Fall 2005

Missile Defense Agency's

TechUpdate

A Quarterly Newsletter for MDA Technology Transfer

▲ Sailcloth made with Cuben Fiber is three-times stronger than conventional dacron at the same weight.

INSIDE

Fabric of the Future

Fiber-based material splits the difference between a fabric and a structural composite.

by Scott Tillett/stillett@nttc.edu

A new class of superstrong, superlight material is taking a leap into the future by combining the flexibility and lightness of fabric with the strength and durability of aerospace-grade composites.

The new material, called Cuben Fiber, was pioneered for use in sails on racing yachts, but researchers are formulating an array of Cuben Fiber compositions for use in a wide variety of commercial and military applications.

Versions of the material are being developed for ultrastrong military parachutes that can be packed in half the space and new types of fabric-based body armor. Other versions of the material are being formulated for more durable balloons, tents, airships, and recreational items such as kites for a surf sport called "kiteboarding."

Cuben Fiber is being manufactured by Cuben Fiber Corporation (Mesa, AZ), which has an MDA SBIR Phase I contract to enhance its pre-existing material to meet specifications for the agency's High Altitude Airship (HAA) program. R.J. Downs, president of Cuben Fiber, said the MDA project calls on the company to engineer a new version of its existing material to meet the needs of the airship program, which proposes to put in place unmanned, untethered, lighter-than-air high-altitude airships that can be used in ballistic missile defense.

continued on page 10

Our New Look

by Pat Hartary/phartary@nttc.edu

In my last column, I mentioned that the fall newsletter was going to look "a bit different." Now I may have to eat my words.

Perhaps I should have said "a lot different." Having planned the redesign for some time, there were many layout and content issues to address. Here are some highlights of the new look that readers should notice.

- **New color scheme.** Two years ago, a new blue and green logo was created for the MDA Technology Applications program to improve its program identity. You now see we're using the same colors throughout the newsletter, giving a more contemporary appearance, making the text much easier to read, and aligning with the program's branding.
- **Longer articles.** From time to time, a particular technology warrants more extensive coverage. A few stories will therefore span at least three pages, providing more details about the potential commercial applications. In this issue, we have two such examples: "Fabric of the Future", our cover story, and "Crafting Cool Composites," which begins on page 12.
- **New departments.** The new design contains sections that will appear regularly. For example, news and information relating to MDA technology transfer will be highlighted under "What's News." Commercialization advice will be featured in "Mind Your Business." And for those who'd like to test their trivia IQ, check out the "Tech Trivia" area.
- **Name change.** The newsletter was called the *MDA Update*; now it's the *MDA TechUpdate*. While still focused on the commercial applications of MDA-funded technology, the new name more accurately describes the newsletter's focus.

I hope you enjoy the new look and feel of this publication. If you have any comments or suggestions, please write and tell me at phartary@nttc.edu.

The Right Chemistry

For any writing staff, finding the right chemistry is important. That's why our newest technology writer is someone we're very excited to have on our team. He has a strong background in both English and chemistry.

Mike Felton previously worked for the American Chemical Society writing and editing for two trade magazines, *Today's Chemist at Work* and *Modern Drug Discovery*. He also wrote for the news section of the journal *Analytical Chemistry*, covering the microfluidics and nanotechnology beats. For other publications, he has written about subjects ranging from instrumentation on the Mars Rover to rational drug design.

Joining us in June 2005, Mike has hit the ground running with three stories in this issue. Welcome aboard Mike!

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CONTENTS

Time Flies

Do you like history? The MDA Technology Applications program has recently created a poster-size timeline chronicling the historical highlights of both MDA and its technology spin-offs from 1985 to 2005. A free copy of the poster can be obtained by sending an e-mail to techapps@nttc.edu. A copy will also be included in the *2005 MDA Technology Applications Report*, which will be available in late 2005. This publication will feature more than 20 MDA-funded technologies—from wide-bandgap semiconductors for today's miniature electronics to high-efficiency portable generators for third-world populations—that exemplify the height of MDA technology transfer.

Hearing Voices

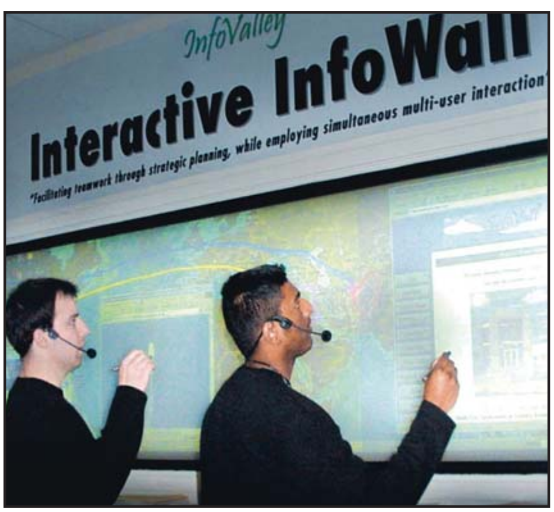
Clarity Technologies has been purchased by Cambridge Silicon Radio, a wireless solutions provider and leading supplier of Bluetooth technology, in a $17.1 million cash deal.

Clarity supplies voice extraction and echo cancellation software based on proprietary technology that enhances the audio performance of wireless headsets, wireless handsets, and automotive hands-free systems.

Clarity was formed in 1998 by IC Tech (Okemos, MI) which developed its proprietary technology under a BMDO SBIR contract. IC Tech's work for BMDO focused on designing a system to separate, localize, and recognize speech in real time.

Interactive Display

InfoValley (Wayne, PA) recently delivered working prototypes of its Interactive InfoWall™ display system to the U.S. Navy's Command Third Fleet Headquarters in San Diego, CA, and the Alabama Department of Homeland Security (ALDHS). An InfoWall system was integrated into the Command's Interactive Cortex system for experimental applications, while ALDHS will use the display in upcoming homeland defense exercises.

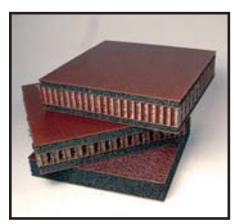


MDA's SBIR program funded InfoValley to develop InfoWall technology for battle management and command and control applications. InfoWall gives a team of workers simultaneous access to a large display wall that serves as a common computer screen.

See Foam

Touchstone Research Laboratory (Triadelphia, WV) built a new 43,000-square-foot facility to produce CFOAM®, a structural material made from coal.

The facility is expected to produce 45 tons of CFOAM material in 2005, ramping up to 175 and 350 tons in 2006 and 2007, respectively. Ten employees will be hired within the first six months of operation, with more to be added as production increases.



CFOAM's physical properties can be tailored to a variety of potential end uses, including composite tooling, aircraft firewalls, electromagnetic interference shielding, decking and bulkheads on marine vessels, lightweight optics, and rocket nozzles. MDA's SBIR program funded the company to develop CFOAM for space applications.

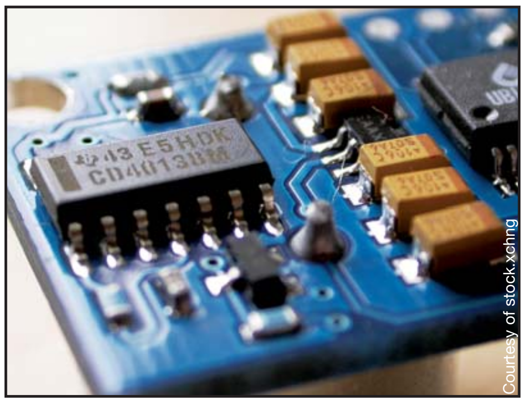
Getting the Lead Out

Lead-free solder will impose a lesser burden on the environment.

by Mike Felton/mfelton@nttc.edu

Japan is voluntarily doing it. Europe is mandating it in 2006. The United States is thinking about it. Getting rid of the lead in electronics—particularly in solder—will protect our environment. But adopting current lead-free solder technology is costly. A new material from MDA-funded Aguila Technologies (San Marcos, CA) may provide manufacturers with a more cost-effective and easier to use option.

The big hurdle in moving to lead-free solder, according to Albert Capote, CEO of Aguila Technology, is that the lead-free solders melt at higher temperatures, forcing other materials to withstand the new temperatures. Traditional lead-based solder is an alloy of tin and lead, melting around 183ºC to 190ºC. The most common lead-free solders are alloys of tin and silver (and sometimes copper) and melt between 217ºC and 229ºC. When shifting from tin/lead solder to tin/silver solder, the change in melting points is small but it has an enormous impact. "When you get to those temperatures all the materials that are being used to fabricate these electronics have to change because they can't take the temperature," Capote said. "They crack; they start to degas. Some of the housings for the components and plastics start to melt…It's a nasty mess."



▲ Due to environmental concerns, semiconductor and electronics manufacturers are seeking alternatives to lead-based solder in products.

HUGE SAVINGS

Aguila estimates that for one customer, a major international automobile electronics manufacturer, Aguila's lead-free solder would save over $125 million a year. "Costs start to add up with other lead-free solders," Capote added. "We have to use higher temperature epoxies in printed circuit boards and higher temperature molded plastics for components."

"Some of the properties of our material are actually better than lead-based solder," Capote said. Today, all solders need flux (a paste applied with the solder that helps it flow to a particular area) and those fluxes must be cleaned off the printed circuit boards. "Our material doesn't require any flux or any cleaning," Capote said. "It also doesn't leave any residues or any kind of contaminants after its use."

Although the United States does not yet regulate lead in electronics, Aguila believes U.S. companies will be very interested in its technology. These companies will be forced to change to lead-free solder if they plan to export products to Europe or Asia. And, because of the economies of scale, producing two versions of the same product will be too expensive.

Still other areas of the world have embraced different types of lead-free solders. Japanese industry is using a tin/bismuth/zinc solder, which melts at approximately 190ºC. However, this solder isn't the ideal solution. "It doesn't flow very well, oxidizes terribly, and requires very strong fluxes," Capote said. Due to these shortcomings, yields will be lower, which can significantly increase costs.

ALMOST SHELVED

Perhaps one of the most interesting aspects of this story is that the technology was almost shelved completely! Aguila Technologies didn't intend to make lead-free solder; instead, it was developing a spray-on electrical shielding material under an MDA SBIR contract. "We initially found there really wasn't going to be a demand for it," Capote remarked, "but soon a customer came to us and said, 'This could be a solution to our lead-free solder problem."

The technology is still being evaluated by this customer as a replacement for lead-based solder used to surface-mount electronics. Aguila is looking for other customers who might be interested in this product. Capote and his coworkers are also working with MDA under an SBIR Phase II contract to develop a semiconductor chip die attachment for radar electronics using this material. In addition, the Department of Defense is pushing for lead-free electronics to meet future regulations. "It could potentially be far, far greater than MDA ever thought the original application was going to be," Capote said. "It's a win-win for everybody."

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Light Work

Deep-ultraviolet LEDs are being developed for water sterilization.

by Mike Felton/mfelton@nttc.edu

Hikers know that taking a drink from even a pristine mountain stream can make them sick from bacteria and parasites. Chemicals (such as chlorine, bromine, or iodine) used in municipal water supplies and hiking kits to combat water-born microbes make water taste bad.

New, deep-ultraviolet light-emitting diodes (UV LEDs) produced by Sensor Electronic Technology (SET; Columbia, SC), using a manufacturing process developed with MDA SBIR funding, may allow the use of UV light to sterilize water in commercial applications. In fact, today one SET customer has already patented a UV LED-based portable sterilization device for hikers and soldiers.

Using UV light to kill bacteria is more efficient and potentially healthier than using chemicals. However, the adoption of UV light systems has been limited because most current systems rely on high-voltage mercury discharge lamps that guzzle energy, need high-voltage electronics, and contain hazardous mercury. In addition, the lamps burn out after about 8,000 hours and only emit certain fixed-UV wavelengths.

BRIDGING THE GAP

SET did not start out with the goal to make UV LEDs, according to Dr. Remis Gaska, president and CEO. "We were focused on developing material and devices for high-power RF applications, such as next-generation MDA radars." To make the necessary electronics, SET developed a new epitaxial growth technique they call migration enhanced metal-organic chemical vapor deposition (MEMOCVD™, pronounced memo-CVD).

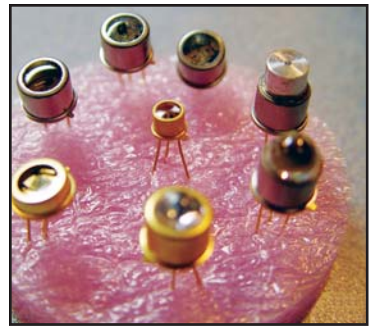
"We believe MEMOCVD bridges the gap between MOCVD [metal-organic chemical vapor deposition] and MBE [molecular beam epitaxy] because it allows you to grow layers at much lower temperatures than conventional MOCVD… temperatures comparable to what is used in MBE," Gaska said. The new technique improves the resulting material's quality allowing the formation of abrupt, high-quality heterostructures (regions of non-uniform composition), accurate control of thickness and composition, and higher wafer uniformity. These add up to a dramatic improvement in the performance and reliability of the electronics that are produced. In addition, the process works with 4-inch diameter wafers, reducing manufacturing costs and increasing manufacturing throughput.

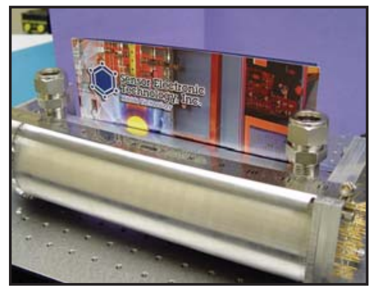
SET researchers realized that this technique could be applied to making blue and UV LEDs. The blue LED market was already competitive, but there were no UV LED suppliers because they require the addition of aluminum gallium nitride (AlGaN). According to Gaska, "It's a real technological challenge to grow high-quality, high-aluminum-content AlGaN materials."

BIO-AGENT DETECTION

Although SET continues to conduct research for MDA, DARPA began funding SET's UV LED development for possible use in handheld bio-agent detectors. Not only would UV LEDs not need high-voltage power supplies or equipment designs to handle excess heat, but LEDs could be made to emit the exact wavelength that best excites the fluorescent markers that bind to biological molecules. "We made a breakthrough last summer; our group improved the device performance by a factor of 15 or 20," Gaska recalled. "We became the first and sole supplier of these deep-UV LEDs with peak emission below 365 nm."

SET is working with many new customers to explore the commercial potential of its UV LED technology. Applications include municipal water and sewage, analytical equipment, sensor calibration, and even secure wireless communication. One day, UV LEDs might even replace the mercury tubes in fluorescent lights for general lighting. Gaska said, "There is some design cycle and adjustment cycle needed, but we clearly see it's a really huge market."





▲ (Above) Deep-UV LEDs meet a variety of end-user needs.

▲ (Below) A specialized reactor is key to SET's proprietary chemical vapor deposition process.

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Magnets Stand the Heat

A new class of permanent magnets performs better in communication systems.

by Scott Tillett/stillett@nttc.edu

A new class of permanent magnets that offers higher temperature stability and greater efficiency could reduce the cost of microwave communications as well as other applications that require high-performance magnets.The magnets, developed by Electron Energy Corporation (EEC; Landisville, PA) have been designed specifically for use in traveling wave tubes (TWTs), which serve as amplifiers of microwave power in communication and electronic warfare systems. MDA's predecessor, BMDO, originally funded EEC to develop permanent magnets that would allow TWTs to operate with higher performance at higher temperatures and minimize system cooling requirements and weight. The project also promises to improve beam focusing, system performance, and tube life.

▲ Permanent magnets from EEC have been used in the ion engine of Deep Space 1, an exploratory space vehicle launched in 1998.

Although the magnets are especially suited for TWTs, EEC researchers say they could be used in a broad range of applications that require permanent magnets, including electric propulsion, high-temperature actuation, high-temperature motors and generators, material mixing, semiconductor manufacturing, and even underground instrumentation for oil drilling. EEC already is producing the magnets and has product ready for sale for TWTs and other systems.

MORE EFFICIENCY

The company has based its new magnets on previously existing magnet materials but has developed new alloys that allow it to build more efficient magnets for TWTs. In the TWT arena, EEC expects that the performance and efficiency of the magnets will result in lower costs for users.

What sets the magnets apart is their ability to withstand higher temperatures. In aircraft, military environments, and space, equipment needs to run across a wide temperature range. Additionally, TWTs include electron-generating cathodes that produce considerable heat.

EEC's magnets, made from samarium cobalt (SmCo), can operate at up to 550°C—beyond the range of previous generations of SmCo magnets and well above the 200°C limit of neodymium iron boron, a commonly used material for permanent magnets. The higher temperature performance makes the magnets more reliable, which translates into efficiency for users. And the greater efficiency should translate into power or cost savings somewhere along the line.

"The ability to work at higher temperatures with better performance is something that allows the designers of TWTs to be able to design more powerful devices," said Peter Dent, director of sales and marketing at EEC. "Better stability allows them to have better reliability in terms of control of the electron beam. If the beam comes out of focus, it adds additional heat."

LIGHTWEIGHT

The magnets are lightweight, too—especially when compared with alternatives such as bulky electromagnets, which might compete with permanent magnets in some non-TWT applications. "We have been working to make these magnets more powerful so systems can be more powerful and more energy-dense—with lighter weight and more performance," Dent said.

EEC tailors alloys for its SmCo magnets by using additives such as holmium, zirconium, manganese, erbium, gadolinium, iron, and copper to develop crystal structures that meet desired specifications. The company continues to refine its line of magnets while also introducing its current magnets commercially.

So far, challenges for the company have included developing the materials' chemistry and processes to produce the current magnets and to reach as much as 250°C above where the state of the art had been, according to Dent. He said future challenges for the company include getting magnets into systems for qualification and finding customers.

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Powerful Retrofit

Supercharged power supply promises savings on ground and in air.

by Scott Tillett/stillett@nttc.edu

A footlocker-sized device could provide the extra juice needed to run air conditioners and computers on aircraft, reducing engine power drain. And over the lifespan of the aircraft, significant fuel savings could be generated.

In addition to providing electrical power for aircraft, the supercharged power supply, which is being developed by Steward-Davis International, Inc. (SDII; Van Nuys, CA), also could be used at ground level to provide supplemental power while taking up a very small footprint. Company leaders, therefore, envision the system as one that could be used to support emergency or disaster field operations or to support large mobile operations that require extensive electrical power. As a supplemental power system on the ground, the proposed system, about 75 x 42 inches, would compete with several truckloads of electrical power-generating systems that might be strewn out over an acre or more.

▲ Boeing 707s still flying in South America and other countries could cut fuel costs using SDII's supercharged power supply. Permanent magnets from EEC have been used in the ion engine of Deep Space 1, an exploratory space vehicle launched in 1998.

MEGAWATT POWER

The 2,000-pound device that SDII is developing would produce 1 megawatt of electrical power at altitudes of 42,000 to 45,000 feet or higher, according to company leaders, who envision marketing a commercial system as a single, integrated "container," which could be placed on the ground for support equipment or located as needed within an aircraft.

Stanley W. Epstein, chief executive officer of SDII, said the power system might be modified to produce as much as 2 megawatts of electrical power or as little as 40 kilowatts. The device should meet the aircraft industry demands for clean, stable, abundant power, he said. And, when the system is inserted in an aircraft, the fuel efficiency of the device would allow it to pay for itself within 200 missions (16 hours of flying time per mission), Epstein added.

The company sees its emerging product as one that would be appropriate for retrofit systems. Legacy aircraft sometimes need to run their engines on the ground to provide electrical power for instrumentation and air conditioning. The current alternative is a ground power station, which has a very large footprint or is part of the ground-based infrastructure at commercial airports, and is very costly. MDA originally funded the company with an SBIR Phase II contract to develop innovative onboard power and cooling solutions for use in the Ballistic Missile Defense System.

SDII's system, based on a 1,500-horsepower helicopter turbine engine, would use diesel/aircraft fuel. The turbine engine would operate a generator. And the entire system, packaged in a pressure vessel, could be mounted virtually anywhere inside an aircraft, requiring only an external air scoop and exhaust port. Because the helicopter-based engine is designed for low-altitude operation, it would become ineffective at typical cruising altitudes. To overcome this limitation, SDII adds a supercharger, providing sea-level air pressure to the engine.

INSIDE LOOK

In the device, air will enter a supercharger compressor (SCC) through an input air scoop, where it will be compressed (and also heated as a byproduct of compression). It then will pass to an intercooler that will improve thermodynamic efficiency and power density by providing cooler input air to the core engine. The engine exhaust will drive a power recovery turbine, which will drive the SCC. The hot gas will be discharged through an exhaust port. A separate drive shaft will operate the generator, via a gearbox.

The company's current challenges include finding markets for the power system and determining a commercialization exit strategy. The company already offers a line of supplemental electrical power systems and is now seeking money to build a prototype or a small version of the new power system proposed under the MDA-funded project.

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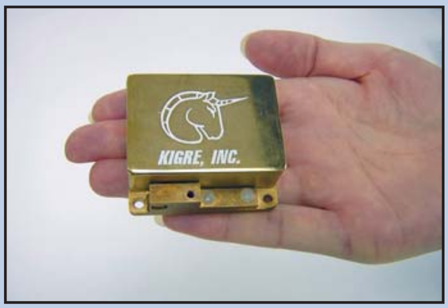
The Technology Application program creates detailed profiles of MDA-sponsored research with commercial applications. New profiles are added quarterly to our Web site, mdatechnology.net. Summaries for some of our most recent additions can be found below. For more information on a particular technology, visit mdatechnology.net. Enter the search code (e.g., #650) for the technology profile in the "Quick Search" box and then click the "Go" button.

Rare-Earth Doped Glass Used in Diode-Pumped Laser Transmitter

Using a new erbium- and ytterbium-doped phosphate glass, Kigre (Hilton Head, SC) has developed a compact, high-efficiency diode-pumped microlaser that operates at a laser wavelength of 1.54 microns. The laser output pulse width is 7 nanoseconds and the pulse repetition rate ranges up to 10 Hz, which makes the unit 3-to 10-times faster than existing laser transmitters used in state-of-the-art laser rangefinders. The shorter pulse width provides better accuracy and better resolution of target images.

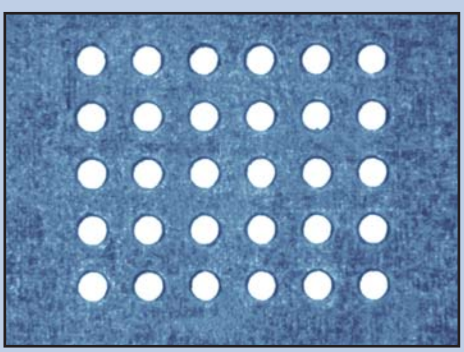


▲ Microlaser transmitter

Search code for tech profile: #651

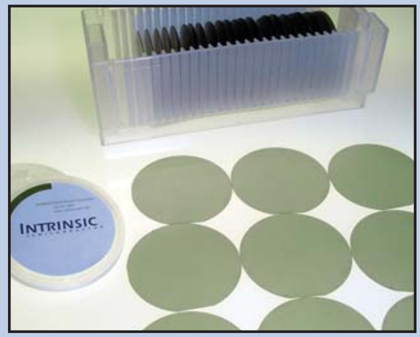
Technique Used in Drilling 170-Micron-Diameter Holes

Laser Fare (Smithfield, RI) has patents pending on a new laser-drilling technique combining beam splitting and low-power optical trepanning. The main advantage to the technique is speed; other techniques can drill precision holes, but several orders of magnitude more slowly. MDA interest in high-speed precision hole drilling was driven by its Airborne Laser program requirement. The technique has several potential commercial applications in the aerospace, automotive, and precision-valve ("inkjet spray") technology industry.



▲ Submillimeter holes

Search code for tech profile: #649



▲ Silicon carbide wafers

Silicon Carbide Bulk Crystal Growth at High Rates

INTRINSIC Semiconductor (Dulles, VA) developed, and has filed several patents on, a manufacturing technique to improve the quality of silicon carbide (SiC) boules, which are sliced into wafers for use as substrates for high-power gallium nitride devices with military applications in X-band radar and commercial applications in wireless base stations. MDA funded improvements in SiC boule manufacturing techniques as early as 2000 through a company called Bandgap Technologies, Inc., which was acquired by INTRINSIC in 2004—though INTRINSIC also has received MDA funding since 2003 in the same field. The company sells to the defense community in the U.S. and also to commercial customers in Europe and Asia.

Search code for tech profile: #650

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Preceramic Polymers to Hafnium Carbide Ceramic Fibers and Matrices

MATECH Global Strategic Materials (MATECH, Westlake Village, CA) has invented equipment to manufacture hafnium carbide (HfC) and hafnium carbide nitride (HfCN) ceramic fiber from preceramic polymers. Parts made with a HfC-HfC-woven fiber-reinforced matrix can withstand more heat than similar parts made with silicon carbide fiber, but at sixty percent of the density of metal-metal alloys such as rhenium-tungsten alloys. HfC composites would be useful in aerospace applications such as rocket nozzles.

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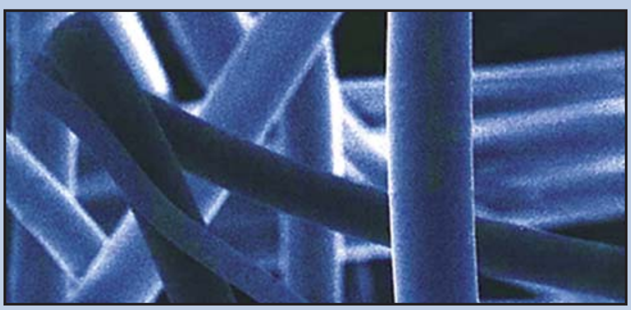

▲ Ceramic fiber

▲ Medical imagery

Algorithms for Improved Performance of Focal Plane Arrays

East West Enterprises (EWE; Huntsville, AL) has created a package of four algorithms the company believes offers superior performance over standard signal processing algorithms. EWE's software uses a unique Bayesian method to provide high resolution and high-confidence levels in identifying and tracking patterns for cases where there is a poor signal-to-noise ratio, where registration is difficult, and where features cannot be extracted by conventional means. Useful for tackling the complex data sets provided by long-range sensors, these algorithms might also be used for medical or security image processing.

Search code for tech profile: #641

Evaporative Spray Cooling for High-Power Solid-State Lasers

Rini Technologies (RTI; Orlando, FL) developed and patented a unique way of spray-cooling solid-state laser components at less weight, with less bulk, than current water-based laser cooling systems. The RTI method combines spray cooling and refrigeration in a unique nozzle array design that reduces the coolant flow rate to the laser by a factor of ten compared to water-based techniques. Company engineers estimate that using the spray cooling method reduces the overall size and weight of a total cooling system by a factor of three or more compared to current state-of-the-art cooling equipment.

Search code for tech profile: #628

▲ Vapor atomizer for spray-cooling solid-state lasers

Fabric of the Future from page 1

The company's recent work on the SBIR project could result in benefits that go far beyond MDA uses. Downs said the project has allowed the company to enhance its basic material with new properties, and the work could help move Cuben Fiber Corporation toward manufacturing product at less cost on a greater scale.

Downs describes the company's core patented product as a flexible material that is also "a serious structural, load-carrying material." Cuben Fiber, therefore, effectively "splits the difference" between a fabric and a structural composite material, according to Downs. "Any place that you would use lightweight nylon or polyester, for example, we have an excellent replacement. It is much stronger and lighter," he said.

In tailoring the material for MDA's application, Cuben Fiber has had to meet unique structural demands. For example, the project has special requirements for temperature, strength, creep, optical properties, gas diffusion, and helium permeability, according to Downs. "It has a lot of different special requirements that are completely out of the norm of any fabric," he said.

▲ Cuben Fiber is using a process that orients the fiber in a composite laminate to match anticipated stress and maximize strength and durability. The laminate often exceeds stated capabilities of the fiber. Pictured above are four styles of Cuben Fiber sailcloth.

NEW TERRITORY

The company's material made its name in the sailing industry, having been used for sails on the 1992 America's Cup winner, *America*^{3}—hence the name "Cuben." And the company has evolved to produce—through its wholly owned subsidiary Cubic Tech—materials for cargo parachutes and tents used in extreme conditions. The material also has been used in artificial ligaments and ultralightweight heart valves. But work on the HAA project is pushing the company into a more complex realm—development of larger and more intricate structures with highly detailed specifications. The work should guide Cubic Tech/Cuben Fiber to large-scale production of large, complex fabric structures.

The company vision is one in which it could more quickly and more affordably churn out new generations of recreational balloons, military parachutes, airships, bulletproof clothing, and even giant kites for kiteboarding—making them all incredibly lightweight, too. For example, the MDA application of the Cuben Fiber product is three-times better than the nearest competing material, a proprietary material made by another vendor. And, in terms of size, the material saves space. For example, a parachute made from this material can be packed in roughly half the space as a standard parachute.

Cuben Fiber is made from high-strength, high-modulus engineered fibers such as Spectra, Kevlar, or carbon fiber. The manufacturing process involves using extruded lightweight unidirectional "tapes" of material. In effect, fibers are converted from little threads into a very thin and uniform film of fibers in a resin matrix. Cuben's approach produces a flexible composite membrane by orienting the fiber material as needed. "We can do it pretty much in any orientation, any particular pattern," Downs said. "We can put the fibers in any direction to create a fabric that can carry structural loads. The ability to engineer a material that can carry those loads and still be flexible and have complex load paths with complex reinforcement patterns is the basis of the technology."

The ability to integrate structures such as reinforcement panels and to reduce seaming requirements means the process is less complex than traditional production methods. A final product made with Cuben Fiber is more of an integrated whole rather than a sewn-together quilt made up of assorted pieces. Downs said the process allows for local thickening and reduction as layers of material are placed down, with the all the layers being laminated together into a final piece. "We actually can make sections, complete large sections, on the order of 15 feet by 30 feet long, that have all the structure—things that you would normally go ahead and sew in, such as reinforcement patches," Downs said. "Those can all be integrally laminated in."

FROM SAILS TO SCALE-UP

That integrated approach results in a more reliable and structurally sound product, according to Downs, who explained that for a product such as an airship, the material can reduce the part content by a factor of five, and the seaming by miles. "We integrate a structure like a parachute that is traditionally made out of all these little pieces of material sewn together," Downs said. "What we can do is manufacture that all in one piece, with all the components, all the little reinforcement patches, all the attachment points, and everything all laminated in and made in one piece."

The company already makes large items such as sailcloth and parachute components, but the MDA work has Cuben officials envisioning manufacture of products on a larger scale. "For example, one of the things we are looking at doing is manufacturing sections for parachutes that are 40 feet by 40

continued on page 11

Fabric of the Future from page 10

feet, all one piece, with no cutting, no sewing, or anything like that," Downs commented. Such a transition would move Cuben from producing a raw material to something more like a final structure or product. "That way, we would be able to cut the cost down substantially, because we would be producing a product that would be much nearer to the final section—the final end product, the marketable product," Downs said.

Courtesy of stock.xchng

▲ Cuben Fiber's material is ideal for kiteboarding, which requires giant kites or chutes to pull riders through the water.

Working on the MDA project has tested what Cuben Fiber researchers can do. The material the company already is working with has great strength and weight advantages, but the ability to add new features, such as UV shielding and helium retention, has shown that the company can enhance an already highly engineered material. For example, the company has kept helium loss for the HAA material at "noise level"—practically immeasurable. In working on the project, the company also has made breakthroughs in UV shielding and in developing material to function at extremely low temperatures. "This is by far the most demanding composite material application I have ever seen—out of any kind of aerospace, marine, or even space application," Downs said, who used to direct research at Stanford University's Aerospace Composites Structures Laboratory.

Going forward, challenges remain. Downs said that, in addition to pursuing volume production of larger, more complex products, Cuben faces the challenge of finding markets and raising public awareness.

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The Root of Cuben

by Scott Tillett/stillett@nttc.edu

To understand how Cuben Fiber Corporation got its name, you must first understand how the sailboat *America*^{3} got its name.

CUBED POWER

The boat, which won the 1992 America's Cup, was christened with "cubed" because its captain, Bill Koch, expected it to represent a cubed power of improvement over previous sailing technology. Koch already had a penchant for exponents. He had previously captained a boat called *Matador*^{2}, which he considered to be several times better than its predecessor, *Matador*.

After *America*^{3} made its debut, the press quickly nicknamed its crew and support staff "Cubens." Members of the *America*^{3} organization had fun with the new nickname. They named their compound the "Bay of Pigs Yacht Club." They even designed an insignia with a sunglass-wearing pink pig on it, which was flown from the boat. The organization also ordered assorted items of clothing bearing the pig emblem and the name "Bay of Pigs Yacht Club."

REVEALED

When racetime neared, an Italian team revealed a new carbon-fiber/Kevlar hybrid sailcloth that it would be using. The Italians even held a press conference. "They talked about their carbon-fiber sails and how they were going to be the next big thing—that they were 30 percent better, that it was going to win them the America's Cup," said R.J. Downs, president of Cuben Fiber Corporation. The next week, the *America*^{3} team revealed its new sail technology—but with considerably less fanfare. "It was even more dramatically different than anything else anybody had seen," Downs said. "I remember getting a call on my cell phone. … 'You can't believe it! There are 30 helicopters circling around us! Every boat in the harbor is coming toward us!' … So it was a big huge event. And we didn't have a press conference."

But the press was trying to pump the team for information. Capt. Koch gave them nothing. So one writer went ahead and made a nomenclatural leap, pointing out that the Italians had first introduced a carbon-fiber sail, followed by the secret "Cuben fiber" sails by Koch's syndicate. The phrase stuck. The Italians lost. Cuben Fiber got patented. And the rest is history.

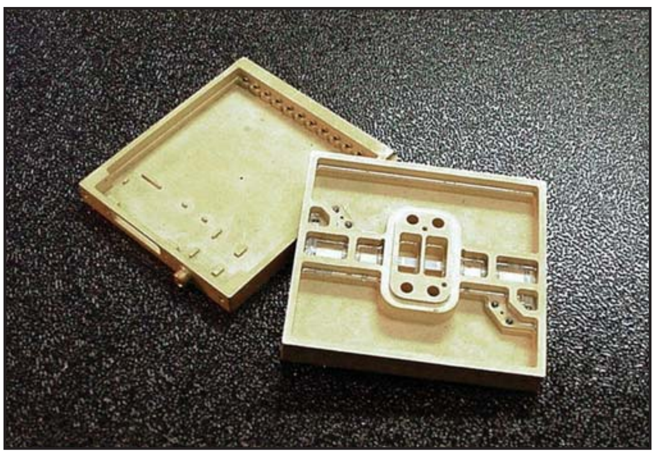
Crafting Cool Composites

New metal-graphite materials provide lighter, cheaper cooling for high-power electronics.

by Mike Felton/mfelton@nttc.edu

high-power electronics in trains, hybrid cars, radar systems, welding equipment, elevators, ship-board systems, and satellite communication systems need to be well-cooled to operate properly. With MDA SBIR funding, Metal Matrix Cast Composites, LLC (MMCC; Waltham, MA), has developed a new composite whose efficiency and light weight enabled it to be used on the latest DirecTV® satellite. The technology also has terrestrial cooling applications.

The new material is a composite of metal, such as aluminum or copper, and graphite that hits a sweet spot in the variables needed for a good heat sink. "It all starts with two key properties," said Dr. James Cornie, CEO of MMCC, "high



▲ MMCC's composite technology has been incorporated into microelectronic packaging for transmit and receive modules.

thermal conductivity and coefficient of thermal expansion." Thermal conductivity is exploited everyday; pans and bakeware conduct heat very well, pot holders do not. As a result, pot holders would not be good for conducting heat away from hot electronics. But what does the coefficient of thermal expansion (CTE) have to do with heat transfer?

MATCHING CTE

Most materials expand or contract as their temperature changes, and this rate of change is called the CTE. Designers take this into account when building both small and large objects. For instance, bridges have expansion joints to allow the steel or concrete to expand and contract with daily and seasonal temperature changes. If these joints were missing, the bridge would buckle or break. If two materials with different CTEs are attached to each other and temperatures change, strain is created. When aluminum or copper heat sinks are directly attached to an electronic chip, the chip will most likely crack due to this stain.

Current low-cost methods, such as those employed in your PC to cool chips without cracking, use an interface of some flexible material between the chip and heat sink. However, this cuts down on the ability of the heat sink to remove heat. "You would like to get the heat out of the chip in the most efficient way," Cornie said. "And the most efficient way is to use a highly conductive material that also matches the thermal expansion of the chip or substrate."

Several alloys have been developed with CTEs that match commonly used chip and substrate materials. However, when chip makers use an uncommon substrate material or are concerned about weight (for instance, when building satellites), these alloys are not effective options. In addition, some of the alloys are expensive to produce and machine.

METGRAF

MMCC's solution combines metal (aluminum or copper) and carbon graphite fiber to make a composite that could be made to match any desired CTE yet still have excellent thermal conductivity. "There were a lot of expensive solutions, and we were charged with looking for an economical solution," Cornie said.

The result of this research was a material the company calls MetGraf™. When MetGraf is made with aluminum, it is as thermally conductive as the pure metal, but can be made with a wide range of CTEs instead of pure aluminum's CTE of 24-parts-per-million-per-degree Kelvin (ppm/K). For instance, it could be manufactured to match silicon's CTE of 4.2 ppm/K. Copper MetGraf is almost as good as copper. "We are talking about a 300-Watts-per-meter-per-degree Kelvin (Watt/m·K) thermal conduction with our material (Copper MetGraf) versus 400 W/m·K if you had pure copper," Cornie said.

"The unique thing about the MetGraf is that by arranging the architecture of the fibers, the density of the fibers, and the casting, you can design a series of products with continuous control of the thermal expansion over the range of about 2 to 10 ppm/K." This covers several important electronic materials that are used as chip substrates. Aluminum oxide and gallium

continued on page 13

Crafting Cool Composites from page 12

arsenide's CTEs are about 6.5 ppm/K and silicon and aluminum nitride's are between 4 and 5 ppm/K.

MANUFACTURING

Combining metals with graphite is not a new idea; and it is advantageous in this instance because graphite has a negative CTE, meaning it shrinks as temperature increases. However, combining metals and graphite generally does not work well. Graphite surfaces resist molten metals from staying on their surfaces, almost like the graphite is metal-proof instead of waterproof.

In the early 1990s, Cornie and his colleagues at MIT started to develop a method to solve this problem. "MDA's predecessor, SDIO, funded my research at MIT where we developed the pressure infiltration casting process," Cornie said. "It was primarily MDA funding all the way." Since 1994, MMCC has received more than 21 STTR and SBIR Phase I and Phase II contracts for both structural and thermal management materials. He added, "We had other agencies, but the one constant was MDA. They have really been instrumental, and we really wouldn't be here today without them."

Pressure infiltration casting forces molten metal into a mold that already contains a graphite scaffold called a pre-

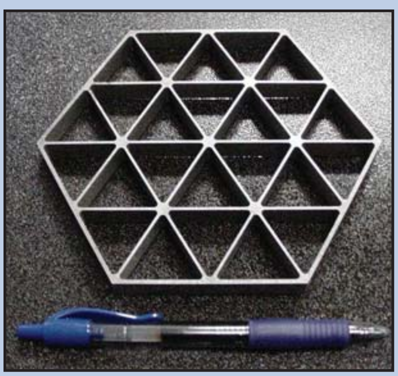
continued on page 14

MetGraf's Younger Siblings

by Mike Felton/mfelton@nttc.edu

HYBRIDS

Current MetGraf technology uses a porous graphite preform to which the metal infiltrates. Future versions may include slabs of graphite that could channel more heat away from a chip. "We can actually insert highly oriented graphite slabs selectively into a preform that is otherwise CTE-matched material," said Cornie. The result: a material that conducts even more heat than aluminum or copper but whose CTE can be adjusted just like MetGraf. For instance, copper can dissipate around 400 W/m·K. But this new hybrid material would have a thermally conductive path of 1700 W/m·K where the graphic slabs reside.



▲ Graphite fiber-reinforced alloys are used to make lightweight space mirror substrates for advanced military optics systems.

How do the graphite blocks, with their different CTEs, not cause the MetGraf to break apart? Cornie said, "We count on the skin of the MetGraf to provide the CTE matching to the rest of the world and to transfer heat—through various means that are covered in patents—to the highly conductive core that has 1700 watts of in-plane conductivity."

The research is being conducted on these materials to support the next generation of high-performance radar systems that will use wide-bandgap semiconductors. "The wide-bandgap semiconductor materials are going to be operating hot and kick out a lot of heat," Cornie said. The new electronics may exceed the thermal densities of current electronics, "by a factor of maybe 4 to more than 10," he said. "So you are going to need a whole different range of cooling schemes."

MIRRORS

MMCC is also working on a version of MetGraf that can be used to replace beryllium alloys as a structural material in spacecraft, especially for optical systems. Beryllium is very hard to work with because it is highly toxic. But it has the unique property of being very stiff and stable over a wide range of temperatures.

Using continuous filament graphite and magnesium, MMCC has developed a material that matches the CTE of silicon carbide (SiC), a material used to make mirrors. "It makes a very good lightweight substrate for a SiC membrane or mirror," Cornie said.

One substrate that MMCC is developing is an "egg crate" for SiC or Si mirrors that would have no thermal expansion in the optical axis allowing the optics to stay in better focus. "This opens up the material to be attractive for optical benches where you are trying to have a gang of mirrors that you don't want to move with respect to one another," Cornie said.

More applications for metal-impregnated graphite are sure to come, in part because the material can be engineered to have a wide range of properties. "We are getting into really designing the material and designing the architecture for very specific applications," Cornie added.

Crafting Cool Composites from page 13

form. The pressure causes the metal to infiltrate the graphite preform and upon solidification create a composite with controlled architecture.

In MMCC's 15,000-ft^2 manufacturing facility the material starts as its elemental forms. Finely milled or chopped graphite fibers are made into a porous graphite preform. The preforms are placed into the casts and the molten aluminum or copper is added, infiltrating the graphite preform to make a nonporous bulk product. The cast plates are then machined using conventional computer-controlled machining equipment to customer specifications. Next, the finished parts are plated with a very thin layer of nickel, gold, or silver to protect the composite from the environment and to allow it to be more readily soldered to a chip.

▲ METGRAF was used in Boeing's Spaceway satellite system, launched in April 2005 to provide high-definition television programming for DirecTV.

Currently, the company can produce 12.5-in^2 plates, in a range of thicknesses. Cornie describes the process as a pipeline. "If we started on Monday with raw material, we would have a finished casting by Friday and the next week we would be doing all the machining and so forth." He added, "There is always material in the cycle someplace, we are casting every day, we are preforming everyday, and we are machining everyday."

ROAD TO COMMERCIALIZATION

Although MetGraf has clear advantages over existing heat sink materials, its adoption has been slow. "Nothing happens fast in the materials business," said Mark Ryals, director of sales and marketing at MMCC, "because they test the hell out of everything before they officially qualify the material, and testing can go on for years."

One customer, according to Ryals, has been testing the material for over three years. "They love it, but don't do anything quickly. Once they do jump, they really commit and organize their equipment around this material." Other companies in different industries may need less time evaluating a material, and Ryals says their goal was to get a number of players testing the materials.

MMCC's MetGraf is now part of Boeing's Spaceway satellite platform, which is being used for new DirecTV satellites as well as a series of military communication satellites, the Wideband Gapfiller System. MetGraf could be applied anywhere high-power semiconductors are used. For instance, terrestrial microwave and millimeter-wave communications, radar systems, welding equipment, elevators, even electric power systems such as hybrid cars and electric trains. Ryals even hinted about a possible medical application of the technology.

MMCC is now rolling out its copper MetGraf in addition to its existing aluminum MetGraf and is looking for additional customers and investors.

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VCs Look for Sustainable Success

by Dr. Milton Chang

Why would someone buy from your company? When will competitors take your customers? Venture capitalists ask such questions because they look for "sustainable competitive advantages," strong indicators of future success.

The competitive advantages that start-up companies boast are often not sustainable or are not even substantiated. Strong intellectual property can provide competitive advantages but invariably better solutions can be found over time. Claims of cost advantage are even more fleeting since they are usually based on the selling price and not cost data, and it is not a given that big companies are inefficient, or that start-up companies understand costs.

A few essential qualities that make a company successful in the long run are listed below.

- **Operational excellence.** All is for naught if a company cannot turn a technology into a useful product that gets into customers' hands at a competitive price and still earns the company a profit. A company cannot succeed if it cannot execute—keeping customers happy by satisfying their needs.
- **Continuous innovation and investment.** In high-tech industries, competitive advantages usually come from performance features that are not available elsewhere, so intellectual property is important. Products eventually become commodities, even with innovation, and then have to compete on price. An efficient manufacturing infrastructure becomes a competitive advantage. Sustainability of competitive advantages in all cases comes from continuous innovation, continuous process development, and investment in the core drivers of the business.
- **Ability to cope with constant change.** The core driver of a given industry is constantly changing as are customer needs. It is the ability of the organization to cope with changes that makes the competitive advantages sustainable.
- **Committed leadership.** It should not come as a surprise that the entire discussion leads us to the leadership issue. Behind every successful company, there is invariably a highly capable champion who has the aspiration, commitment, and energy to lead the organization to cope with changes in the marketplace.

Having a clear understanding of the competitive advantages can help you get your funding; maybe even more important, it can help you focus precious resources on building sustainable competitive advantages to succeed. Focus on what really counts; raising money is only one step in a long process of building a successful company that benefits society and your pocketbook.

BIOGRAPHY

Dr. Milton Chang is the founder of Incubic, a venture capital fund in Silicon Valley. A successful entrepreneur, he has incubated more than a dozen companies. He currently sits on the boards of Arcturus Engineering, Lightwave Electronics, OEpic, OpVista, Rockwell Scientific, and YesVideo. Active in the technical community, Dr. Chang has received numerous prestigious awards. He also writes monthly business columns for *Laser Focus World and Photonics Spectra* magazines.

How to Ruin a VC Pitch: Be Arrogant

Beware! When pitching your company to potential investors, be self-confident without being arrogant. "We won't invest in entrepreneurs who we cannot work with," said Dr. Milton Chang (see biography at bottom left). "When management rejects input, it is likely that common start-up mistakes will be made, even repeated." Approach the issue of raising money as if you are seeking a new business partner. Select your partner carefully, and negotiate with them in ways that lead to the start of a professional working relationship.

Courtesy of stock.xchng

Inspiring Quotes

"Opportunity is missed by most people because it is dressed in overalls and looks like work."

Thomas Edison

"In reading the lives of great men, I found that the first victory they won was over themselves … self-discipline with all of them came first."

Harry Truman

"Nothing happens until something moves."

Albert Einstein

Nanotechnology is big on small. Test your knowledge of this emerging science by answering our nanotechnology trivia questions below:

1 — Tech Trivia

How small is nano?

A. One hundredth
B. One millionth
C. One billionth
D. One trillionth

2 — Tech Trivia

What does the prefix 'nano' actually mean in the language from which it was derived?

A. Advanced
B. Dwarf
C. Exotic
D. Invisible to the eye

3 — Tech Trivia

What is the difference between a single-walled carbon nanotube and a multiple-walled carbon nanotube?

A. The number of nanotubes
B. The shape of the nanotubes
C. The type/form of carbon
D. There is no difference

4 — Tech Trivia

What physical phenomena become significantly important at the nanoscale level (i.e., this is what makes nanotech so different from the regular macroscale world we live in)?

A. Gravitational effects
B. Quantum mechanical effects
C. Magnetic effects
D. Newtonian mechanical effects

Trivia answers: 1. C 2. B 3. A 4. B

Thanks to NanoApex.com for providing the nanotechnology trivia information.

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