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Missile Defense Agency

# TechUpdate

A Quarterly Newsletter for MDA Technology Transfer

## INSIDE




▲ Software developed by MDA-funded Opto-Knowledge Systems, Inc., analyzes hyperspectral data on crop health to help farmers determine which areas of their fields need irrigating.

# Sensing a Healthy Harvest

## Imaging system should help improve scheduling of irrigation while reducing costs.

by Joe Singleton/jsingleton@nttc.edu

Farmers could soon reduce water, energy, and labor costs by using new MDA-funded imaging technology that analyzes crop health.

Opto-Knowledge Systems, Inc. (OKSI; Torrance, CA), has developed modeling and simulation software to work with a hyperspectral imager to analyze and monitor the health of crops on large multiacre farms. Hyperspectral imaging produces computer-enhanced graphic depictions based on a targeted object's spectral absorption, reflectivity, and thermal radiance.

The ability to analyze and monitor spectral data is critical for MDA. Through a 2005 SBIR Phase II contract, the Agency funded OKSI to enhance its existing modeling and simulation algorithms to discern live warheads from clutter and countermeasures. Such technology would be used with hyperspectral imaging sensors on space-based missile defense platforms.

After the MDA contract concluded, OKSI began considering commercialization potential for the technology. If the software could be used with a hyperspectral imaging system to detect and analyze

continued on page 12

# Hail to the Chief

by L. Scott Tillett/stillett@nttc.edu

MDA-funded researchers are not just researchers. Many of them are entrepreneurs, too. And that dual role can prove challenging. What's scientifically promising and what's commercially promising often are two very different things.

Through free events such as Business Focus Workshops (BFWs) and Technology Applications Reviews (TARs), the MDA Technology Applications program helps these researcher-entrepreneurs. BFWs help MDA-funded researchers figure out the strengths of their technologies and their companies, while TARs delve deeper into business plans and commercial potential.

At the heart of both offerings are volunteer reviewers who have vast experience in areas such as technology commercialization, business development, intellectual property, product development, and financing. These reviewers know technology, and they know business.

Sometimes our reviewers advise MDA-funded researcher-entrepreneurs to take a backseat in leading their companies. Not every researcher who is passionate about his or her technology is cut out to be a chief executive. So reviewers might urge some of these researchers to hire a full-time CEO and then step fully into the role of chief company technologist.

Why hire a "professional" CEO? Because running a company is about more than making the technology work. And it is about more than simply signing contracts, staring at balance sheets, filling job vacancies, and writing checks. Running a company is about understanding the implications of each management action on the company as a whole, and it's also about understanding markets and knowing how to operate in a competitive environment.

What a professional CEO knows is that often the most robust technology does not necessarily win as a product in a market. Often, the technology or product with the most motivated, knowledgeable, savvy, or plugged-in champion wins. And that's what a full-time CEO should be.

A full-time CEO worth his or her salary knows that the "build a better mousetrap mentality" is, unfortunately, just that—a mentality. Just because a researcher is great at reinventing mousetraps doesn't mean a better mousetrap is the product and the world will beat a path to your door. A full-time CEO can guide the company in determining whether the most marketable product is, in fact, just one component of a better mousetrap—not the whole mousetrap. And a full-time CEO might help discover more promising opportunities for building, say, rat traps or insect traps instead of mousetraps. Or the CEO might discover that an internal process (not the better mousetrap) is really the wise technology to pursue—one that might be licensed to others for many types of applications, thereby providing a steady revenue stream to help fund future technology development.

Knowing when to bring in a full-time CEO remains a challenge for many researchers. In the early stages of technology development, it probably doesn't make sense. But when opportunity is ripe and technologies are mature, hiring an expert executive might be a smart move. The Technology Applications program continues to help MDA-funded researchers figure out if and when "the new CEO decision" is the right decision.

**Editor** L. Scott Tillett
**Production Manager** Lisa Hylton
**Contributing Writers** Keith Costa, Joe Singleton, Joan Zimmermann, Varin Zimmermann
**Advisors** Jeff Reynolds, Alan Sherwin, Duane Zieg
**Layout** Lan Crickman

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Address inquiries and mailing list corrections to:
National Technology Transfer Center-Washington Operations
2121 Eisenhower Avenue, Suite 400
Alexandria, Virginia 22314
Attn: Editor, *MDA TechUpdate*
Tel: (703) 518-8800, ext. 500, Fax: (703) 518-8986
E-mail: stillett@nttc.edu
Web sites: www.mdatechnology.net, www.mda.mil/mdalink/html/mdalink.html

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## CONTENTS

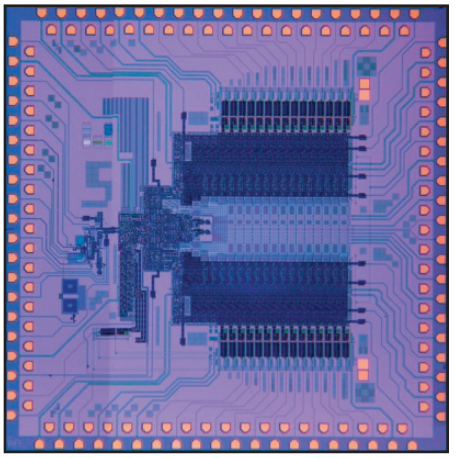
# Coming to a Radio Near You

## New all-digital RF technology simplifies the radio environment.

by Joan Zimmermann/jzimmermann@nttc.edu

Someday your radio will decide for itself what part of the spectrum it feels good about using, thanks in part to the support of MDA. Such flexibility would allow radio equipment to adjust on its own to avoid interference or to select among allocated bandwidths.

The concept of a software or "cognitive" radio has been knocking around for a couple of decades and has progressed to the point where open-source software code is available for the curious. A cognitive radio is "smart" in the sense that it is continuously aware of changes in radio-frequency (RF) spectrum and can decide which frequency and power choices are best at a particular time.



▲ So-called cognitive radios rely on components such as this chip for a digital receiver, which Hypres, Inc., has developed with help from MDA.

The problem has not been the concept, which most industry insiders believe is rooted on a strong business case, or the radio's baseband processing, which is fairly well developed. The biggest challenge to date, rather, has been the RF front-end technology. Receivers and transmitters based on conventional analog technology have struggled to provide the full spectrum performance needed for a true software or cognitive radio. The RF front-end of an intelligent, flexible radio must be reprogrammable—on the fly, just as the baseband processors—to operate over a very wide swath of spectrum and a multitude of wireless standards, protocols, and waveforms.

Now Hypres, Inc. (Elmsford, NY), is developing a superconductor-based, all-digital RF transceiver that can help pave the way to intelligent radio design.

Marketed under its Digital-RF™ product line, Hypres is developing a line of reprogrammable all-digital receivers and transmitters through a variety of government and commercial contracts. The Digital-RF product line includes versions for satellite and tactical communications, signals intelligence, electronic warfare, and RADAR.

Hypres has been developing the Digital-RF transceiver program for MDA and other government services through Phase I and II SBIRs and in collaboration with research institutions such as the University of Rochester. The company recently built and delivered four prototype units, targeted toward various RF applications, to the U.S. Army, Navy, and Air Force. In partnership with SELEX Communications, a Finmeccanica company, Hypres is building a high-dynamic-range software radio receiver. When completed, this Digital-RF receiver will provide multichannel wideband reception with superior interference rejection and tolerance, which also is a necessary feature of cognitive radios.

Key to Hypres' Digital-RF receiver is its analog-to-digital conversion technology that allows for wideband direct digitization at RF. Whereas conventional analog front ends require a series of components to down-convert the analog signal for the digitizer (before baseband signal processing), Digital-RF chips directly digitize the signal as it comes from the antenna. MDA funding has enabled development of the transmit side of the Digital-RF transceiver architecture, which features high-fidelity synthesis of broadband multicarrier transmit waveforms without the distortion associated with analog components. Most major signal-processing operations, including up-conversion and initial stages of amplification, are carried out in the digital domain, moving the analog-to-digital boundary as close as possible to the antenna.

At the heart of Digital-RF transmitter technology is a digital predistorter that operates directly on the digitized RF waveform, providing improved transmit power amplifier efficiency and reduced signal distortion. The immediate result is improved range (distance) and capacity (data rate), lower power consumption, and less waste heat.

This creates a massive boost in performance and reduction in analog components and associated costs. The resulting all-digital RF system is more robust, and it is reliable and interoperable across all required waveforms and spectrum ranges.

According to Deepnarayan Gupta, vice president of R&D at Hypres, Digital-RF technology will benefit both military and commercial users who are struggling with the ever-expanding number of waveforms and standards, the allocation (and thus restriction) of certain frequencies, and an explosion of equipment needed in both the transmit and receive portions of the communication system. "Everyone is being forced to look at new solutions," Gupta said. "The military already has too much RF interference, and the commercial marketplace is increasingly having to deal with this problem." Gupta believes

continued on page 5

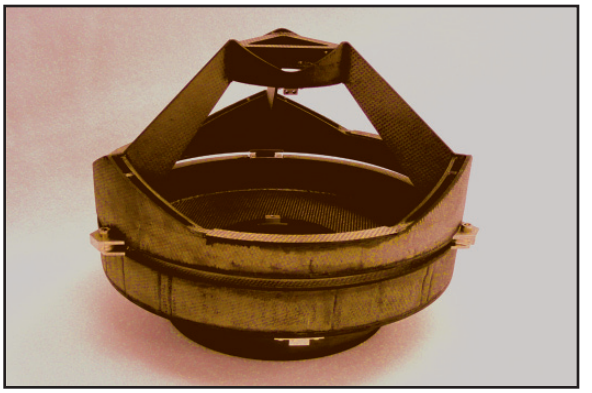
# Lighter, More Affordable Optics

## Composite could replace beryllium in space applications and communications.

by Keith Costa/techapps@nttc.edu

San Diego Composites, Inc. (San Diego, CA), is pouring its energies into fine-tuning technology that could solve a problem MDA and aerospace manufacturers have wrestled with for years: finding a high-quality, low-cost replacement for beryllium in space-bound optical systems.

The company's solution is a composite material called carbon-carbon, known for being heat-resistant and useful in structures that can sustain thermal shock. Carbon-fiber-reinforced composites are proliferating throughout aerospace and general commercial markets. Typically, carbon fibers provide strength, while epoxy or other resins, infiltrating the spaces between the fibers, offer rigidity and shape. For carbon-carbon composites, the polymer matrix material is carbonized (converted to carbon through heat) and additional carbon is infused into the structure to densify it. Carbon-carbon has been used as a material in brakes installed on aircraft and high-performance cars, and it protects the substructure under the nose cone and leading edges on the Space Shuttle.



▲ This photograph shows part of the structure of a telescope that San Diego Composites, Inc., has been developing with its carbon-carbon material, an alternative to toxic beryllium.

San Diego Composites has been working on carbon-carbon mirrors for MDA's exoatmospheric interceptor seekers, as well as an accompanying carbon-carbon telescope structure. Recently, the company began considering commercial spinoffs of its mirror technology, seeking outside advice on potential applications, which could include selling mirrors to observatories for telescopes, and to aerospace companies for optical systems aboard satellites.

Beryllium has an extensive heritage as a material for MDA interceptors and other optical components because it is lightweight and features very high specific stiffness. Plus, it has good thermal conductivity and excellent thermal capacitance. However, there is a trade-off. For a variety of reasons, beryllium is expensive, and lead times for optical components limit design options. It is also carcinogenic, demanding precautionary measures during manufacturing and handling.

Carbon-carbon is used by San Diego Composites as the substrate for its beryllium-alternative mirrors. Processing steps are employed to achieve the desired figure, or shape, before a proprietary coating is applied on its face. In comparison, glass is the substrate for household mirrors, to which a reflective coating of silver, among other materials, is added to the back.

Carbon-carbon has a number of advantages compared to other mirror materials. Its low density means it can be used for lightweight mirrors in a frequency-driven design, which is important for interceptors and directed-energy systems. Minimum gauge frequency limits other mirror materials, including beryllium. But carbon-carbon, like any composite, can be fabricated in very thin facesheets. A carbon-carbon honeycomb core is commercially available and, when integrated into a sandwich configuration, can lead to very lightweight mirrors.

A benefit of carbon-carbon over resin-matrix composites is that the former, once coated, does not absorb or change shape in the presence of moisture, whereas the latter does. There may, therefore, be an opportunity to use carbon-carbon mirrors in uncontrolled environments—for example, placing them in balloons for relaying laser communications, according to Gary Wonacott, San Diego Composites' CEO.

The company says its carbon-carbon mirrors can satisfy many of the optical, structural, and radiation-hardening requirements for MDA systems. Further, the mirrors can be built at a potentially lower cost compared to those made with beryllium, in part because carbon-carbon requires far fewer controls for protecting the health of workers during fabrication. The holy grail of mirror technology is replication. With carbon-carbon composites, the manufacturing process has the potential to achieve this goal, which would lead to accelerated production times, as well additional cost savings, Wonacott said.

Carbon-carbon mirrors are lighter than those made with silicon-carbide, another material that has been the subject of MDA-funded research for high-performance beryllium-replacement mirrors. They also have the potential to be weight-competitive with the beryllium versions. The beryllium mirrors weigh about 10 kilograms (kg) per square meter (m), which is lighter than glass. (Weight divided by surface area is a measure of merit for mirrors.) The comparable figure for carbon-carbon is about 8.5 $kg/m^2$, and San Diego Composites believes with further refinement it can bring that number down to 5 $kg/m^2$.

continued on page 5

Lighter, More Affordable Optics from page 4

San Diego Composites' carbon-carbon mirror work began with a 2002 Phase I SBIR from MDA. The award and a few others financed the start of the company that very year. A Phase II to develop carbon-carbon mirrors ensued, along with a program to craft a carbon-carbon telescope structure. The company, which began with three employees, has grown rapidly to 20, and has branched out into a wide array of endeavors, to include engineering and testing services, benefiting both military and civilian customers. Leveraging technology developed for NASA, as well as some of the know-how accumulated while working with MDA, the company even played a key role designing and setting up manufacturing for a prototype composite monorail car for public transit in Kuala Lumpur, Malaysia. In 2005, San Diego Composites received an SBIR "Partner of the Year" award from Raytheon Missile Systems.

As part of its Phase II carbon-carbon mirror project, San Diego Composites fabricated primary, secondary, and tertiary interceptor seeker mirrors for MDA from both 2-D and 3-D carbon-carbon. The primary and tertiary mirrors were made from 2-D continuous fiber that went through several steps of production, whereas the secondary was made with 3-D carbon fiber that came in bricks capable of being machined into shape, a quicker solution that lowers costs. One of the breakthroughs of the project was the use of diamond turning to achieve an optical surface in the visible range, according to Wonacott.

San Diego Composites is using its own funds to conduct thermal-stability testing on its coated and polished mirrors to determine if they can retain optical quality when subjected to fluctuating temperatures over long periods of time. Carbon-carbon is known to be one of the most thermally stable non-metallic materials; test results available later this year will tell the company which version of its coating material responds best to temperature swings.

The processes for making the carbon-carbon mirrors and the coating materials are currently protected by trade secret, but San Diego Composites is preparing patent applications for them. Wonacott said the company has started talking with potential government customers, including NASA's Jet Propulsion Laboratory, which is interested in carbon-carbon mirrors for a ground telescope it may build around 2010. The company believes other possible applications are in high-energy laser weapon systems, as well as laser or optical communications systems in commercial satellites. Each application would have to be evaluated to determine if the requirements would justify higher costs for carbon-carbon compared to mirrors fabricated from glass, aluminum, or resin-matrix composites.

New technologies and the possibility of replication could drum up renewed military interest in carbon-carbon mirrors, as well as generate enthusiasm among other consumers, Wonacott said. Recent breakthroughs in diamond turning, as well as magneto-rheological finishing, open up new possibilities for the technology—possibilities San Diego Composites is just beginning to explore.

**CONTACT INFO**

Gary Wonacott
San Diego Composites, Inc.
Tel: (858) 751-0450
E-mail: gwonacott@sdcomposites.com
Web: www.sdcomposites.com

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Coming to a Radio Near You from page 3

Digital-RF technology can dramatically reduce the RF complexity in both the commercial and military arenas.

True all-digital systems will also be critical in disaster scenarios in which responders are required to communicate with unfamiliar equipment and in environments with significant radio interference. All-digital radios will solve these problems and allow first responders to talk and listen simultaneously on any communications equipment—with the radio system automatically making any needed adjustments. In an age where wireless communication devices, both personal and professional, are becoming more numerous and sophisticated, sorting out signals digitally is becoming the primary solution for maximum exploitation of the electromagnetic spectrum.

Superconductor electronics offer an attractive combination of very high (40 gigabits per second) clock speeds for large-scale integrated circuits and high-linearity RF data converters. Much higher speeds are envisioned in the future and are being demonstrated on small-scale circuitry. For future applications, Gupta foresees the ability to demonstrate hundreds of gigabits-per-second chips and multichip modules for more complex systems that operate across multiple frequency bands, address a variety of standards, and offer greater flexibility to accommodate diverse modalities (e.g., voice, data, video, detection and ranging, and electronic countermeasures).

**CONTACT INFO**

Dr. Deepnarayan Gupta
Hypres, Inc.
Tel: (914) 592-1190, ext.7817
E-mail: gupta@hypres.com
Web: www.hypres.com

# In Search of a Single Photon

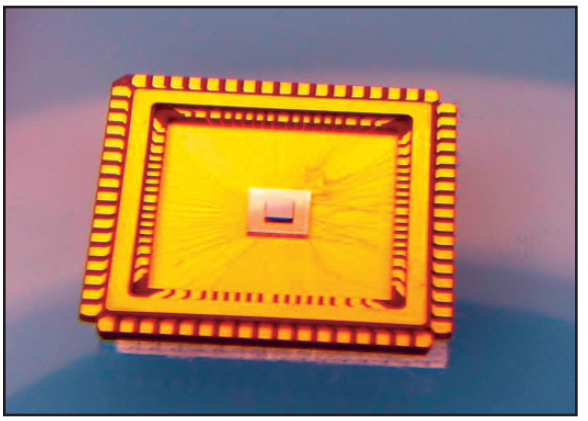
## Detection device offers advantages for telecom and sensing applications.

by L. Scott Tillett/stillett@nttc.edu

A single particle of light, a photon, can carry information, but detecting that solitary photon can prove a challenge. One MDA-funded company, Epitaxial Technologies, LLC (Baltimore, MD), has developed a highly sensitive detector that can sense a single photon—a breakthrough that should prove useful for telecommunications as well as for detection of chemical, biological, or other hazardous threats.

Epitaxial's technology consists of a photon detector, which is based on special materials developed by the company, and an optical amplifier—as well as associated electronic devices such as a transimpedance amplifier, used for delivering a clean signal out of the device. The technology developed by Epitaxial could be packaged in a product roughly the diameter of a penny, with a depth of a half-inch or less.

Company president Leye Aina said Epitaxial's intellectual property includes techniques to develop the materials used in the detector, to fabricate the amplifier on top of the detector, and to magnify electrons coming out of the amplifier to produce signals that can be analyzed by a microprocessor. The company's specially crafted materials are based on indium gallium arsenide and aluminum indium arsenide. Epitaxial has three patents that cover its basic technology.



▲ Epitaxial Technologies' packaged array includes a detector that can sense a single photon.

Since the late 1990s, MDA and its predecessor, BMDO, have funded Epitaxial through several SBIR and STTR awards, for both Phase I and Phase II projects. The MDA/BMDO funding has focused primarily on developing materials, amplifiers, detectors, and other devices that could be used in radars or other systems for detecting missile threats. Along the way, DARPA also provided a contract that funded some of the company's research and development, allowing Epitaxial to improve its technology and subsequently garner even more funding from MDA, in the form of a Phase II SBIR award.

For MDA, the ability to detect a single photon can be crucial, especially in applications that involve bouncing light off of potential targets to determine their nature. "You need to send a high-intensity burst of light, but by the time it travels hundreds of kilometers or more and gets back to your detector, the amount is too small," Aina said. But if even a single photon bounces back and can be detected, its properties—such as the direction of its spin—can reveal crucial details about the target. "So we came up with a technology that takes the incoming light signal and magnifies it optically before it gets converted into electrons in the detector," said Aina, who explained that the optical amplifier has been designed essentially as a laser. "If you design the laser so that it never gets to the point of lasing, whenever a signal comes in—any signal—it will just amplify it."

Epitaxial's technology is competing against existing technologies such as the photomultiplier tube, a standard device for detecting low light levels. Aina said such tubes are essentially little vacuum tubes that do not work well in wavelength ranges such as those needed for particular MDA applications. "They are susceptible to magnetic fields, and they do not have the sensitivity to single photons at long wavelengths," said Aina, explaining that his company's technology could have up to three times the performance of photomultiplier tubes in terms of sensitivity.

Epitaxial's offering also will compete against so-called Geiger-mode avalanche photodiodes, solid-state devices that generate current when exposed to light. "That has a lot of drawbacks. The detection probability is very low." Aina said. "For the kind of wavelength that MDA wants, they don't operate at room temperature. They have to be cooled—as with other current technologies that are out there." Epitaxial's technology does not require cooling.

Beyond potential military applications, one of the biggest markets for Epitaxial's technology is in fiberoptic-based telecommunications, where detecting and processing photon-based information is key. As light-based signals travel through a fiberoptic network, they fade and often have to be regenerated one or more times before reaching their final destination—before the signals fade entirely away. And such regeneration requires expensive equipment at certain

continued on page 13

# Limiting Bad Vibes in Electronics

## Polymer coating material could reduce chip loss due to abrasion and shock.

by Joe Singleton/jsingleton@nttc.edu

Applying a new adhesive coating to fragile electronic components may soon limit computer damage caused by vibrations, whether in vehicles, chemical plants, or in mines.

Cornerstone Research Group, Inc. (Dayton, OH), has developed an organic, polymer-based material that can be directly applied to any circuit board—as well as other metal- and plastic-based objects—to protect against vibrations.

The protective hard-coating technology, originally developed for the Air Force Research Laboratory (AFRL), is now being funded by an MDA SBIR Phase II to determine whether it can protect information system technologies used in current and proposed space-based ballistic missile defense platforms.

Cornerstone originally engineered the protective hard-coating material for circuit board systems, components, and assemblies from damage caused by abrasion, shock, impact, chemical damage, and sandstorm damage that can be common on the battlefield. The company says development of the technology has continued under the MDA contract, and the material has been improved so that it now can protect almost any kind of electronic device from vibration damage—from home computers and personal data assistants to car radios and cellular telephones. Typically, manufacturers minimize vibration damage to electronics by integrating acoustic-dampening features, adding cushioning, and coating circuit board components with plastic compounds.

The hard-coating material protects circuit boards and other electronic components in a way that other compounds cannot, said Mark Stacy, Cornerstone program manager. Many of the options to mitigate vibration damage, such as coating with commercial off-the-shelf plastic compounds, do not have the same coefficient of thermal expansion as the components they protect. When such compounds undergo heating or cooling, they expand or contract at different rates than the components to which they are attached—a situation that can lead to cracking or breaking. Cornerstone's durable, hard-coating technology, however, is engineered to allow the material to shrink and expand at a rate close to that of circuit board assemblies, so no damage is done to the board components.

Since the hard coating's successful high-endurance tests with AFRL, Cornerstone researchers have been actively trying to find its niche in the commercial market. Stacy said businesses needing their electronics protected against vibrations and harsh conditions—such as mining, transportation, and the chemical, oil, and gas industries—should welcome this new technology's usefulness. The technology is also expected to be useful in mitigating vibrations in the electronics of the burgeoning off-road vehicle market.

▲ Cornerstone's material minimizes vibrations that can damage components of circuit boards and other electronic devices.

And considering the protective hard coating would be used in a variety of electronics and environments in both heavy industry and the home electronics markets, the product has to be adaptable. Cornerstone starts off manufacturing the material in three distinct formats: a paste that allows a user to apply and coat a piece of equipment as thick as deemed necessary; thin sheets that use direct-applied adhesion, similar to contact paper; and machine-molded coatings fitted to a customer's specifications. Since the hard-coating material can be used on virtually any electronic device to protect against vibration, it is more versatile and compatible than competitive coatings on the market, which tend to be specialized toward use on specific applications.

While Cornerstone plans to continue manufacturing its protective coatings, the company hopes to partner with electronics companies to supply the material for coating components. Stacy said the coatings can be integrated into standard manufacturing processes with little to no impact on production.

**CONTACT INFO**

Mark Stacy
Cornerstone Research Group, Inc.
Tel: (937) 320-1877, ext. 110
E-mail: stacyma@crgrp.com
Web: www.crgrp.com

# Porous But Powerful

## A new material shows promise for better batteries as well as functional fabrics.

by Varin Zimmermann/techapps@nttc.edu

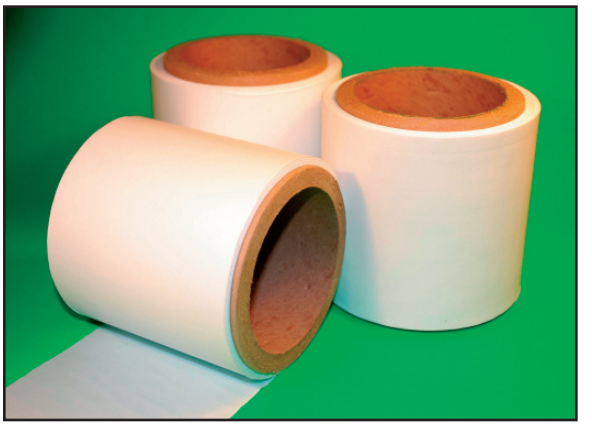
Lighter, faster-charging lithium-ion batteries are becoming a reality thanks to a separator material developed with MDA funding. Power tool batteries made with this separator could supply bursts of power up to four times that of other batteries. Makers of hybrid/electric vehicles also could benefit from the new technology in the form of longer-lasting batteries that are lighter, more powerful, and less expensive. And the technology is being applied to protective breathable fabrics for athletes and first responders.

The 80-percent porous separator, developed by Porous Power Technologies (PPT; Lafayette, CO), serves as a porous divider between the anode and the cathode of a lithium-ion battery, providing low resistance for high ionic conductivity. The higher the porosity, the higher the ionic conductivity—a factor that could increase battery power, capacity, charge rate, and cycle life. In PPT's case, the small pore size and highly uniform structure is ideally suited for lithium-ion batteries and many other applications.

MDA originally funded development of the microporous separator material through an SBIR Phase I contract awarded to Boundless Corporation (Boulder, CO), for the Terminal High Altitude Area Defense (THAAD) program, the Patriot missile program, and other advanced technologies requiring high-power, lithium-based batteries for increased agility, speed, and range. Through an MDA SBIR Phase II award, Boundless produced and tested a microporous separator with highly uniform porosities of 80 percent or greater using a simple, inexpensive process. Boundless co-founder Tim Feaver and Boundless employee Kirby Beard, the product inventor, spun off to form PPT after acquiring all property rights to the technology.

Makers of batteries for cell phones and other consumer electronics should find PPT's technology attractive because of the company's ability to laminate electrodes together, making the production of these flat cells simpler and less costly. For the hybrid/electric vehicle industry, PPT's new technology answers the need for lithium-ion batteries made of large flat cells instead of cylindrical cells. Today's cylindrically wound cells tend to accumulate heat internally and have difficulty dissipating heat. PPT's lamination process creates a planar shape, allowing the heat to be easily radiated outward. And these cells can be efficiently stacked to take up less space than a cylindrical battery. These cells also are easier to manufacture. The laminated cells can be produced in a low-cost, highly automated process that increases reliability and performance, since the laminated components stay aligned in high-vibration environments—on a truck traveling down a rocky road, for example.

And PPT's process has use beyond batteries. Waterproof, highly breathable textiles made with PPT's membranes would be an appropriate choice for sports shoes and clothing that need to keep out the weather but keep even an active wearer cool and dry. The material also could be used to create durable hazmat suits. Other applications include "breathable" mildew-resistant wallpaper, materials for gas and fluid filtration, membranes for fuel cells and ultracapacitors, and fabrics for bedding and hospital garments.



▲ Porous Power Technologies produces rolls of material that can be used as a separator in lithium-ion batteries or as a component in weather-resistant apparel.

Lithium-ion batteries using PPT's separator can last up to four times as long as competitors' products when discharging at high rates, according to Feaver. The discharge capacity of cells made with PPT's technology after 700 cycles remains 50 percent higher than competitors. And in temperatures around 0°C, the discharge capacity of competitors' batteries is only half that of PPT's.

PPT's unique patent-pending process maintains the separator's strength while keeping the membrane 80-percent porous, thus providing low resistance to ion flow, which results in less heat. The process is also inexpensive and provides a membrane that is uniformly porous, nonflammable, and heat-tolerant. Other available laminable separators are made of polyolefin and need a thin coating of polyvinylidene fluoride (PVDF) on the outside of the separator to make them thermally laminable. This extra step adds cost to manufacturing and decreases the performance of the battery because the coating layer melts into the pores of the separator, further decreasing the porosity of the membrane. PPT's separator is

continued on page 11

# Labs on a Chip Get a Laser Boost

## A new micromachining method brings a significant upgrade to microfluidic chip technology.

by Joan Zimmermann/jzimmermann@nttc.edu

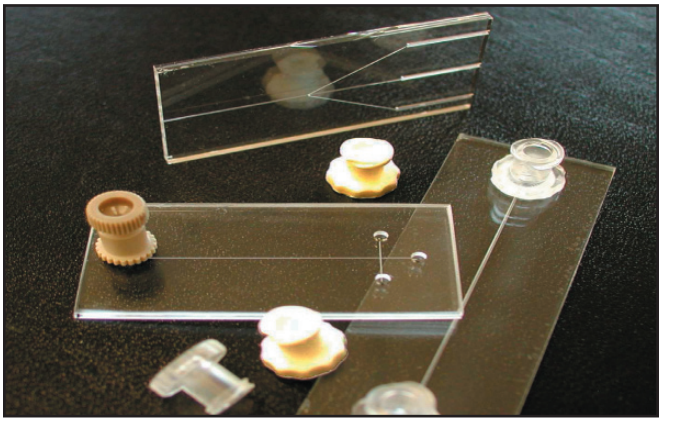
Imagine going to your neighborhood drugstore and choosing from Aisle 4 a diagnostic kit that can test for high cholesterol, for a faulty gene that predisposes you to diabetes, or for a staph infection.

The automation and miniaturization of laboratory functions have undergone a steady evolution of tweaks and improvements. These changes have enabled researchers to dig more deeply into biology, shorten assay times for pharmaceutical testing, and even take some items from the inner sanctum of the doctor's office to the open shelves of the drugstore. Translume is the latest contributor to the field, bringing both improved materials and manufacturing to microfluidic chips for biological and chemical testing. Such chips contain tiny channels that route reagents and reactants in sequence, replacing the researcher mixing chemicals at the bench for needs as diverse as antibody testing and DNA hybridization.

The technology has some tangled technological roots in MDA history. Translume (Ann Arbor, MI), with the help of a 2004 Phase I STTR from MDA, investigated the use of femtosecond lasers for maskless etching of glass materials and micromachining of optical structures. Philippe Bado, chief technical officer for Translume, also worked for Clark-MXR, Inc. (Ann Arbor, MI), another company that received MDA SBIR support in the early 1990s for the development of femtosecond lasers, which also are being used by Translume to carve channels in its new chip offerings.

Once upon a time, labs on chips were simple wells in which nanoliters to microliters of sample were used to carry out various reactions of interest. Today's more sophisticated chips use microfluidic channels, which with their very small dimensions add some advantages to the dynamics of chemical reactions, by adding what is essentially a plumbing system to route and direct reactants. As labs on a chip become more accepted in the consumer market and physicians let go of the diagnostic monopoly, pharmacies and other stores could sell inexpensive test kits to consumers. Quicker time to diagnosis also would be welcomed by physicians and patients alike.

Most commercial microfluidic chips are wet-etched in silicon (chemically), a method that results in trapezoidal or rectangular cross-sections with large rounded corners. These shapes are not suited to the chemistry desired by its users. Translume addresses these shortcomings with its direct laser-etching methods that produce deep channels with nearly vertical walls. In addition, Translume's chips are made of fused silicate, making them ideal for tests like fluorescence in situ hybridization (FISH), in which fluorescent markers are used to mark genes on stretches of DNA. Many materials possess natural fluorescence, or fluoresce in response to ultraviolet (UV) light, creating false signals. Fused silica does not autofluoresce and is transparent to UV. Its additional advantages are longevity and ruggedness, and it lasts well beyond the lifetime of the experimenter (centuries). The material has a hardness of 6.5 on the Mohs scale, slightly below that of quartz, and is thus highly resistant to scratches, making it ideal for robotic applications, in which the chips are handled repeatedly by not-so-gentle mechanics, or for the dirtier conditions of field work.



▲ Examples of products etched using Translume's laser process.

Translume has developed four femtosecond-laser-based fabrication processes to fabricate and commercialize fused silica devices, including its microfluidic chips: femtoTrim™, femtoWeld™, femtoEtch™, and femtoWrite™. The company uses the femtoWrite process to produce deep three-dimensional microchannels with sharp-shaped features that are unavailable using traditional mask and etching techniques. The reactions as conducted in these chips are roughly 10 times faster than "conventional" lab-on-a-chip offerings, owing to factors such as small reaction volumes and the relative distances traveled by the reagents as they travel through the microfluidic channels. The combination of the laser technology, robust materials, and Translume's efficient manufacturing approach allow the company to offer the new chips at a cost advantage.

The company also plans an expansion of this line to include micro-reactors, flow cytometers, and capillary electrophoresis modules, which are used in the pharmaceutical and biotech industries.

continued on page 11

# Scheduling On-time Aircraft Deliveries

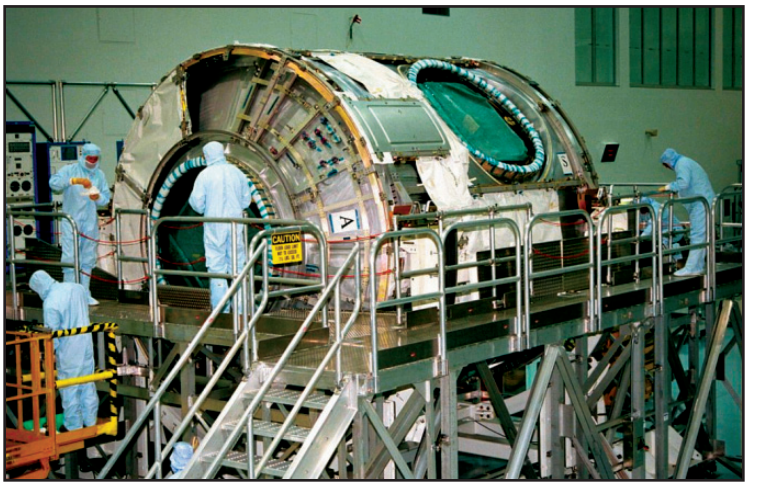
Software saves prime aerospace manufacturer time and money.

by Joe Singleton/jsingleton@nttc.edu

Building next-generation aircraft may be a daunting task logistically, but using new software developed with MDA funding could save manufacturers time, cost, and labor, ensuring quicker deliveries around the world.

Stottler Henke Associates, Inc. (San Mateo, CA), originally developed its Aurora™ scheduling technology for NASA to use in managing the timing of International Space Station construction. After serving NASA, Stottler Henke upgraded Aurora's capabilities with new algorithms developed for missile defense engagement planning. The enhancements were funded through an MDA SBIR Phase I contract in 2006 and a Phase II contract in 2008.

The upgraded Aurora system is a proven success story, gaining not just the attention of Government agencies, but also a prime contractor. Stottler Henke was awarded a multimillion-dollar contract from the Boeing Company following the release of a benchmark study conducted by the aerospace behemoth. The study concluded that Aurora is more efficient in managing resources than the one used by Boeing for almost two decades. Stottler Henke's technology is now the primary scheduling tool for production of Boeing 787 aircraft, of which the first deliveries are scheduled for late 2009.



▲ A scheduling system by Stottler Henke Associates, Inc., helped NASA construct parts of the International Space Station. The system, funded in part by MDA, can be used in many other manufacturing applications.

With the contract in hand, Stottler Henke's challenge was to improve the manufacturing efficiencies of Boeing's 787 project by optimizing aircraft assembly schedules through the use of software designed for better resource management—from equipment to personnel. Richard Stottler, the president of Stottler Henke, said the problem could be tackled only after fully realizing the scope of Boeing's operation.

"[Boeing's] plan is to pump out an airplane every three days. That's 10 a month, and 120 a year," he said. "That turns out to be worth $14 billion a year. They have two assembly lines, and each assembly line turns out one every six days. There are about 3,000 activities; the average activity has about five different resources. The resources are manpower, workspace, and specific tools."

Boeing's internal tests showed that Aurora was the best technology to effectively schedule worker assignments throughout the assembly hangar. In operational tests, Aurora reduced the amount of time needed on Boeing 787 construction projects through a more efficient use of resources by 10 percent to 30 percent over other commercial schedulers. Better resource management also allows Boeing to spread out its labor force more effectively, thereby reducing overstaffed areas. And through optimization of time, labor, and resource management, Boeing is likely to save millions of dollars per year, according to Stottler.

Initially, the central problem Boeing faced was a lack of space due to a large number of workers manning stations around the center part of a fuselage where the wings were being mounted, while fewer workers were busy elsewhere on the aircraft. So Boeing first asked Stottler Henke to program Aurora for optimal assignment of workers during production of a generic 787. The programming took into account that only a limited number of people could work in a given area—to ensure safety and to ensure that tasks would be performed properly. Once Stottler Henke had completed the programming for a generic 787, Boeing created additional configurations to meet the specifications of purchasing airlines. Such airline-specific scheduling continues today at Boeing, aided by the efficiencies of Aurora software.

Design of the Aurora software is based on the premise that order is the key to success. A company like Boeing might be working on several large projects in its assembly plant—but corporate executives are well aware that each large project requires completion of many small tasks, in a certain order, and within prescribed time limits. Most advanced

continued on page 11

Scheduling On-time Aircraft Deliveries from page 10

scheduling systems competing with Aurora can crunch such data without much of a problem. But according to Stottler, none of them uses intelligent breakdowns of data—including variables that can change the entire picture of how time and labor need to be distributed.

Enter Aurora. The software offers companies more than just a simple schedule for best managing a project's tasks. It also can instruct company officials how to best use its workforce. Using corporate data that is input into Aurora, the software can analyze the full potential of the workforce—based on skills, work shifts, staffing requirements for certain tasks, actual working space where a task is being conducted, and perhaps most importantly, keeping the workflow in sync with schedule completion requirements. A company can also use the program to interchange variables—such as the ordering of projects or staffing requirements on certain tasks to develop a production schedule that best suits specific corporate interests. Aurora offers a company maximum flexibility in scheduling, based on the incorporation of as many variables as a user wants programmed into the system.

Stottler Henke continues to look beyond the Boeing contract, seeking to have Aurora in many aerospace manufacturing and repair centers across the country. The company most recently contracted to provide scheduling services for a division of Acument Aerospace Technologies, Inc., which makes aircraft fasteners and bolts for many manufacturers, including Boeing.

Outside of the company's aerospace contracts and success, Stottler said he would entertain partnerships with companies that desire high-quality scheduling models as part of their software systems.


▲ Stottler Henke's system is being used to improve the Boeing Company's manufacturing efficiency, helping to schedule tasks for workers on Boeing's 787 aircraft assembly line.

**CONTACT INFO**
Richard Stottler
Stottler Henke Associates, Inc.
Tel: (650) 931-2714
E-mail: stottler@stottlerhenke.com
Web: www.stottlerhenke.com

Porous But Powerful from page 8

wholly made of PVDF and consequently is already thermally laminable.

PPT's process also does not involve any stretching of the membrane, thereby reducing the chance of a short circuit. Other separator manufacturers stretch the separator to increase its porosity, but under high heat the separator may shrink, causing a short. Eliminating the stretching step in the manufacturing process also allows PPT to cut production costs.

PPT continues to partner with other companies and is seeking venture capital. Feaver said that the company has existing patents for the separator applied to battery and nonbattery applications, as well as patents pending on its technology developments.

**CONTACT INFO**
Tim Feaver
Porous Power Technologies
Tel: (720) 890-4888
E-mail: tfeaver@porouspower.com
Web: www.porouspower.com

Labs on a Chip Get a Laser Boost from page 9

The process of developing three-dimensional glass microstructures is termed GMEMS™ (Glass Micro Electro Mechanical Systems). The technology is useful in many other areas, such as the creation of micron-scale optical waveguides that can move or flex. Thus, Translume has much to offer in the optical communications area, as well as general manufacturing of materials requiring precision etching or drilling.

Translume continues to work with the Michigan Economic Development Corporation to further develop its market. In addition, the company is using some of its original venture-capital funding to improve its production line.

**CONTACT INFO**
Philippe Bado
Translume, Inc.
Tel: (734) 528-6371
E-mail: philippebado@translume.com
Web: www.translume.com

Sensing a Healthy Harvest from page 1

spectral signatures of objects in space, what about monitoring something closer to home? OKSI decided that the best use of the software and imaging system combo on land was in agriculture—due to the difficulty of monitoring the health of acres upon acres of individual plants. The company's decision was not a simple brainstorm; it was based on more than 10 years' experience in designing remote-sensing programs for DOD and NASA.

### From idea to scientific challenge

With the technology and application idea in hand, OKSI met with some farmers who grow the nearly 750,000 acres of cotton in the San Joaquin Valley of California, as well as with experts from the U.S. Department of Agriculture, local county government, and the University of California. What company researchers found was a problem endemic to farmland in Southern California—the land is desert that relies heavily on irrigation canals from the northern part of the state. Because of the natural lack of water, farmers tend to irrigate—typically mixing nutrients in with the water—and apply chemicals and insecticides on fixed schedules. But the typical means of irrigating does not really take into consideration the balance between the health of the crops and environmental concerns. Crops will die if not watered or protected against insects. But if too many nutrients, chemicals, and pesticides are applied, the environment may be adversely impacted.

▲ Farmers in California's San Joaquin Valley are using OKSI's software to help monitor the health of their cotton crop.

So OKSI gathered a team of biologists, entomologists, and other experts in the area to size up the problem and determine how OKSI's technology could directly benefit the cotton growers of the San Joaquin Valley. They collected data—including specific spectral signatures and stress caused by lack of water, lack of nutrients, salinity of the soil, or insect infestation—on cotton plants grown in San Joaquin Valley. The scientists determined the spectrally significant features of cotton are generally found in the visible spectrum and near-infrared wavelengths, rather than midwave infrared, as is the case with missiles. OKSI and its team were then able to incorporate the information into the software suite for use with hyperspectral imagers and sensors.

OKSI's technology differs from similar products on the market because its hyperspectral imager and proprietary software use preprogrammed spectral signatures of specific crops to analyze and produce detailed maps of fields. Most other technologies are not programmed with the high spectral resolution signatures of specific plants, and simply do a "color" analysis of an entire field, without regard to the type of crop being viewed. Furthermore, the level of detail provided by OKSI's equipment offers farmers either a macro-view of the entire field, to locate where unhealthy plants are grouped, or a micro-view of individual plants in a dying cluster, should such specificity be desired.

### From map-making to irrigation

To get a clear view of a large cotton field, OKSI goes airborne. The hyperspectral imager and thermal cameras are mounted in a camera pod on the underbelly of the aircraft, which is linked to a laptop computer positioned in the cockpit. Once the aircraft is flying over a cotton field, the imager is turned on; its sensors and software begin crunching the data being received. The end result is a series of color-coded maps, each showing a 0.5-square-mile section of the field, with blue representing good health, and red meaning extreme stress. After mapping the field, the team returns to OKSI's laboratory, where the gathered data is analyzed and converted to maps and a user-friendly information report that a farmer can download within 24 hours of data collection. The information in the report is very specific and provides the exact geographic coordinates of the particular section of field. And to help lessen the burden of finding specific stressed plants or areas of stressed plants, the maps can be easily downloaded to a personal data assistant and hand-carried to the crops needing assistance.

By being able to discern which areas of a field are unhealthy and need irrigation, farmers can save many thousands of dollars a year just by reducing the amount of water normally used, according to OSKI. The cost of irrigating cotton—primarily done by flood irrigating—is one of the largest expenses facing farmers in the San Joaquin Valley.

OKSI's technology also is used in conjunction with crop-dusting aircraft to ensure that insecticides are spread in areas where needed, not in one blitz with the hope that everything is covered. To ensure insecticides are spread over infested areas, a farmer could take the data acquired through the OKSI analysis and match the unhealthy areas with coordinates

continued on page 13

Sensing a Healthy Harvest from page 12

plugged in to a global positioning system (GPS) device. Company tests of this technique were successful and resulted in less pesticides being used.

During the early part of the growing season, the farmer could drive out to the OKSI-specified unhealthy area, guided by GPS navigation, and make a firsthand determination of the need for spraying insecticides. The farmer could then contact a crop-duster pilot and request a particular area be sprayed. This selective spraying process could save farmers thousands of dollars annually.

Near harvest time, the crops are often too tall for vehicles to effectively navigate without damaging plants. So to get very precise location details, farmers can install a differential GPS antenna, according to OKSI.

### From farmers to museum curators

Beyond managing resources used to grow cotton, OKSI has been using its hyperspectral imager in a laboratory setting to inspect old oil paintings. The company recently inspected a 16th Century painting in which the layers of oil on the canvas were carefully analyzed. The analysis revealed that another painting was beneath the original's surface. Hyperspectral imaging allowed OKSI researchers to look through several layers of paint.

The company is now looking ahead to numerous business opportunities. In the agricultural arena, OKSI researchers are studying the characteristics of other crops—mainly tomatoes and corn—to see if hyperspectral imaging could benefit those farmers. The company is particularly interested in fielding this technology outside of the San Joaquin Valley, particularly in the Midwest and the South, where much arable land exists. OKSI is also interested in working with museums and art collectors to help unlock mysteries of centuries-old paintings. OKSI also has been successful in demonstrating its technology onboard unmanned aerial vehicles.

**CONTACT INFO**

Nahum Gat
Opto-Knowledge Systems, Inc.
Tel: (310) 756-0520, ext. 237
E-mail: nahum@oksi.com
Web: www.oksi.com

In Search of a Single Photon from page 6

intervals along a network. But with Epitaxial's highly sensitive technology, the signals could travel possibly four times the current distance before they would need to be regenerated, Aina said. In other words, network operators could save money because they would need fewer pieces of equipment between transmit and receive points in a network.

The single-photon capability of Epitaxial's detector/amplifier also means that it would work well in freespace (wireless) optical communications—to snag signals that might otherwise be lost in fog or pollution. And the technology could be used to enhance the sensitivity of devices for detecting chemical, biological, or other hazardous threats. "Any situation where you need to either image or sense some target or object but there are just not enough photons to do anything with it, our technology will definitely have a big advantage," Aina said.

While Epitaxial continues to improve the performance and reliability of its detector/amplifier technology, the company is selling small unit quantities on a custom basis, lining up distributors for its product and has begun advertising its technology in trade publications. Epitaxial also is considering pursuing venture capital funding, Aina said.

**CONTACT INFO**

Dr. Leye A. Aina
Epitaxial Technologies, LLC
Tel: (410) 455-5594
E-mail: oaina@epitaxialtechnologies.com
Web: www.epitaxialtechnologies.com

# Discover a Multitude of Online Technology Profiles

The MDA Technology Applications program hosts an extensive archive of technology profiles on its Web site. The summaries below spotlight two technologies featured on the site, which includes profiles on hundreds of innovations originally funded by MDA and its predecessor agencies. To browse other technologies—from sensors to advanced materials—visit www.mdatechnology.net.

## UML-based Programming Support Environment

▲ Tool makes programming easier.

A new tool developed by CohesionForce, Inc. (Huntsville, AL), will allow programmers to more easily diagram and revamp existing software systems, enabling better management of future code modifications. MDA orginially funded CohesionForce's technology through a Phase I SBIR award to develop methods for upgrading or migrating software in evolving systems. The company's tool is commercial-ready, and CohesionForce remains on the lookout for new customers.

The tool allows programmers to diagram and revamp existing software systems and also helps programmers diagram and then build new systems. CohesionForce calls its tool a "Programming Support Environment" (PSE). The product is based on the nonproprietary Unified Modeling Language (UML), which allows a user to create an abstract model (a set of diagrams) of a software system.

The company's approach lets software engineers take existing source code and pull information into the PSE, so that programmers can use it to edit or enhance the system. The method, therefore, begins with source code to create diagrams.

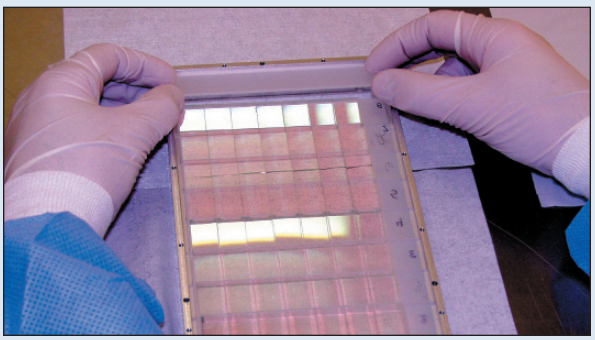
Also—in building new systems—CohesionForce's tool can reverse-engineer the final product and then compare it with the original design, to validate the system and to verify whether programmers actually built what they set out to build.

## Improved High-power Diode Array

SiMMtec, Inc. (Allison Park, PA), has developed a laser diode pump with minimal cooling requirements, meaning that more vehicles, as well as smaller vehicles, might be able to carry laser weaponry onto the battlefield. SiMMtec's laser diode pump technology also could find use in application areas such as medicine, telecommunications, and microchip manufacturing. MDA originally funded the technology through a Phase II SBIR contract for its potential to improve high-energy "heat-capacity" lasers. SiMMtec continues to pursue primarily military customers for this technology while also scouting for new funding and sponsors.

The company has addressed cooling and power issues for solid-state lasers by employing special metallization processes and microchannel etching techniques to create its solid-state diode pumps. SiMMtec's end product is a 10-bar diode array that can be packaged with other 10-bar arrays to create powerful lasers capable of many kilowatts (kW). Each 10-bar array measures roughly ½ inch by ¾ inch by ½ inch and can produce 2 kW peak power or 1 kW average power.

Solid-state lasers promise a safer, cleaner, and more efficient alternative to chemical lasers, and interest in solid-state solutions has grown as the technology has matured. High-power, solid-state laser systems could shoot mortar rounds out of the sky or neutralize landmines on the ground. Such systems must be light and mobile, as well as durable and easy to service. For SiMMtec's technology, a 10-bar array can be cooled with only 5 gallons of liquid per hour, compared with an estimated 30 gallons per hour for competing solid-state laser technology based on copper microchannels.



▲ Device offers cooling benefits.

# It's Up to You to Protect Your SBIR Data Rights

by Fred Patterson/coach@sbircoach.com

One of the hallmarks of the SBIR Program is the intellectual-property protection provision that provides the SBIR awardee with the retention of the rights to data generated in the performance of an SBIR award.

What this means is that, unlike with most government programs where the government pays for the development work, you, the small business concern, get to keep the rights to any new IP created during the SBIR period of performance. And these rights also apply to STTR awards, with the additional proviso that your IP-sharing agreement with your research institution partner also is in effect. Unfortunately, these rights don't last forever—five years for DOD, four years for civilian agencies. Moreover, you can unintentionally abrogate these rights by failing to properly mark your deliverables, including all reports and briefing materials you provide to your contract officials.

**If you don't tell the government what data falls under protection provisions, the government has no obligation to protect it.**

In your SBIR or STTR contract with MDA, you'll find reference to clause DFARS 252.227-7018. This clause specifies the proper marking (wording) that should accompany all information provided to the Government relating to your work on your SBIR project. If you don't properly mark the title page of any briefing or report, and if you don't tag anything that you provide to the government, you are in jeopardy of forfeiting your rights to the data associated with that deliverable.

I strongly recommend that you review this clause. (You can find a copy of the full wording at: http://www.acq.osd.mil/dpap/dars/dfarspgi/current/index.html.) And I recommend you include the following marking (and fill in the appropriate information) on the title page of a report or briefing—or on a tag attached to a deliverable item:

SBIR DATA RIGHTS
- Contract Number:
- Contractor Name:
- Contractor Address:
- Expiration of SBIR Data Rights Period:

*The Government's rights to use, modify, reproduce, release, perform, display, or disclose technical data or computer software marked with this legend are restricted during the period shown as provided in paragraph (b)(4) of the Rights in Noncommercial Technical Data and Computer Software—Small Business Innovative Research (SBIR) Program clause contained in the above identified contract. No restrictions apply after the expiration date shown above. Any reproduction of technical data, computer software, or portions thereof marked with this legend must also reproduce the markings.*

The "Contractor" is you. The "Contract Number" is just that, not the SBIR topic number. The "SBIR Data Rights Period" expiration date for a DOD contract is five years after the scheduled date of the final deliverable of the contract. Note that follow-on projects, be they Phase II or Phase III, will extend the data rights period to an appropriate point after the end of that follow-on project.

Even though the law provides for protection of your rights to the data you create in your SBIR work, by contract law, if you don't tell the government what data falls under the provisions of that protection, the government has no obligation to protect it. You tell the Government by properly marking the data, and it's up to you to remember to do it.

If you don't believe that you have an exposure here, take a lesson from the court decision in Night Vision Corporation's data-rights battle with the Air Force. In a nutshell, Night Vision lost rights to its technology by failing to mark a prototype of the goggles it had created in Phase II—when the company delivered the goggles to the Air Force. The Air Force turned over the prototype to a competitor for reverse engineering and issued the competitor a contract to manufacture the goggles. Night Vision sued and lost.

So why is it so important to protect your technical data? There are two basic reasons. (1) The agency cannot disclose your SBIR data to your competitors during the protection period. And (2) the agency cannot use your SBIR data to develop technical specifications for purposes of competing a procurement, and must award procurements based upon it to you on a sole-source basis.

That should be enough incentive to do a good job with your markings. Remember to mark everything you provide. You never know when a piece of data will prove to be the key to your future success.

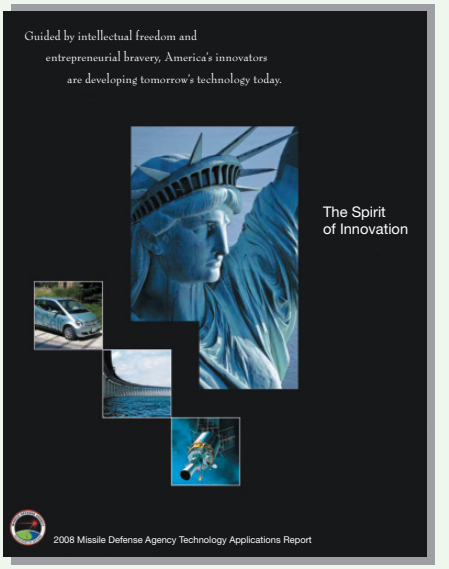
*Fred Patterson (aka The SBIR Coach®) is the former co-founder and executive officer of two successful SBIR-award-winning companies. Since 2001, he has served as a panelist for Technology Applications Reviews sponsored by the MDA Technology Applications Program.*

# New Report Available Online

Visit www.mdatechnology.net to find a special annual report titled *The Spirit of Innovation*.

The report, produced by the MDA Technology Applications program, explains how the commercialization of MDA-funded technologies contributes to fundamental American ideals and values.

Readers who would like to receive a printed, bound copy of the report by mail may request one by sending their contact information to techapps@nttc.edu.

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