO of Fulcrum Edge Inc., business advisory and consulting firm. He cut his teeth in the aerospace and defense industries before shifting to executive roles in the automotive and industrial marketplace. The company helps individuals; organizations and businesses realize their greater potential. ■

'Nanorex' from page 1

temperature and from temperature you can get the energy and things like that.” Khoury has in mind several additional features and he said Nanorex is very good at communicating and is interested in incorporating suggestions. “So I'm still trying to determine what we can do with [the program]. But it's evolving, and they keep sending us new versions, including new features as we go.”

“We have a lot of people from the education and academic markets that are looking at the software for courses,” said Sims. “One of the things our software is very good at is introducing the fundamentals of molecular modeling and simulation.” Sims has the competition at the tip of his tongue, admitting that there are other programs on the market, “But with those kinds of programs you're typically interested in modeling a very simple system -- a couple of molecules at the most with each molecule having a few dozen atoms. And those programs are geared towards modeling how those molecules will react.”





Images courtesy of Nanorex

NanoEngineer-1 tools makes model building more intuitive for students and researchers alike.

What separates NanoEngineer-1 from the competition, said Sims, is that the software “is more focused on modeling larger systems with literally tens of thousands or hundreds of thousands of atoms in them. You can imagine if you had to do that in one of these other programs, where each button click represents a new atom that you add to the structure, you'd be sitting there for a very long time.”

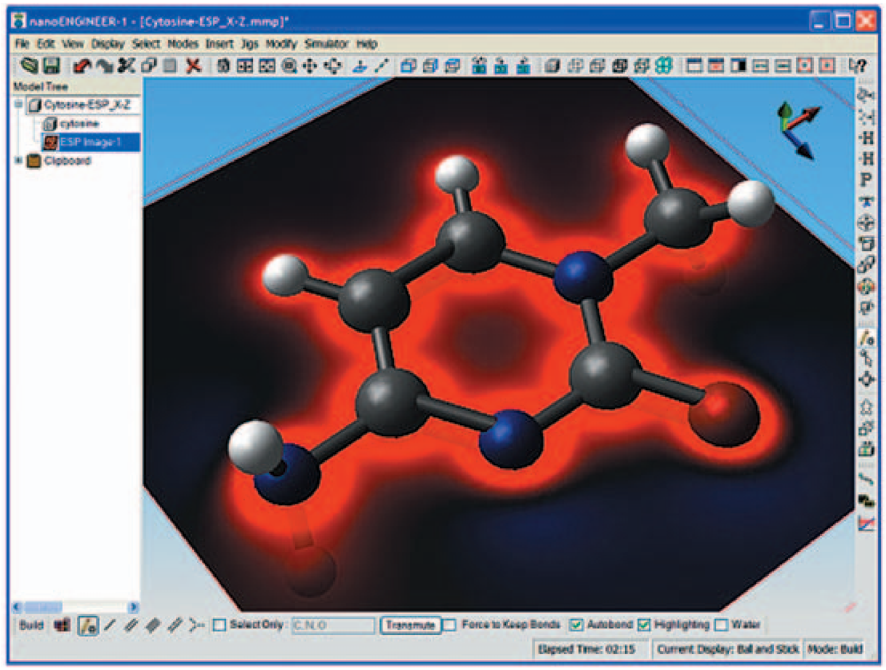


Image courtesy of Nanorex

NanoEngineer-1 includes both a sophisticated CAD module and a molecular dynamics module for simulating the movement and operation of mechanical nanodevices.

With NanoEngineer-1, Sims said they've incorporated features found in traditional CAD and parametric modeling programs. “For instance, you take a molecular fragment and you want to build a rod out of it. So you just select it and extrude or add a length dimension interactively, or you can type in the length dimension and it will adjust to that size.”

Sims said that including such features makes the model-building more intuitive for students and researchers alike, and that both will appreciate publication-quality graphics. Whether there will be an eventual market for such features in the business market is, for now, an educated guess. “It's a double-challenge really. Most companies just have to build a product because there's a market that is already there. We don't have that luxury. We have to not only create a product, we have to create a new market for this product. And that's one of the reasons why we've gone this route: making our product free and making it open source.”

Michigan Economic Development Corporation

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MICHIGAN ECONOMIC DEVELOPMENT CORPORATION

Business heats up for Traverse City thermoelectrics developer

By Kimberlee Roth
Michigan Small Tech Correspondent

Several recent announcements from Tellurex Corp. of Traverse City likely mean business will be heating up in the coming months and years. The 20-year-old company develops and manufactures solid state thermoelectric power generation and heating and cooling technologies for automotive, medical, military and food service applications.

In June DaimlerChrysler unveiled its 2007 Sebring, complete with a center console cup heater/cooler from Tellurex. The product, which uses Tellurex's Z-Max thermoelectric module, chills beverages to 40 degrees below the interior temperature of the car. When an occupant moves the rocker switch to heating mode, beverages are warmed up to 140 degrees.

At the heart of the cup cooler/heater is a thermoelectric module comprised of an array of bismuth telluride semiconductor pellets. The pellets are doped so that either the positive or negative charge carrier handles the majority of the current. Metalized ceramic substrates provide the platform for the pellets and conductive tabs that connect them. The modules range from 30- to 50-square mm and are about 3 to 4 mm high. The result is a solid state heat transfer device, explained Peter Schmitz, the company's sales manager, that can change from a heating to a cooling device by flipping a switch and reversing the flow of electricity.

The modules can also generate electricity when exposed to a temperature gradient, making them attractive in military and other applications that require power generation in off-the-grid situations. "With the limits of battery technology, our technology can enhance battery life by being the alternator, if you will, for a lot of devices," said Schmitz.

And therein lies one of the company's main challenges, he added. "There are a tremendous number of opportunities, and our challenge is to build a broad customer base that allows us to pursue a lot of different applications. We also want to remain focused on a few key industries so that we serve our existing customers well."

To date Tellurex has focused on the automotive and trucking industries with aftermarket and other products, such as the ThermaWave cup heater/cooler. Medical applications include keeping blood and other sensitive biomaterials at the proper temperature during processing and analysis. Thermoelectric modules also cool microprocessors in computers and test equipment and other optical devices. Although consumer applications abound, Schmitz says that "the challenge [with consumer applications] is pricing. If someone can find something that's cheaper and 'good enough,' that's not a market we want to spend a lot of time pursuing. We're looking for those that desire performance and reliability."

The technology can control temperature within a wide range, from about 20 below 0 to 100 to 120 degrees Celsius. "We're a great alternative because of the reliability -- there are no moving parts or fluids," Schmitz said. Within that range, the thermoelectric "sweet spot" is between 30 and 50 degrees Celsius. "That's the area where we can be a slam dunk application for customers."

Tellurex recently received a Phase II Small Business Innovation Research grant from the U.S. Department of Defense Office of Naval Research to continue work on the development of new bulk thermoelectric materials. The new materials incorporate nanostructural elements. Tellurex is working with Michigan State University's Department of Chemistry, Michigan Technological University's Institute of Materials Processing and Sandia National Laboratories on the $750,000, two-year project, which could eventually have a significant impact on vehicle fuel efficiency and the ability to power silent, micropower generators.

"Nanomaterials for thermoelectrics is a new idea in this field," said Mercouri Kanatzidis, a professor of chemistry at MSU and renowned thermoelectrics expert. "We have shown that enhanced thermoelectric performance, i.e. higher thermal to electrical conversion efficiency, can be achieved with nanostructured semiconductor materials. The addition of nanomaterials enables

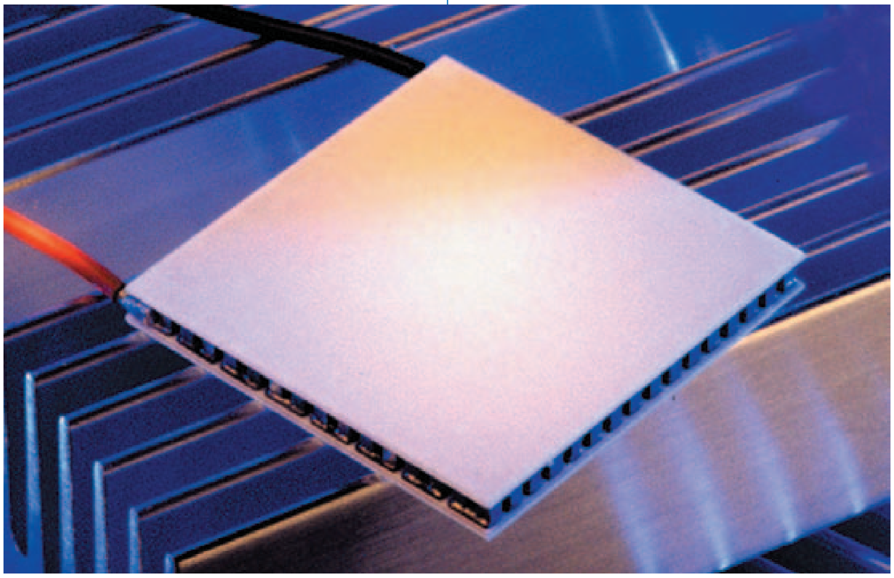

Photo courtesy of Tellurex

The Tellurex thermoelectric device produces a solid state heat transfer that heats or cools a device depending on the flow of electricity.

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Focus on technology

MEMS fabrication

What is it?

The fabrication of MEMS, microelectro-mechanical systems, is rooted in the integrated circuit (IC) industry dating back to the post-WWII era. The technology uses concepts and materials similar to its semiconductor big brother, silicon or glass wafer platforms, photolithography to attain fine detail, cost-efficient batch manufacturing and precise creation methods.

MEMS are manufactured in clean rooms, which are controlled environments with filtered, recirculated air to remove free-floating particles. Workers wear special space-like suits to prevent contamination from clothing, breath and human skin.

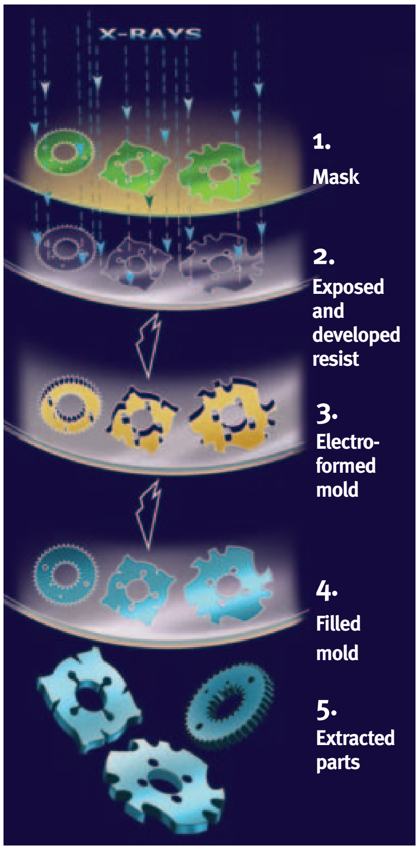
The manufacture of MEMS is intricate, and uniform foundry applications do not yet exist. Each company involved in microsystems development has a unique way of making them using a handful of fabrication processes. Lack of universal standards hinders the MEMS industry.

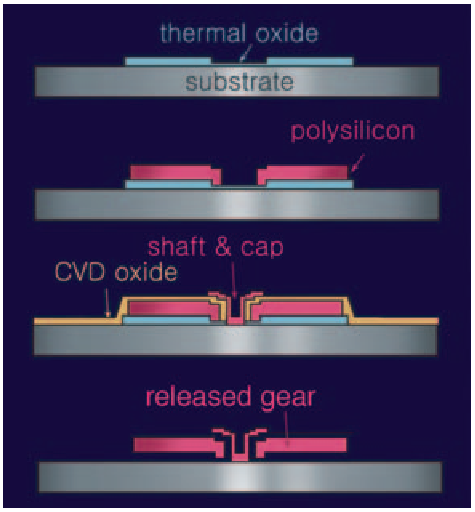
Research by Tom McGannon
Illustration by David Edgington

Fabrication processes

LIGA

An acronym from German words for lithography “lithographie”, electroplating “galvanoformung”, and molding “abformung”, LIGA is a micromachining process popular in Europe dating back to the early 1980s. X-rays are shot through a 2-D mask to produce microstructures with extremely small features such as gears with micron-sized teeth and high vertical walls.



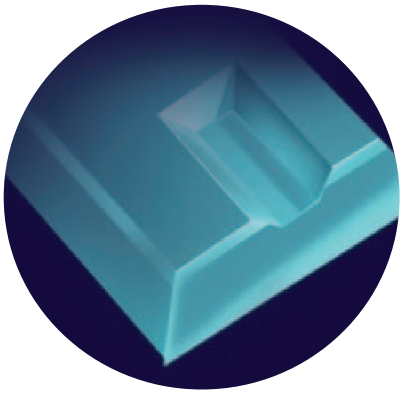


Silicon Surface Micromachining

Directly evolved from integrated circuit manufacturing, silicon surface micromachining uses the same IC fabrication practices of depositing materials to create patterns on a silicon platform. On the surface of a silicon wafer, thin layers of structural and sacrificial material are deposited and patterned. When complete, sacrificial material is removed and a completely assembled micro mechanical device remains.

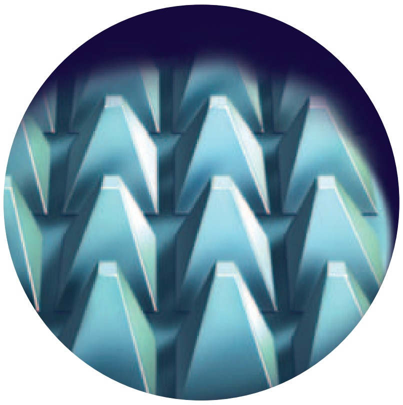
Silicon Bulk Micromachining (wet)

Used to create a large number of tiny structures inexpensively. Silicon bulk micromachining’s “wet” etch process produces angular details in silicon. It is reliant upon the atomic form of the crystal and creates a pyramid-like effect in silicon using chemicals like potassium hydroxide as an etchant. This process best produces beams, cantilevers, and membranes for sensors.



Silicon Bulk Micromachining (DRIE)

Another form of silicon bulk micromachining, DRIE (Deep Reactive Ion Etching) is a process that allows for the creation of deep walled MEMS products. It is widely used to form beams, holes and grooves with its geometric freedom. It provides a better etch and control rate in silicon than its wet version counterpart.



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the thermoelectric device to maintain a higher temperature difference than otherwise possible. By doing so, the device can convert a higher fraction of heat into electricity," he explained.

Tellurex's work may be a little easier now, since the company moved into a 22,000-square-foot facility in Traverse City in November 2005. Traverse City has been home since Tellurex was founded, but the move provides additional capacity for the anticipated growth, according to Schmitz. Currently Tellurex employs a staff of about two dozen. Schmitz says the new building should allow for at least three times that number and for multiple shifts to be implemented.

It's not just the beauty of Grand Traverse Bay that's kept Tellurex in the state for so many years. "We've had a great relationship with Michigan State University -- their thermoelectric expertise has been beneficial to us. Particularly right now, we see Michigan as a great opportunity. There's a lot of technical know-how available in the state....And there's an emphasis right now to foster and develop entrepreneurialism and technology. The incentives to keep [businesses like Tellurex] in the state make it desirable."

Photo courtesy of Tellurex

Tellurex's THERMOWAVE device can be integrated to bring its features to the trucks, boats, industrial equipment or even a golf cart as shown here.

'SSIM' from page 2

Science Foundation, NASA and industry collaborators, including Delphi Corp. In 2003 Delphi donated close to $7 million (replacement cost) in clean room equipment, which helped bring the lab to six-inch wafer capability.

Delphi is currently working through SSIM in the areas of power electronics for hybrid vehicles, cooling of electronics and low-cost infrared sensors for night vision. Delphi's "open innovation" process allows it to collaborate with suppliers, start-ups and universities to investigate new technology platforms and potentially develop applications not only for automotive but adjacent markets. Those include consumer electronics and the medical market, said Joseph Mantese. Mantese heads materials, components and packaging for Delphi Research Laboratories; he also sits on the MISTA advisory board.

"Elements of the technology from our power electronics and cooling of electronics work have very nicely been integrated into systems developed by Delphi divisions," he said.

"Some of the concepts explored in the SSIM facility have also been utilized in our automotive products and systems." One example includes the tailoring of the flow of magneto-rheological fluids for actuators and dampers. The technology will soon emerge in some Delphi products, Mantese said.

"Delphi is a technology driven company, and SSIM allows us to test a lot of 'what if' scenarios so that we can get to market fast with a good product."

Auner expects the groundbreaking on the new facility to begin in the next several months and be completed two years later.

Photo courtesy of WSU

The SSIM placed the MISTA logo on a wafer. The device shown here is thermal oxide on silicon, with Lansing, Detroit and the freeway system deposited in gold.

Michigan Small Tech Journal is a publication of the Michigan Small Tech Initiative in conjunction with the Michigan Economic Development Corporation.

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