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MDA Update

Linking American Businesses to Missile Defense Technology
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INSIDE

Pioneering Spirit —*by Scott Tillett*

MDA taps historically black and minority schools for innovative research.

Historically black colleges and universities have long been home to pioneers.

Students from these universities often were at the forefront of the Civil Rights movement—defying social segregation, challenging whites-only policies at lunch counters, and generally flouting racism in commerce and in society at large. For decades, such universities emerged as progressive centers of social thought.

Today, more than 40 years after President Lyndon B. Johnson signed the Civil Rights Act of 1964, historically black colleges and universities and minority institutions (HBCU/MIs) have become more culturally diverse. Whites and blacks walk shoulder to shoulder in the halls. Their professors come from all over the world to teach students who also have traveled the globe in search of an American education. In effect, the notion of race has become almost secondary to HBCU/MIs. But these institutions remain on the edge of transformation. They remain centers of progressive thought—including the realm of science and technology.

Innovation at HBCU/MIs, however, can remain overlooked as universities with bigger budgets, broader name recognition, more celebrated sports teams, and more deep-pocketed alumni get greater attention—from would-be faculty members, from prospective students, and from potential industry partners. But Federal efforts including an MDA research and development (R&D) funding program, help ensure that HBCU/MIs don't get overlooked as potential sources of innovation.

MDA's HBCU/MI program was initiated in 1993 by Stephen Moss, director of the Office of Small and Disadvantaged Business Utilization (SADBU). The program includes a broad agency announcement (BAA) that invites scientists from the institutions to submit R&D proposals that one day might have a payout in terms of usable technology for MDA. And as the scientists at these universities continue to push technology boundaries, they create opportunities to apply emerging technologies in areas beyond missile defense.

The MDA BAA for HBCU/MIs runs every two years, and since the early 1990s dozens of researchers have been funded. The program responds to Section 832 of Public Law 101-510, the Defense Authorization Act of 1991, which focuses on minority business contracts. The MDA program includes HBCUs and MIs within the overall 5 percent DOD goal for minority business contracts and serves to introduce the institutions to MDA technologies as well as the particulars of the MDA procurement process.

Back to school. *MDA seeks to advance innovative science and technology concepts by sponsoring more research at historically black and minority schools such as Alabama A&M University. In one project, researchers at the Chambers Science Building (pictured above) are investigating ferroelectric crystals for transducer applications.*

Continued on page 14

MDA Update

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FROM THE EDITOR

A PLACE FOR THEORY

Innovation may end with the practical, but it begins with the theoretical.

MDA needs practical innovations to create a superior defense against ballistic missile attacks. These innovations mainly come from large businesses such as Lockheed Martin, Northrup-Grumman, and Raytheon as well as from small and medium businesses.

Theoretical innovations also have their place. When a solution isn't obvious or is far too complex or expensive, which is often the case with missile defense applications, basic research may be necessary to break through fundamental barriers of science and technology. This task falls to academia's best and brightest minds.

Since the late 1980s, MDA and its precedessor organizations have funded hundreds—if not, thousands—of researchers at colleges and universities across the United States. One of MDA's principal funding vehicles is the Small Business Technology Transfer (STTR) program, which is similar to the agency's Small Business Innovation Research (SBIR) program. STTRs are similar to SBIRs in that they both move ideas from the theoretical to the practical where they can benefit MDA and other military customers as well as the private sector. However, STTRs are cooperative R&D projects that involve not only a small business, but also a research institution (e.g, a university, Federally funded R&D center, or nonprofit research institution).

MDA also supports basic research performed at historically black colleges and universities and minority institutions (HBCU/MIs)—places that unfortunately have been overlooked as potential sources of innovation (see page 1). In 1991, the agency created a program specifically for HBCU/MIs to develop technology that can be leveraged not only into missile defenses but also commercial products.

Renewing its commitment to colleges and universities, MDA recently created the Missile Defense Science, Technology, and Research (MSTAR) program (see page 3). MSTAR's goal is to develop new and innovative concepts, stimulate technology innovation, and exploit breakthroughs in science to offer robust technical improvements to all elements of the ballistic missile defense system. It accomplishes this goal by sponsoring fundamental, MDA-relevant R&D at accredited United States universities and academic institutions as well as supporting training of future scientists and engineers in the field of missile defense.

Together MDA and academia are at the forefront of technology R&D. As new devices, concepts, and approaches are created by this partnership, theoretical innovations will prove that they do indeed have their place within MDA.

—*Patrick Hatary*
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MSTAR LAUNCHED FOR UNIVERSITY FUNDING

Attention university researchers: Take a close look at MSTAR! We're not talking about your hook-up to a new Internet service or the latest intergalactic discovery billions of miles from Earth, but rather we are describing a new university research program funded by MDA's Advanced Systems Deputate. MSTAR stands for Missile Defense Science, Technology, and Research and represents new opportunities for U.S. universities to obtain seed-funding for research into leading-edge missile-defense-related technology.

The program is designed to revitalize MDA's investment in basic research at universities, which has dwindled drastically since the days of the Strategic Defense Initiative Organization. The program will also encourage one of our Nation's greatest natural resources—our young scientist population—to pursue careers developing defense technology.

"Essentially," explained Paul Koskey, program manager for Innovation and Analysis, "MSTAR is an avenue for MDA to identify and obtain technologies that could revolutionize the ballistic missile defense architecture and system. It allows us to exploit breakthroughs for the system while also grooming a new generation of researchers who will enable further enhancements."

The first MSTAR solicitation has been released. Plans are to release an MSTAR solicitation each year. This year's solication, which was posted December 2, 2004, had 10 broad topic areas ranging from sensors to power generation. Each contract funded will range from $150,000 to $200,000 per year and last for three years, ensuring that our Nation's best and brightest graduate students can complete a particular field of study. You can view the solicitation at www.mdatechnology.net by clicking on MDA BAAs at the bottom left-hand corner of the site under "More MDA Info."

FREE SCREENSAVER

Flying toasters and aquarium scenes just don't cut it anymore. Bring some visual excitement back to your desktop with the MDA TA program screensaver!

This free software, which is a quick load for PC users, features some of the best examples of MDA-funded technology adapted for commercial use. Visit www.mdatechnology.net and click on the link or icon under "Free Screensaver."

NOW AVAILABLE: COMMERCIALIZATION GUIDE FOR MDA-FUNDED RESEARCHERS

Researchers interested in commercializing their MDA-funded technology often don't know where to begin. A new commercialization guide developed by the MDA Technology Applications program will solve this problem.

The guide is a compendium of online resources that explain the process of commercializing technology. Each page provides a brief description of a commercialization topic, with links to more detailed information or to related Web sites. Some of the commercialization issues addressed by the guide include:

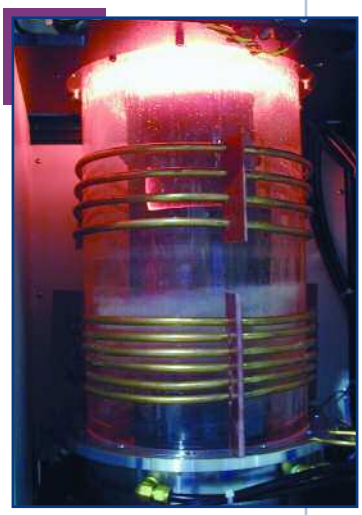
- *How can I obtain funding to keep my business alive?*
- *How do I prepare a business plan?*
- *How do I protect my intellectual property?*
- *How do I license my technology?*
- *How can I create a strategic alliance?*
- *What problems will I encounter when I scale-up my business?*
- *Where can I get professional advice?*

You can view the guide at www.mdatechnology.net. Look under "Commercialization Guide" in the bottom right-hand corner of the home page.

Courtesy of stock.xchng

Help yourself. *The MDA TA program has created a free collection of online resources to help MDA-funded researchers understand the process of technology commercialization.*

THE NEW ECONOMY: 'SILICON-CARBIDE' VALLEY?



Set oven to broil. *Cape Simulation's specially designed HTCVD reactor can create high-purity silicon carbide quickly.*

Cape Simulations is forming a new company to work exclusively on electronic materials with an initial focus on wide-bandgap materials.

Silicon carbide (SiC) is the next big thing in optoelectronics. The wide-bandgap material promises high-power radars, fast high-voltage switches, and light-emitting diodes. There's just one problem though: it's hard to make without impurities that weaken its effectiveness.

Enter Cape Simulations, Inc. (Natick, MA), and their use of simulation tools to design a new kind of SiC manufacturing process that promises to reduce impurities by an order of magnitude. With MDA SBIR funding from 2002 to 2003, the company not only proved the feasibility of growing SiC boules quickly and cost-effectively, but also started to design and build a specialized high-temperature chemical vapor deposition (HTCVD) reactor for the process. It has partnered with a materials company to demonstrate this process. If the HTCVD reactor operates as designed and intended, SiC may become as ubiquitous to the optoelectronics industry as silicon is today for the electronics industry.

The traditional method of growing boules of SiC is called physical vapor transport, and it has some problems, chiefly impurities caused by heating SiC powder to 2000°C inside a graphite container. Powder heats (and turns into gases) unevenly and it is difficult to control the composition of the gas at the seed crystal. The result is the formation of "micropipes" (small cavities), high impurity levels, and low process yield. High-quality large-diameter crystals are currently hard to create and are expensive.

The HTCVD process was invented several years ago at the Linkoping University in Sweden and commercialized by the Finnish company Okmetic, Ltd. In theory, HTCVD solves the problem of impurity in growth of boules by replacing the heating and sublimation of SiC powder with the direct introduction of high purity gases. The key is to introduce into a growth chamber the right amount of gases, in the correct proportions, and to maintain a thermal environment favorable to the formation of certain kinds of gases, while accounting for many variables including fluid dynamics, heat transfer, gas-gas reactions, and gas-solid reactions.

Designing a reactor to do that at commercially acceptable costs is a complex problem, but one that Cape Simulations believes it has solved. The company's innovation is to have designed a reactor by simulation. It has created a high-fidelity simulator that captures all the physics and chemistry of crystal growth by the HTCVD process. The simulator predicts all parameters that influence crystal growth, including gas composition at the growth surface, impurities in the crystal, and thermo-mechanical stresses that the crystal experiences during growth and cooling down to room temperature. The simulator was used to design the reactor.

SiC withstands heat significantly better than conventional electronic materials such as silicon; devices with SiC can operate up to 450°C and would be useful for high-temperature environments such as turbine engines, high-power radio frequency systems, and nuclear reactors. MDA interest in improving yield and processing time on high-purity SiC manufacture is related to the uses of the material in high-power radar systems. However, the anticipated commercial market for relatively inexpensive manufacture of high-purity SiC would probably be light-emitting diodes in the blue and high-frequency range for such applications as solid-state lighting and high-density DVDs. Because SiC has high-voltage breakdown, it enables high-voltage switching, which would be a boon to designers of both electrical systems and grids as well as motor controllers.

Cape Simulations is forming a new company to work exclusively on electronic materials with an initial focus on wide-bandgap materials. The design of the HTCVD reactor for SiC manufacture is patent pending, and both it as well as the simulation software can be licensed to any interested party. The company welcomes inquiries about partnership and licensing arrangements. Additionally, the company has been in the forefront of providing conceptual engineering solutions to the materials processing industry, and it continues to seek out customers who want to bypass trial-and-error approaches to solving manufacturing problems.

—A. Gruen

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SILICON ARCHITECTURE MAY ENABLE FUEL CELLS TO GO MAINSTREAM

Fuel cells have been on the sidelines for decades due to their large size, high cost, and low efficiency and power density. A new silicon architecture may overcome these limitations, allowing fuel cells to enter the commercial mainstream as power sources for next-generation portable electronic devices.

NanoSciences Corporation (Oxford, CT) has developed a high-rate, low-cost method for anisotropically etching silicon using an electrochemical process. MDA funded the company to develop this process for fabricating microchannel plates (MCPs)—which amplify photons or electrons depending on the application—on silicon wafers. The silicon MCPs could be used to detect ultraviolet emissions for missile defense. While the electrochemical process can create silicon MCPs, it may also be applied to the fabrication of silicon fuel-cell separators.

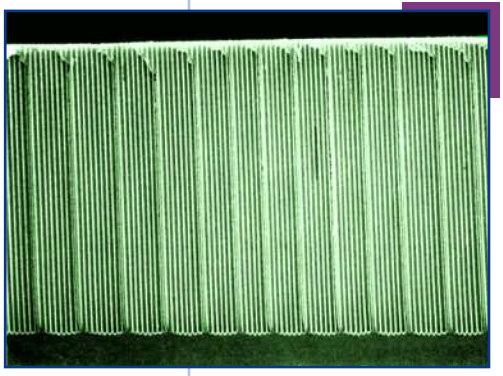
NanoSciences' electrochemical process anisotropically etches silicon wafers with square holes 6 microns in diameter spaced 8 microns apart. The company has produced 12-inch diameter wafers, which will yield 9 times more devices than a standard 4-inch wafer. A higher yield of devices will reduce the overall cost of fuel cells. The silicon architecture may also increase energy efficiency and thus reduce the fuel-cell size (larger cells and more fuel are required to compensate for the lack of energy efficiency).

NanoSciences initially targeted the electrochemical process to the fabrication of silicon MCPs for the night vision industry. Later, Burle Industries made a $5 million investment in the company to become an equity holder and acquired a license to use the MCP. With the help of Burle, NanoSciences changed strategies away from night vision applications to photomultiplier tube (PMT) technology. NanoSciences modified the silicon MCP's photosensitive surface to enable it to amplify photons instead of electrons.

There are drawbacks to using conventional glass MCPs, including fixed-pattern noise (unchanging pattern of anomalies) caused by the geometry of the channels and amplifier noise (random electron emissions), which is inherent in the material. Replacing the glass in MCPs with silicon enables precise packing of the holes to form a uniform array. In addition, NanoSciences' process uses wider bandgap materials to coat the channel walls, enabling an order of magnitude reduction in amplifier noise compared with glass MCPs.

In one of the first applications of the silicon MCPs, a NASA researcher is using the technology to create intensifier tubes, which are PMTs that incorporate MCP amplifiers. These tubes are being used to build a 2-D imaging sensor system for imaging galaxies in the ultraviolet, performing high-resolution spectroscopy, analyzing highly excited gases, and studying the composition of the atmosphere of other planets.

The glass MCPs NASA is using require extended processing time and effort to go from a raw channel plate to a working device because of outgassing. This is the removal of a mixture of water vapor and free lead that occurs on glass channel plates. Silicon MCPs' robust materials not only prevent gases from being absorbed, reducing processing time, but they also can withstand temperatures between 700° and 800°C. A glass MCP melts at approximately 400°C. Also, when trying to detect various light or particles in space, the fixed-pattern noise and amplifier noise generated by glass MCPs can be limiting.



Silicon solution. *NanoSciences' electrochemical process etches silicon wafers for MCP applications. In the cross-section of a p-type silicon MCP (pictured above), the channel depth is 406 microns, while the overall wafer thickness is 440 microns.*

NanoSciences seeks new commercial, government, and scientific applications for its silicon MCPs. It is also interested in licensing its electrochemical fabrication process to interested parties.

—T. Robinson

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ADVANCED MATERIALS

CONDUCTIVE WHEELS OFFER CLEANER SOLUTION THAN RINGS OR BRUSHES

Stoked for spokes. *Honeybee's conductive wheels can be compressed to increase surface contact area, which translates directly into high current-carrying capability.*

Honeybee engineers boast that their design is much cleaner and therefore more reliable than brushes and slip rings.

Anybody who has used slip rings and carbon brushes in rotating equipment is familiar with their wear, dust, and noise issues. When the parts wear down, they create dust. In operation, electrical and acoustical noise is significant.

Addressing these debris issues, Honeybee Robotics, Ltd. (New York, NY), has developed new hardware that eliminates the need for slip rings or brushes yet efficiently transfers current into or out of rotating machines. The hardware ultimately will find new applications in mechanisms for boat radars, printing presses, and other industrial machinery.

Honeybee's technology relies on spoked, wheel-like rings made of beryllium copper (BeCu) spring material. The rings sit slightly compressed and sandwiched almost like ball bearings between two larger rings in the mechanism. (The assembly resembles a planetary-gear arrangement, in which smaller "planet" gears rotate around a central "sun" gear.) Electricity passes from the outer ring, through the BeCu wheels, and into the inner ring, delivering power to a rotating machine. As one ring turns inside the other, the BeCu wheels roll along between them and, due to the spring compression, are constantly in contact with both the inner and outer rings.

Honeybee engineers boast that their design is much cleaner and therefore more reliable than brushes and slip rings. "There's never particle generation. And the wear concerns aren't there either," said Tom Myrick, chief engineer of Honeybee. The lack of serious friction and wear also means that the rings involved in this mechanism should last longer than brushes and slip rings, he said. Moreover, the rolling motion of the wheels means devices using them would operate more quietly and also generate less electrical noise than brushes and slip rings.

The versatility of the spoked wheel and the planetary-gear-like arrangement of the wheels and rotating rings is key. Wires or rods could be used in the hubs of the spoked wheels to control their positions and keep them from straying when using many wheels or multiple layers of wheels and rotating rings, according to Myrick. Moreover, Honeybee can tune the dimensions and shapes of the spokes as well as the thickness of the wheel surface, effectively controlling the stiffness of the wheel as needed for the task at hand. "By adding spokes and leaving the wall thin, you increase its stiffness, but you don't add any extra stress to the system," Myrick said. The spokes also could act as a current-carrying path, theoretically cutting in half resistance in the wheels.

The design of the wheels also can provide a higher current-carrying capability than might be achieved with brushes and slip rings. The wheels can be compressed to increase surface contact area between them and the rings. The increased contact area of the surfaces translates directly into high current-carrying capability, Myrick said.

Know-how for Honeybee's technology has come from work on an MDA-funded project. The agency originally funded the company with a Phase II SBIR award to develop a lightning protection system for the revolving nose turret for the Airborne Laser (ABL) program. The ABL project will put a movable high-power laser on the nose of an airplane, allowing the plane to strike at missiles from the air. Honeybee envisions its wheels embedded in the turret, allowing the ABL to channel a sudden electrical surge and avoid damage to equipment in the nose.

On the commercial front, Honeybee wants to get its technology in front of manufacturers of mechanisms that involve rotary motion and require electricity. Such mechanisms could include boat radars, industrial power washers, and printing presses, as well as other industrial machinery. The company seeks help discovering new applications for the technology. It has patents on a related technology and has a patent pending on its current MDA-funded design.

—S. Tillett

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EYE SAFETY, FASTER THAN THE BLINK OF AN EYE

As lasers become more common in the workplace, eye-safety concerns grow. A new technology developed to defend sensors against blinding laser beams may find use to help defend people from being blinded accidentally.

Kent Optronics, Inc. (Fishkill, NY), has created a material called holographic cholesteric liquid crystal (CLC) that can be transparent to light or block specific wavelengths, and can switch between those states at electronic speeds. MDA's SBIR program funded the material as a way of filtering and protecting delicate sensors from blinding laser attacks, but the technology may have an important payoff in more mundane industrial uses. Goggles using a filter based on holographic CLC, for example, would be more convenient than traditional welding goggles.

Traditional holographic liquid crystal films work on the principle of sensitivity to an electrical field. Liquid crystal molecules inside liquid crystal droplets orient themselves in the direction of an applied field. Where there is no voltage, the droplets have an "average" refraction index, meaning the molecules are randomly ordered. With a sufficiently strong voltage, all of the molecules align and the film is said to have an "ordinary" refraction index. Depending upon voltage, a liquid crystal film can provide anything from total transparency to opaqueness to one frequency of light.

Holographic liquid crystal film is manufactured by using a laser beam tuned to one particular frequency. The beam is fired through a "sandwich" consisting of polymer and liquid crystal, forming polymer layers and liquid crystal layers.

Kent Optronics took this manufacturing technique one step further and figured out how to get a single multiple-layer sandwich to block multiple frequencies or allow them to pass through. The CLC uses "pure" liquid crystal layers without droplets. Using a proprietary technique, lasers can rearrange the molecules of the supporting polymer layers as well as those of the liquid crystal layers.

Having the capability to choose wavelengths at electronic speed is especially important for enabling sensors to do useful work. It is possible to block all incoming light from any source—by using, for example, a brick wall—but then again it is impossible to look out through the same shield. The useful innovation would be to create a filter that would allow a sensor to work normally while not under attack, but to block an incoming laser frequency when necessary and still respond to other frequencies.

The possibilities for use of a CLC-based filter in safety equipment are intriguing. One of the most inconvenient things about using a welding mask, for example, is the need to constantly flip the visor down during welding, and then up again to visually inspect the results. With a small sensor and a power source attached to a pair of CLC-based goggles, it would be possible for a welder to work continuously without interruption and simply allow the filter to turn itself on or off as necessary.

Another possible application for CLC is in use as part of scanning laser projection displays. Currently, laser projection displays work with a combination of lasers, dichroic mirrors, mechanical scanners, and modulators. The dichroic mirrors are optoelectronically adjusted. By using CLC devices as replacements for the combination of mirrors and modulators, laser projection displays would require fewer components, lowering their cost.

Kent Optronics is a small but growing optics R&D firm with two patents filed on its CLC technology. The company is looking for partners who might be willing to invest time and money to develop commercial products using the new material and manufacturing technique.

—A. Gruen

Courtesy of stock.xchng

No stopping now. *In the future, welding goggles equipped with CLC-based filters would turn on and off automatically.*

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ELECTRONICS

NEED A LIFT? POWERED ASCENDERS NOW AVAILABLE

Great escape. *Quoin researchers test the company's electric ascender product, which is part of a tripod system that will extricate F-22 pilots from their aircraft quickly and safely.*

Do you remember trying to climb a rope in gym class? Only the strongest and most skilled people could do it. Now, times have changed.

Quoin International, Inc. (Carson City, NV), is marketing a line of lightweight PowerQuick™ Personal Lifting Devices that allow people to scale vertical surfaces quickly and safely. The powered ascenders move along the length of a rope—unlike typical winch devices that wrap around a capstan—at a steady pace to control ascent and descent. Also, to ensure safety each ascender contains an integral clutching system, which engages in the event the mechanism and brake fail. Each ascender has unique specifications that can meet the requirements of different applications.

For example, an air-powered ascender has been designed for use in flammable atmospheres. The environmental, electrical, and agricultural industries require personnel to work in potentially explosive confined spaces, such as underground tunnels and dust-filled storage areas. Quoin's air-powered ascender has no igniting capabilities. It is driven by 150-psi compressed air, which is squeezed through a tiny turbine. The unit weighs 14 lbs. and can lift 300 lbs. at 1 foot per second (fps). The air-powered ascender is expected to be on the market in 2006.

A gas-powered model is ideal for situations in which speed is critical. The prime market for this device is DOD tactical applications. For instance, the U.S. Navy Seals could use it to quickly board a vessel at sea. Driven by solid-propellant gas generator cartridges and high-speed turbines, the device weighs 7 lbs. and can lift 300 lbs. at approximately 10 fps and 500 lbs. at approximately 7 fps. The gas-powered ascender is also expected to be on the market in 2006.

A third ascender is powered by electricity. There are two versions of the electric ascender currently for sale. The PQ 300-1 weighs 14 lbs. and lifts 320 lbs. at 1.5 fps. The PQ 500-1 weighs 11 lbs. and lifts 500 lbs at 1 fps. Both versions of the electric ascender are explosion proof and can be used in confined spaces like the air-powered model.

Oil companies are purchasing electric ascenders for worker access and egress on oil rigs. The conventional technology, a framework of ropes and pulleys similar to a roped elevator system, costs about $27,000. Quoin's electric ascender sells for about $8,000. The U.S. Air Force has issued a contract to Quoin to develop a self-extracting pilot access tripod to be used in conjunction with an electric ascender. The device will be used to train personnel to rescue pilots from the F/A-22 stealth aircraft without wear and tear to the body. In the event of an actual emergency, it will enable emergency personnel to evacuate the pilot from a plane in 3 minutes. The Air Force is also evaluating the electric ascenders for maintenance in aircraft hangars.

The air- and gas-propelled ascenders incorporate a flywheel-based attitude control device, which was funded by an MDA Phase II SBIR and can be used to replace conventional stabilizing thruster technology in missiles and satellites (see "Flywheel Research Advances 'Pocket Rocket' Engine System" *MDA Update* Spring 2002).

Upon completing the flywheel device for MDA, Quoin received Defense Advanced Research Projects Agency funding to develop the ascender. From the MDA project, Quoin used the same concept of hot gas spinning up a turbine to create the air- and gas-propelled ascenders. To test the devices' components and rope-handling capabilities, Quoin installed a battery-powered motor in each ascender. This led to the creation of the electric version.

Quoin opened a subsidiary under the name Bonanza Products, Inc., to manufacture the ascenders. The company seeks additional funding to ramp up manufacturing and hire more employees.

—T. Robinson

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DIODE IMPROVES THE EFFICIENCY OF COMPUTER POWER SUPPLIES

Power supplies for computers and peripherals may soon be made more efficient, thanks to a new diode technology that uses gallium nitride (GaN) instead of silicon.

With the help of MDA funding, EMCORE Corporation (Somerset, NJ) has developed a GaN-based Schottky diode that can replace the silicon diodes used in a wide range of power supplies. (Schottky diodes are devices that include a layer of metal on top of a semiconductor.) The EMCORE diode offers greater efficiency than silicon, and it costs less than a diode made with silicon carbide (SiC), another high-efficiency alternative to silicon. In other words, EMCORE's diode has the cost of silicon, but with the efficiency benefits of SiC.

Silicon diodes cost less than $1. A diode made with SiC, meanwhile, costs more than $2. Because of the cost advantage over SiC, most computers and other consumer electronics use the silicon diodes in their power supplies, according to Boris Peres, director of contract research at EMCORE. But Peres said EMCORE should be able to produce GaN Schottky diodes for less than $1.

EMCORE's tests show that a 600-volt GaN-based circuit at 250 watts can have efficiency near 91 percent, compared with 89 percent efficiency for a silicon-based circuit. An efficiency gain of only 1 to 2 percent means that power losses are decreased by 10 to 20 percent, according to Peres. And that reduction in losses translates into a diode operating temperature as much as 20°C lower. The lower operating temperature would require less cooling and could altogether eliminate active cooling equipment such as electric fans.

The GaN diodes operate more efficiently because, like competing SiC diodes, they have zero recovery time. Recovery time refers to the time it takes for a diode to stop conducting when the applied voltage is reversed. Manufacturers that use silicon diodes rely on special components known as "snubber circuits" to compensate for recovery effects. But a snubber circuit adds bulk and heat. A silicon-based circuit might include as many as 18 components, including snubbers, while a GaN-based circuit could have as few as six components—yet another advantage of GaN over silicon.

Peres said that using GaN diodes instead of silicon allows manufacturers to decrease board area by 35 to 40 percent and board weight by 40 to 50 percent. The space and weight savings mean manufacturers could produce smaller products or add features to existing designs. Having fewer components also streamlines the inventory-management process for manufacturers of circuit boards.

EMCORE's product still faces competition from SiC products. Like SiC Schottky diodes, EMCORE's GaN Schottky diode has zero recovery time. But the company can produce its GaN material more cheaply than SiC because it can manufacture 4-inch wafers, while SiC comes mainly from less economical 2-inch and 3-inch wafers.

EMCORE's work on the diodes sprang from an MDA-funded Phase II SBIR project in which the company developed an epitaxial process for solar-blind photodetectors using GaN on a sapphire substrate. EMCORE, however, has seen little commercial potential in the photodetectors, but the company has used processes and know-how from the project to develop the GaN Schottky diodes and other products, including a field-effect transistor. The company continues to use GaN on sapphire in its products, as requirements dictate.

Courtesy of stock.xchng

Cool running. *In a computer server farm application (pictured above), EMCORE's GaN Schottky diodes would require significantly less cooling and reduce operating costs.*

In addition to computers, EMCORE wants to target makers of power supplies for telecommunications equipment and other motor-based devices. The company continues to seek inroads into the power-supply market and wants to explore partnerships with players in the silicon industry.

—*S. Tillett*

EMCORE's GaN diode offers the cost of silicon with the efficiency benefits of SiC.

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A RECIPE FOR SUCCESS IN SIGNAL PROCESSING

Courtesy of stock.xchng

Sharper images. *East West Enterprises has algorithms that might improve resolution on medical images distorted by motion.*

It's difficult to recognize a pattern amidst clutter in a still image. If your target is moving—a face in a crowd, for example—it's even tougher to maintain that recognition frame by frame. An MDA contractor may have solved that problem.

East West Enterprises, Inc. (EWE; Huntsville, AL), has created a package of four algorithms the company believes offers superior performance over standard signal processing algorithms. MDA was interested in improving clutter suppression of images of moving targets. EWE believes the same algorithms might also be used for medical imaging or security image processing. Company engineers are testing medical image data sets and hope to attract new funding from the National Institutes of Health to demonstrate the use of the algorithms for specific medical imaging problems such as detecting cancer.

Most signals do not have significant clutter, and a standard algorithm is sufficient to "clean" a signal for use in transmitting and receiving text, audio, still photo images, and video images. However, clutter becomes a bigger problem when the target object is small and the range from sensor to target can be measured in kilometers. The "signal-to-noise ratio" is very low and poor.

The EWE set of algorithms not only improves the signal-to-noise ratio, but does three other important things as well: non-linear registration, resolving closely spaced objects, and target tracking.

Non-linear registration is a special kind of mapping technique that allows someone to compare two dissimilar images. If there is a time interval between two pictures, the pixels in the former don't necessarily correspond to the same pixels in the latter. Imagine, for example, staring at a road map and then rotating it clockwise and moving it a few feet away. It's the same map, but your brain has to do some transformation and registration to make sense of the two different images of the same object. The EWE algorithm for non-linear transformation and registration is the "brain" behind the camera lens.

When two objects are so closely spaced that they cannot be resolved—when you can't tell using normal methods whether you are looking at one or two objects—a special statistical method called Bayesian modeling comes into play. EWE engineers believe they have a unique modification of known Bayesian techniques that perform better than anything on the market today.

Outside of recognizing missiles, there are a few other applications that might also take advantage of EWE's algorithm set. One of these is medical imaging in real time. An annoying aspect of magnetic resonance imaging (MRI) scans is the need to stay as still as possible to provide a clear image for a specialist to study. Adults have the discipline to remain relatively motionless, but small children, infants, and animal companions do not so they need to be partially or wholly anesthetized prior to and during a scan. In theory, compensating non-linear registration and tracking algorithms would enable a specialist to make sense of an image distorted by motion.

In hopes of advancing interest in this application, EWE is working with a medical cancer center to acquire and test medical data sets to see how well the algorithms work in providing clear resolution of small objects in an image.

The company can design a special processing board in which algorithms reside directly in the processors. In effect, they can design an interface between data input and output that will provide whatever real-time features a customer might need. EWE welcomes inquiries about its unique Bayesian method and algorithm package from designers with identification and resolution problems in medical imaging or other fields such as security or transportation safety.

—*A. Gruen*

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ELECTROFORMING PROCESS REDUCES COST AND IMPROVES QUALITY OF MIRRORS

Single-point diamond turning (SPDT)—the standard for machining high-quality aspheric mirrors—is expensive and inconsistent. But now there's a new process being developed that reliably fabricates high-quality mirrors for one-quarter the cost of SPDT.

Multigenerational electroforming is a viable alternative to SPDT for making aspherical and spherical mirrors, according to Advanced Optical Systems, Inc. (AOS; Huntsville, AL). AOS developed the new process with Phase II SBIR funding from MDA. While the technology can be used to make more affordable optics for MDA missile seekers, it also has applications in mirror manufacturing for telescopes and commercial cameras.

SPDT is a subtractive process that uses a diamond turning machine to hollow out a flat substrate, known as a blank, into a mirror. Alternatively, the AOS technology is an additive process that deposits materials, such as nickel, onto a mandrel (the negative of the desired shape of the product). The proposed material is then removed from the mandrel to create a mirror, which is the very precise inverse replica of the mandrel.

Typically, a mandrel will degrade after approximately 20 uses. Mandrel degradation leads to poor quality mirrors, but to replace the mandrel after only 20 uses is very expensive. The AOS multigenerational process reduces cost by producing a quantity of "daughter" mirrors from the mandrel. Then, rather than using the daughters as mirrors, they are instead employed as mandrels to produce a similar quantity of "granddaughter" mirrors. As long as sufficient optical quality is maintained from one generation to the next, a very large number of spherical and aspherical mirrors can descend from a single mandrel.

An additional benefit to consistent high quality is the reduced weight of the resulting mirror. The conventional SPDT process may stress the substrate so there is a limit to how thin the mirror can be made. Typically, diamond-turned optics require a diameter-to-thickness ratio of 8:1 to hold their shape. In the AOS process, as soon as the mirror is thick enough to support its own weight without deforming, it can be removed from the mandrel. The company has achieved aspect ratios as high as 50:1. The process is producing mirrors as thin as 0.02-inch and may be capable of reaching 0.005 inches. The rigidity of the material and its shape help reduce deformations due to gravity.

In one of its first defense applications, AOS created a 4-inch, wildly aspheric mirror for the MDA Foveated Panoramic Seeker mock-up. This system is designed to mimic the human eye, which has a very high-resolution area in the center surrounded by a very low-resolution area on the edges. Combined with a secondary adaptive optical component, the mirror will provide the seeker with a wider field-of-view and real-time adjustable areas of high resolution.

Camera and telescope manufacturers also may benefit using the AOS process. When producing large quantities of mirrors, the AOS process is much more cost-effective than SPDT. For example, if a single mirror costs $2,000 using a SPDT process, the cost of manufacturing 1,000 will be $2 million. Using its process to make multiple mirrors from a single generation of mandrels, AOS can produce 1,000 mirrors for about $500,000. As the quantity increases, so does the cost savings.

Eye spy. *Pictured above is the first of several prototype primary mirrors AOS fabricated. Its unusual aspheric shape allows for a very wide field-of-view while still maintaining a central area of high resolution.*

Currently, AOS is capable of producing infrared-quality mirrors for imaging cameras using the electroforming process. However, the process requires further development to reliably fabricate high-quality mirrors in the visible. AOS welcomes inquiries about potential mirror applications and further development of this technology.

—T. Robinson

Camera and telescope manufacturers also may benefit using the AOS process.

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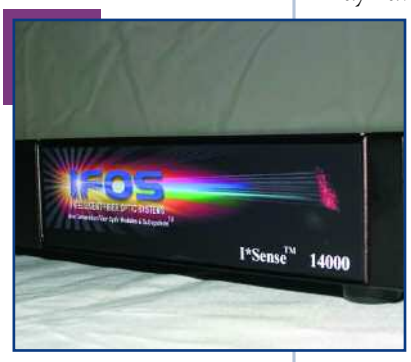
SENSORS

FIBER SENSORS PROVIDE 'WEIGH-IN-MOTION' INFORMATION



Feeling the pressure. *IFOS' I*Sense multisensor system calculates environmental changes at high speed.*

IFOS' sensing system is easily affected by almost any change in its environment, whether that be strain, temperature, pressure, displacement, or acceleration.

Advanced fiber sensor technology funded partly by MDA may have found a concrete application. The next step will be testing it in asphalt.

Intelligent Fiber Optic Systems, Inc. (IFOS, Sunnyvale, CA), is currently working with a state transportation department to test how well fiber-optic sensors embedded in concrete can provide "weigh-in-motion" information. A truck can drive over a concrete roadway equipped with sensors that relay the vehicle's gross weight and speed instantly and accurately to local or remote command centers. Such a sensor system can augment current weigh station networks and would obviate the need for truck idling time and perhaps even the need for weigh stations themselves. This would save transportation firms millions of dollars in wasted driver time and spent fuel, and save transportation departments precious budgetary resources in money and people.

The IFOS multi-sensor system is called I*Sense™ and some of its underlying technology was funded in Phase I and Phase II SBIR contracts by MDA and MDA's predecessor, BMDO, as early as 1995. The interest of the organization at that time was to investigate high-speed fiber Bragg grating (FBG) filters and other optical signal processing technology such as wavelength switching devices, with the intent of improving processing speed for optical sensors and potentially also for optical computing and telecommunications. The use of fiber systems as strain gauges and structural health monitoring evolved from that early work.

An FBG sensing system is extremely sensitive to almost any change in its environment, whether that be strain, temperature, pressure, displacement, or acceleration. The reason why is because of the way an FBG sensor works: any stretching or compression due to an external force changes the spacing of the grating—like a Venetian blind being stretched out or squashed—and thus alters the center of the wavelength of the light reflected from the grating. In short, its reflectivity spectrum changes, and that change can be detected.

Placing multiple FBG sensors on a single strand of fiber is a tricky problem, since each sensor must have its own wavelength segment so that various signals do not overlap. As an FBG sensor undergoes strain, signals shift in wavelength within their bandwidth range. The complete sensor system has an optical source that continuously monitors the sensors. The resulting reflection spectra are analyzed by an advanced photonic spectral analyzer and an interface module that records wavelength shifts.

In sum, the more sensors on a single strand, the harder it is to control. Accuracy in the light source and detection module is paramount, as is the specific wavelength-division-multiplexing technique used. The higher degree of accuracy often forces a low sampling rate. However, IFOS specializes in maintaining very high (kilohertz speed) sampling rates.

Fiber sensors are not new. Their advantages over traditional electronic sensors have to do with the fact that fiber is immune to electromagnetic interference, is lightweight, is electrically passive, can be multiplexed, has near-infinite lifespan, and can be embedded or laminated into materials to operate in harsh environments. In many cases, their operation and maintenance is actually more cost-effective than a traditional counterpart.

The advantage of the IFOS I*Sense product suite is that IFOS takes customer requirements and then provides a tailored, complete sensing solution of both hardware and software. A customer wanting to measure the total weight of a truck as it passes over a section of highway doesn't need or want to know complex spectrum analysis—just the measured weight.

Weigh stations aren't the only commercial application of this previously exotic technology. Fiber sensors can be deployed in hard-to-reach places such as on oil and gas pipelines, to measure corrosion levels and possible intrusions on mile after mile of pipeline sections. Every day that a pipeline is shut down for inspection can cost millions of dollars, and the longer the pipeline, the more likely a shutdown. This is the kind of inspection process that can be done with fiber sensors remotely and automatically.

Continued on page 16

TOMORROW'S FORECAST: BETTER RADAR TRACKING AND MORNING SHOWERS

Scientists at Propagation Research Associates, Inc. (PRA; Marietta, GA), are developing a radar-enhancing system that increases the accuracy of not only missile tracking, but also weather prediction.

PRA is developing the enhanced tropospheric effects compensation (ETEC) system, which can create a model of the atmosphere just above the horizon based on a time history of global positioning system (GPS) satellite observation. A key potential of this system is its ability to accurately measure water vapor content—a major contributing factor to atmospheric distortions—over large areas and at various altitudes.

While all radar systems share an inability to accurately track objects at low elevations, the problem is more pronounced with missile defense systems because they operate at longer ranges. MDA awarded PRA a Phase II SBIR contract to develop the ETEC to improve missile defense radar system capabilities just above the horizon, where atmospheric refraction (caused by water vapor) and air turbulence disturbs its ability to locate and track an object. ETEC aims to improve radar performance at low elevations—0.5 to 5 degrees above the horizon—by modeling correction factors for the troposphere, or lower atmosphere, potentially expanding a radar's range by 400 kilometers (km).

Due to atmospheric conditions, radio wave signals bend (atmospheric refraction) so the target appears to be at a different angle of elevation than it is relative to the radar. At an elevation of 4 degrees a typical refraction bending error is approximately 3.8 milliradians (which at 2,000 km downrange is a cross-range error of 7.6 km). Air turbulence also distorts radar by causing a signal to fade in and out of view. Every break in the signal can cause the radar system to begin tracking anew if it does not bridge the dropout and identify the signals as coming from the same object.

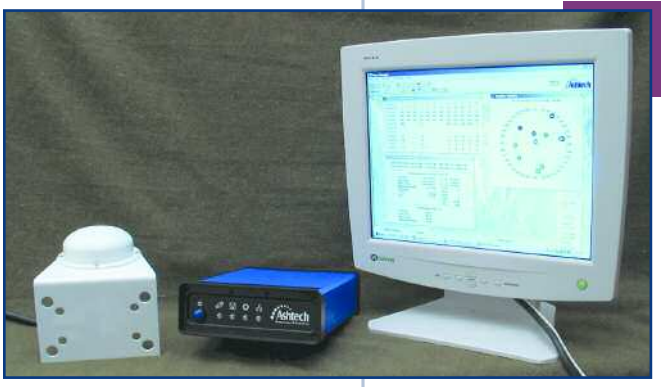
Using a time history of GPS satellite position as viewed by the radar, ETEC creates a model of the atmosphere that enables it to supply refraction- and turbulence-correction estimates to radar systems. ETEC's turbulence detection capabilities bridge the gap between signals that fade in and out by estimating the duration of the break in the signal. The final ETEC prototype should be finished and ready for testing in about two years. According to PRA, The Boeing Company is interested in acquiring the technology for missile defense radar systems if the prototype tests well.

ETEC's atmospheric modeling ability may also have a direct benefit in weather prediction. For example, it could provide data estimates of water vapor content every 30 minutes. The current method of measuring this data is a balloon-based instrument called a radiosonde, which takes approximately six hours to report a full atmospheric profile.

PRA has established an agreement with the National Center for Atmospheric Research (NCAR) to incorporate the data generated by ETEC in the fifth mesoscale model (MM5). This model is designed to measure a weather system or storm between 100 to 1,000 square miles in size, for example squall lines (mesoscale atmospheric circulation). ETEC can enable water vapor content, as a function of altitude, to factor into the weather modeling. Water vapor is a major component of how the atmosphere evolves when creating weather. It is also the most difficult variable to estimate when predicting weather. If NCAR could precisely measure water vapor, it could more accurately predict the weather. NCAR should have PRA's measurements to incorporate into the MM5 in the next year.

PRA seeks additional funding for technology development as well as organizations that may be interested in ETEC's capabilities.

—T. Robinson



On the horizon. *In two years, PRA expects its ETEC system to be ready for testing. The technology converts GPS signals into turbulence and refractivity corrections that improve atmospheric effects modeling for radar tracking and weather prediction.*

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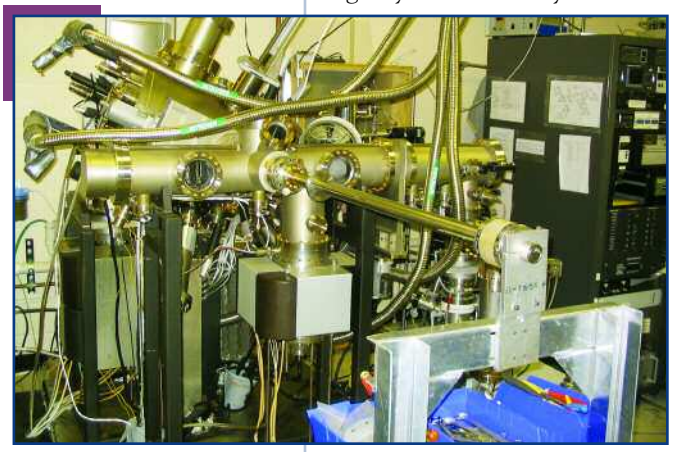
MDA's HBCU/MI program is managed by MDA's SADBU and is administered by the agency's Advanced Systems Deputate (MDA/AS), to include technical management and recommendations of HBCU/MI contract awards. Research topics under the most recent BAA cover 10 key technology areas, from sensing and imaging to robotics to photonic materials to information processing. However, over the years these topics have evolved to meet the agency's technical needs and changing priorities. One objective of the program is to prepare HBCU/MIs to participate in mainstream research programs of MDA and other DOD entities, according to Paul Koskey (MDA/AS), technical manager for the HBCU/MI program and program director for technology transfer at MDA. The period of performance for the awards in the current BAA program ranges from 12 to 24 months. The program is funded at $1.5 million annually for 2005 and 2006. Koskey said he is hopeful that awards under the BAA will give HBCU/MIs critical support for research that can be leveraged into missile defense technologies as well as commercial products, thereby tapping an often overlooked source of innovation. Researchers funded by the program also could provide attractive partners for industry, which might team with universities on MDA-funded STTR projects.



Materials machine. *This molecular-beam epitaxy machine at NC A&T State University is used to develop materials that could be used in components for optical local-area and metro-area networks.*

Elbow grease and ingenuity

The environments in which MDA-funded projects are undertaken at HBCU/MIs bear some resemblance to corporate R&D environments: The lab equipment looks familiar. Heads are constantly scratched over tough scientific questions. And money is almost always in short supply. But for universities—especially state-funded universities such as North Carolina Agricultural and Technical State University (NC A&T; Greensboro, NC)—budgets can be especially tight.

Dr. Shanthi Iyer, a professor in the Department of Electrical Engineering at the university, has spent years alongside students researching antimonide materials that can be applied in infrared optoelectronic devices, for possible use in applications such as sources and detectors in long wavelength for fiber-optic communications. MDA funding through the agency's HBCU/MI program has helped that research progress.

Iyer and her students specifically have focused their MDA-funded work on gallium arsenide antimonide nitride (GaAsSbN) grown on gallium arsenide (GaAs). The work ultimately could lead to a more robust and cost-effective semiconductor material for optoelectronic devices such as edge-emitting and vertical-cavity surface-emitting diodes in the range of 1.3 to 1.6 microns, for use in optical local-area and metro-area network applications, according to Iyer. MDA funded the project because the technology showed promise for use in infrared devices.

A tour of the labs at NC A&T reveals the ingenuity as well as the focus on the basics that prevails at the university. After winding through a labyrinth of cavernous halls, a visitor might be ushered into a no-frills lab where scuffed copies of the periodic table lie taped to desks and where preliminary designs for devices are pieced together out of butter-cookie tins. But another jaunt through the labyrinth will bring the visitor to a lab dominated by computers and a million-dollar molecular-beam epitaxy (MBE) machine. It is this machine that is at the focus of much of Iyer's MDA-funded work. It is this machine that produces the materials that Iyer and her students are researching.

The machine itself is one that has been built piecemeal over the years, primarily from DOD-funded research projects and partly from department funds. Labor to build and maintain the MBE machine often has come from internal sources, according to Iyer, who explained that she sometimes has had to serve as a plumber as well as a professor. For instance, about six years ago, David Jones, an undergraduate student in the department, showed an interest in the complex, Death Star-like epitaxy machine that was taking shape. That student, as a part of his undergraduate project and later

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on as master's thesis work, built in-house accessories for a nitrogen plasma source and helped maintain the machine, Iyer said. Another graduate student, one who is currently studying under Iyer, also was drawn in by the hands-on project. The student, Kalyan Nunna, said he initially began doing clerical work for Iyer but later became intrigued by work in the lab, so he began participating in research. Today, Nunna's graduate work focuses on the effects of nitrogen incorporation on optical properties of GaAsSbN/GaAs single quantum wells. All told, seven people including Iyer are involved in research that in some way stems from the MDA-funded project.

Embracing challenges

Meanwhile, a few states to the southeast, another group of researchers at an HBCU/MI is leveraging MDA funding to investigate ferroelectric crystals for high-performance transducer applications. The researchers, based at Alabama Agricultural and Mechanical University (Alabama A&M; Normal, AL), are led by Dr. Mohan D. Aggarwal, whose MDA-funded project focuses on the development of new and improved piezoelectric and electroresistive crystals for actuators and transducers (devices that transform mechanical energy into electrical energy). Work centers on lead magnesium niobate/lead titanate (PMN-PT) single crystals. Aggarwal said single crystals show better properties than PMN-PT ceramics and PMN-PT films, but he said the lack of a simple, reproducible fabrication technique remains a limitation for use of single crystals in device applications. So research continues, with Aggarwal and other Alabama A&M researchers focusing on high-temperature solution techniques using a lead-oxide (PbO) flux method.

Aggarwal, whose MDA-funded project includes a team of nine professors and students, said the resulting materials show promise for components that can be used in sensor applications such as mine detectors, sonar transducers, lighter high-energy devices, and even cell phones and laptops. But researchers at the university want to continue to work on optimizing methods for growing the material, as well as new materials. The team also wants to explore other growth methods and study properties of materials produced.

The work itself is challenging, and attracting graduate students to the field of physics at the 6,500-student university also can be challenging, according to Aggarwal, who heads the Physics Department. "Everything has some challenge in it," he said. "Otherwise, it does not make it interesting." His department has graduated more than 50 Ph.D. students since the program began in 1986, and Aggarwal said the MDA-funded project is helping students see the possibilities that physics holds as a field with commercial career potential.

'Everybody gains'

MDA acknowledges that the possibilities for agency-funded projects do indeed lie beyond just military applications. The MDA-funded work being conducted at minority institutions and historically black colleges and universities fits with a broad view of technology, according to MDA's Koskey. He said that the origins of a technology—and whether it's initially developed for military or commercial use—is less of an issue to users these days. Instead, potential applications—how a technology might be used—is key. "Technology is neutral, but it has applications," Koskey said. "There are few technologies that don't have applications in both the commercial world and the military world."

Moreover, pushing MDA-funded technologies toward commercialization offers a winning prospect for everyone, from universities to businesses to government agencies. "Right now we are finding out that everybody gains from getting a technology commercialized," Koskey told HBCU/MI professors during a recent tour of campus laboratories. "The cost comes down for us. People start businesses. They become profitable. They develop new products. They make us more competitive in the world. It's a snowball."

Continued on page 16

Tangible results. *Mohan Aggarwal of Alabama A&M (left) shows material to Paul Carroll of the National Technology Transfer Center (center) and Paul Koskey of MDA.*

Pushing MDA-funded technologies toward commercialization offers a winning prospect for everyone, from universities to businesses to government agencies.

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"There are few technologies that don't have applications in both the commercial world and the military."

—Paul Koskey, MDA

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With MDA funding, HBCU/MIs continue to help roll that snowball, carrying on the tradition of challenging the status quo and pushing limits in science and technology. For more information on MDA's HBCU/MI program and other R&D programs, visit http://www.acq.osd.mil/mda/mdalink/html/oppor.html or http://www.acq.osd.mil/mda/mdalink/html/sadbu.html.

A total of 11 HBCU/MI contracts were awarded during the most recent cycle. Contact information for the two HBCU/MI awardees featured in this article is included on the right. For information on the other nine awardees, contact stillett@nttc.edu.

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Fiber Sensors . . . from page 12

Weigh-in-motion trials on concrete surfaces have proven successful. IFOS intends to tackle the more complex problem of sensing asphalt surfaces, which are subject to more frequent changes in strain, temperature, and pressure. Most of the world's road surfaces are paved with asphalt, not concrete. For customers with any environmental sensing problems, IFOS welcomes inquiries on the I*Sense suite of products, services, and pricing.

—*A. Gruen*

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