TECH BRIEFS

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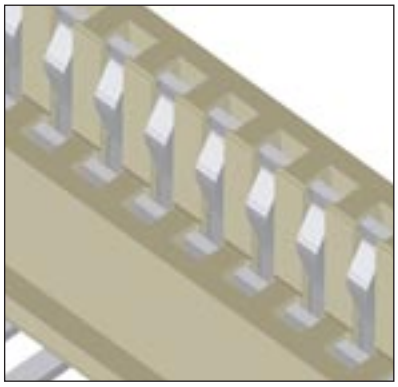

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On the cover

Three-dimensional scanning and virtual reality technologies developed by the Office of Naval Research (ONR) are demonstrated by Lt. Clay Greunke as he walks through processed scanned data from a ship. The ONR fosters scientific and technological innovations in a wide range of fields, including sensing, information technology, materials, biomedical, communications, and autonomous systems. ONR oversees the Naval Research Laboratory (NRL), which is profiled in this month's Facility Focus on page 60.

(U.S. Navy photo illustration by Lt. Clay Greunke and Dawn Stankus)

Product of the Month

WinSystems (Arlington, TX) released the PPC65B series panel PC for extreme environments and industrial IoT applications.

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UP FRONT

Linda Bell
Editorial Director

Editor's Choice

A method was developed that allows a smartphone camera to noninvasively monitor heart health. The app works because the walls of arteries are almost completely elastic — they expand and contract with each beat of the heart. That expanding and contracting can be measured and described as a waveform that encodes information about the heart. The technique could be developed to diagnose heart valve diseases like aortic stenosis, and coronary artery blockages. Find out more on page 50.

What's New on Techbriefs.com

On a snowy day in 1926, a 44-year-old physicist named Robert Goddard went with his wife Esther and some colleagues to his Aunt Effie's ranch in Auburn, Massachusetts. What happened next was not a typical day on the farm. The group tested the first liquid-fueled rocket. This month, only on techbriefs.com, we spoke with writer Rob Garner about how the 60-yard blastoff that day helped to launch spaceflight efforts almost 100 years later. Find "How Robert Goddard Launched Present-Day Spaceflight" in the News section at techbriefs.com.

Contact me at billy@techbriefs.com with your comments and suggestions.

Next Month in *Tech Briefs*

In the December issue, we'll ask you to vote for the 23rd annual Readers' Choice Product of the Year Awards. You'll find information on all 12 nominated products for 2017, and how to cast your vote in our online ballot.

Smartfoam Signals Concussions in Real Time

Most football fans have seen players get hit so hard they can barely walk back to the sideline. All too often, those players were back on the field just a few plays later, despite suffering what appeared to be a head injury. While football-related concussions have been top of mind in recent years, people have struggled to create technology to accurately measure them in real time.

Brigham Young University researchers have developed and tested a nanocomposite smartfoam that can be placed inside a football helmet (and shoulder pads) to more accurately test the impact and power of hits. The foam measures the impact of a hit via electrical signals. The data is collected in real time and sent wirelessly to a coach's or trainer's tablet or device on the sidelines. A coach can know within seconds how hard a player has been hit, and whether or not they should be concerned about a concussion.

The foam, which replaces the standard helmet foam, measures a composite of acceleration, impact energy, and impact velocity to determine impact severity and location of impact, all with 90 percent accuracy. To date, no one — not even the NFL — has been able to successfully measure the impact energy and velocity of a collision. BYU is currently working with the U.S. Army on an insole to understand biomechanical forces and devise strategies to prevent musculoskeletal injuries.

Visit https://news.byu.edu/

Wearable Devices Could Use Ultrasound to Sense Hand Gestures

Computers are growing in number, and wearable computers such as smartwatches are gaining popularity. Devices around the home, such as WiFi light bulbs and smart thermostats, are also on the increase. Current technology limits the capability to interact with these devices. Hand gesture recognition can be achieved in many ways, but the placement of a sensor is a major restriction.

A research team at the University of Bristol (UK) is using ultrasonic imaging of the forearm to recognize hand gestures. The team used image processing algorithms and machine learning to classify muscle movement as gestures. The findings showed a very high recognition accuracy, and more importantly, this sensing method worked well at the wrist, which is ideal for allowing future wearable devices such as smartwatches to combine this ultrasonic technique to sense gestures.

Watch a video demonstrating the EchoFlex technology on Tech Briefs TV at **www.techbriefs.com/tv/echoflex**.

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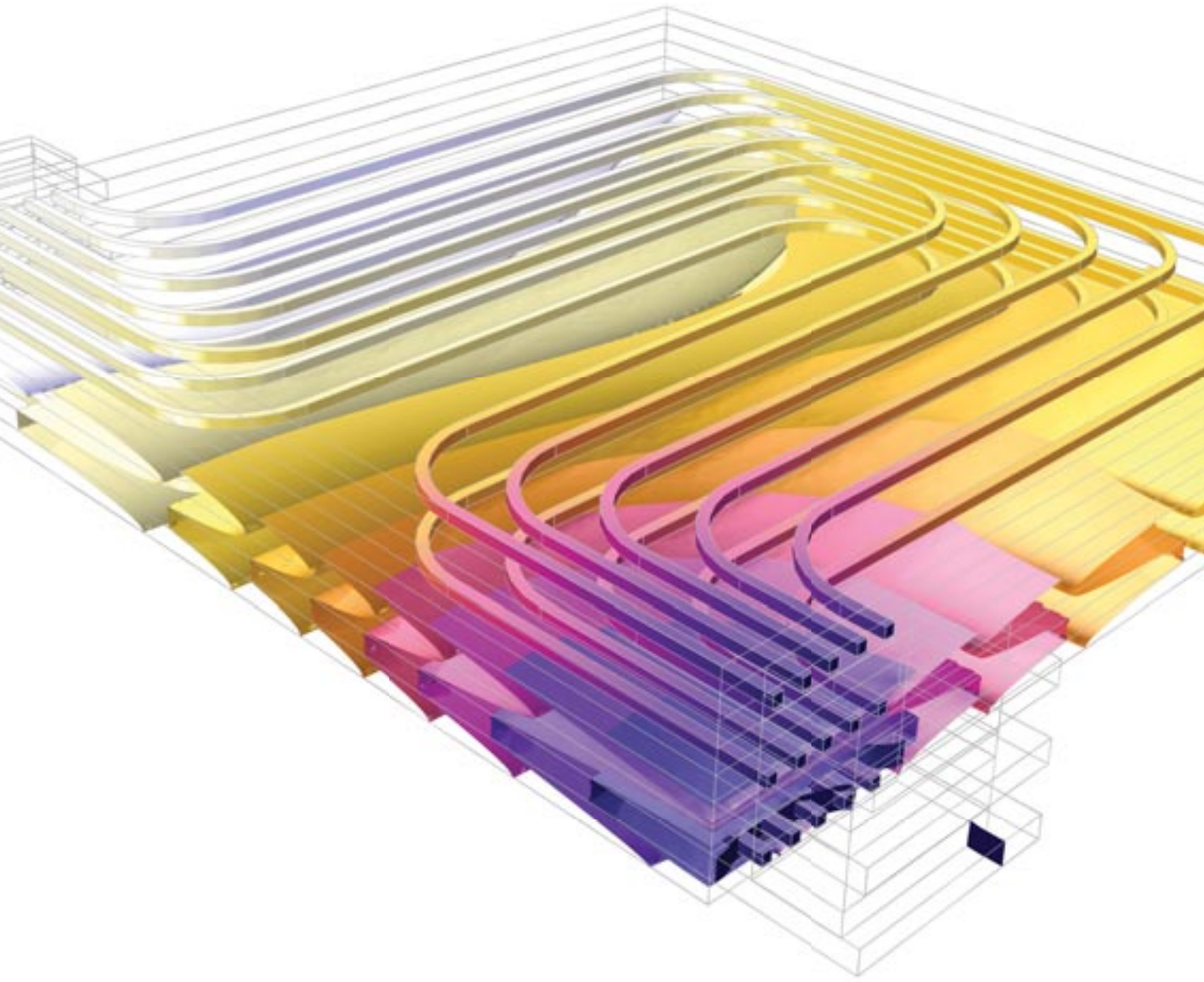

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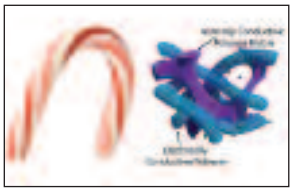
Products of Tomorrow

This column presents technologies that have applications in commercial areas, possibly creating the products of tomorrow. To learn more about each technology, see the contact information provided for that innovation.

▶ Multi-Stage Filtration System

While HEPA filter elements can last for years without intervention, pre-filtering systems that remove larger particles before they reach the HEPA filter need to be treated (most often by cleaning or replacement) as often as once a week. These treatments can be resource-intensive and expensive, especially in extreme environments. NASA's Glenn Research Center developed a multi-stage filtration system to collect a wide range of particle sizes with minimal filter changes. This breakthrough capability keeps high-efficiency media and devices from becoming overloaded with larger particles. The system uses an impactor filter to capture larger particle matter. After becoming heavily loaded, this filter can be cleaned automatically through a unique feed system, thereby reducing maintenance costs.

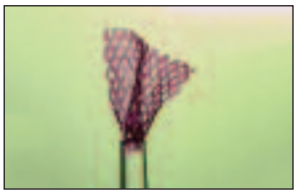
Contact: Glenn Research Center
Phone: 216-433-3484
E-mail: GRC-techtransfer@mail.nasa.gov
https://technology.nasa.gov/patent/LEW-TOPS-93



▶ Supercapacitor for Fast Charging of Mobile Phones

Supercapacitors promise recharging of phones and other devices in seconds and minutes rather than hours for batteries. But current technologies are not usually flexible, have insufficient capacities, and for many, their performance quickly degrades with charging cycles. Researchers at Queen Mary University of London (QMUL) and the University of Cambridge developed a polymer electrode that achieves energy storage close to the theoretical limit, but also demonstrates flexibility and resilience to charge/discharge cycling. The technique could be applied to many types of materials for supercapacitors; devices could be made in soft and flexible freestanding films, which could power electronics embedded in smart clothing, wearable and implantable devices, and soft robotics.

Contact: Rupert Marquand, Queen Mary University of London
Phone: +44 (0) 20 7882 3004
E-mail: r.marquand@qmul.ac.uk



▶ Injectable Tissue Patch to Repair Damaged Organs

Repairing heart tissue destroyed by a heart attack or medical condition with regenerative cells or tissues usually requires invasive open-heart surgery. University of Toronto researchers developed a technique that lets them use a small needle to inject a repair patch without the need to open up the chest cavity. The AngioChip is a tiny patch of heart tissue with its own blood vessels — the heart cells even beat with a regular rhythm. The patch features a shape-memory material that unfolds itself into a bandage-like shape as it emerges from the needle. The shape-memory effect is based on physical properties, not chemical ones, so the unfolding process doesn't require additional injections, and won't be affected by the local conditions within the body.

Contact: Marti Leitch, OSU Wexner Medical Center
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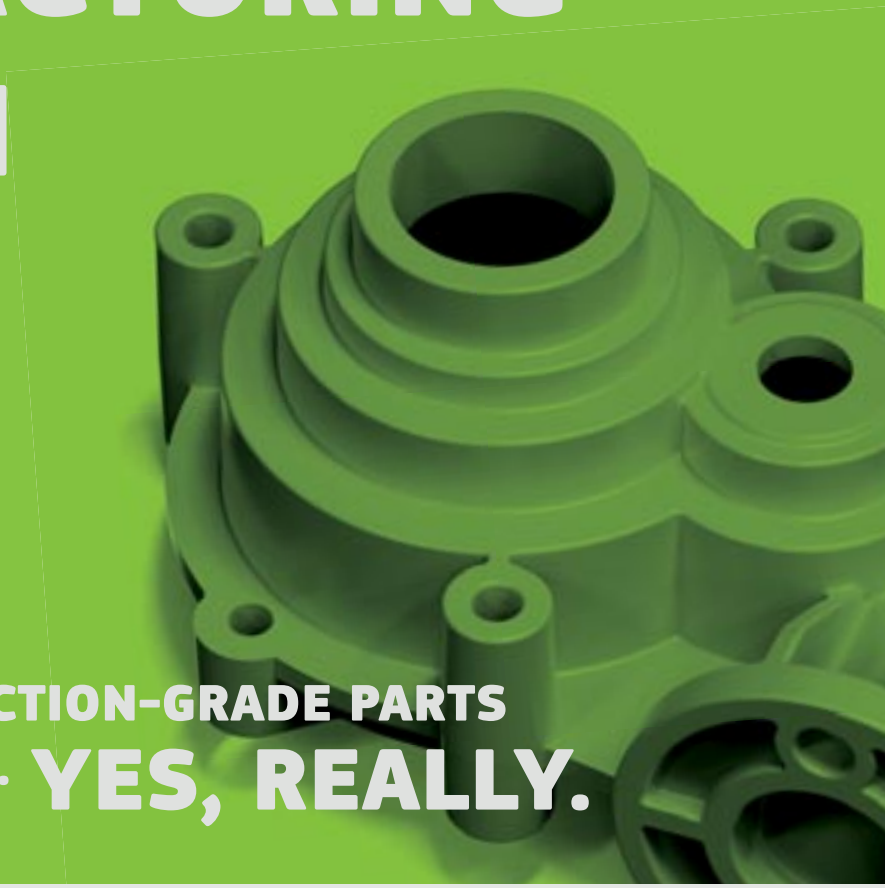

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Q&A

Dr. Manyalibo "Ibo" Matthews, Deputy Group Leader, Laser Materials Group, Lawrence Livermore National Laboratory, Livermore, CA

Dr. Matthews and his team have developed a new laser-based method for 3D printing of large metal objects called Diode-Based Additive Manufacturing (DiAM). It uses high-powered lasers to flash-print an entire layer of metal powder. The process will enable large metal objects to be printed in a fraction of the time typically needed for metal 3D printers.

Tech Briefs: How did you come to consider 3D metal printing?

Dr. Manyalibo Matthews: While 3D printing of metals was not explicitly considered within R&D activities supporting the National Ignition Facility [used for testing materials at extreme pressures, temperatures, and densities], an overlap was recognized in the optics that are used in both areas. NIF has a device called an Optically Addressable Lite Valve (OALV) that works such that shining blue light on it enables it to rotate the polarization of incoming laser light; light passing through will have its polarization rotated if the valve is not addressed, and the polarization not rotated if it is addressed. A mixed-polarization-state beam is then sent through a polarization filter that will block the rotated polarization beam and allow the unrotated one through.

Tech Briefs: How is the OALV used for 3D printing?

Dr. Matthews: The same spatial light blocker that we've used to take out parts of the high-energy laser beam for an NIF experiment can be used with light suitable for 3D printing. It can pattern that light to print an entire layer at once by allowing light to irradiate and melt layers of powdered metal. In the standard process, you have a build plate of metal and a device that spreads a thin layer of metal powder on the order of 30 microns thick. A 50- to 100-micron laser beam writes a desired pattern in one layer. Where you've written with the laser, the powder is melted, and is surrounded by powder that didn't melt. You lower the part down, spread another layer, and repeat. It takes a long time for the laser beam to go around, spread the powder, and move the part down. We use the OALV so that instead of having to write each trace, we can produce an entire image at once.

Tech Briefs: What sorts of parts are made using this process?

Dr. Matthews: What it does well is complex designs — things that you can't easily or cheaply machine or assemble; for example, removing material to manufacture a high-strength, low-weight metal lattice. 3D printing can remove enough solid material to make the part light but strong, which can lead to a new generation of parts.

Tech Briefs: What are some commercial applications?

Dr. Matthews: At this moment, it depends on the industry. For medical, there are titanium-based alloys for implants and magnesium-based alloys for dissolvable implants. There are also aerospace and automotive applications. A number of alloys are used, depending on the application, such as nickel superalloys for turbines, and titanium and aluminum alloys for structure. The most common, but probably not as useful in the long term, are stainless and tool steel.

Tech Briefs: Is there still more work to do on this project?

Dr. Matthews: We just demonstrated the printing, but there's a whole world of material science that needs to be studied to understand how different thermal gradients and thermal histories affect the microstructure and ultimate mechanical properties. There's a new project we are starting soon that will do just that.

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Contacts for Hi-Rel Connectors: Comparing Technologies

Contact design is critical to the performance of any connector — especially for devices that must function in harsh environments where extremes of temperature, shock, and vibration are to be encountered. Yet there are many different contact styles, and each supplier will claim an advantage. This article aims to set out clearly and concisely the merits and drawbacks of each of the main styles.

Twin Beam

Twin beam contacts have two spring fingers on opposing sides. The mating pin is normally square, but twin beam contacts can also be used with circular (round pin) or rectangular (blade terminal) contacts. The twin beam contact provides two points of contact to the pin, ensuring electrical continuity. This design offers good performance levels for industrial and commercial connectors. It performs well in conditions of vibration and shock, particularly if the direction of vibration is considered.

The disadvantages of this design are that if made in phosphor bronze, the upper operating temperature is limited to 105 °C. Also, if the mating pin is oversized or misaligned, it can result in the twin beam contacts suffering permanent (an irreversible deformation of the shape) set with the risk of discontinuity.

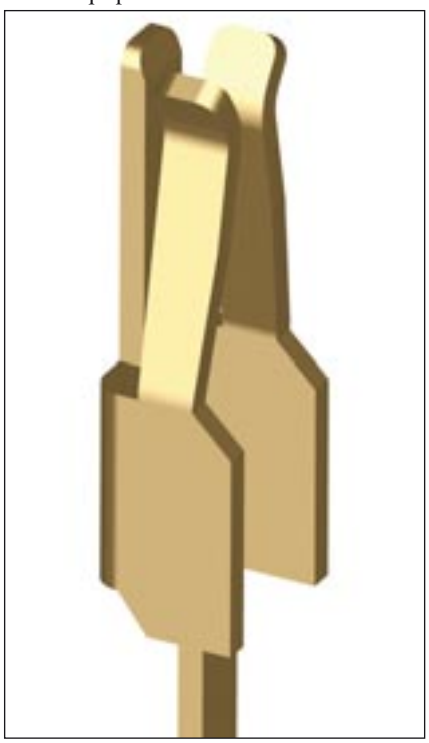
Typical applications include automotive units, consumer electronics, white goods electronics, industrial electronics, medical electronics, and military equipment in a benign environment.

Single Beam

With this design, there is only one point of contact on each of the male and female connectors. The separate mating contacts are designed to connect using a sliding motion; the design can be hermaphroditic, i.e. both mating parts have the same shape. The designation of plug and socket is determined by the molded shape of the housing in which the single beam contact is contained.

Single beam contacts are most commonly found on fine pitch connectors of 1.00-mm pitch or smaller, which is enabled by the thin contact design. The advantages of this design include low cost as a result of the stamping process, and a low, or zero insertion force (ZIF). A disadvantage is a low resistance to vibration and shock, which is dependent on molding design.

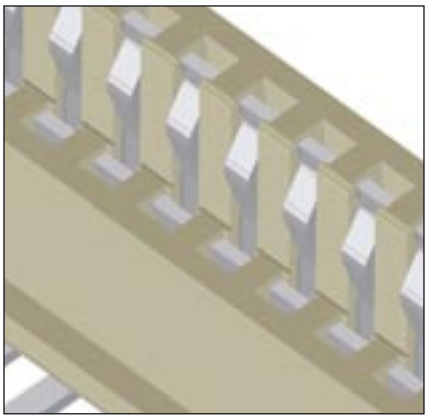
Typical applications include consumer electronics, industrial electronics, test equipment, medical electronics, and office equipment.



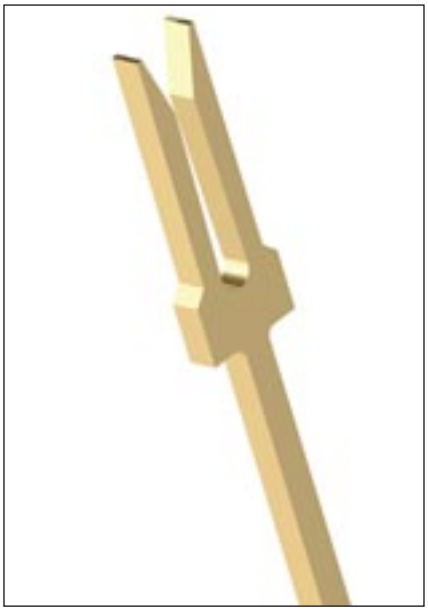
Twin beam contact.

Tuning Fork

The similarity in appearance to a musical tuning fork gives rise to the name. This flat, stamped component has two contacts on opposing sides that provide a rigid shape to accept the mating pin. The mating pin is normally square,



Single beam contact.



Tuning fork contact.

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Circular stamped contact clip.

Circular turned multi-finger contact.

and on PC/104-compatible connectors, the square handle of the tuning fork becomes the PC tail of the connector stacked above. The advantage of using such a design is the low cost due to the pressed metal manufacturing process.

The disadvantage is that a mating pin must be within tolerance since there is only a small movement of the tuning fork contacts on insertion of the pin. An oversized mating pin would result in a permanent set with a risk of discontinuity. Also, the low spring tension makes this design unsuitable for applications in environments of extreme vibration or shock.

Typical applications are industrial control systems, servers, communications devices, test equipment, automotive systems, data loggers, vending machines, medical instruments, PCI bus adapters, and bridges.

Circular Stamped Contact Clip

This is a stamped beryllium copper contact strip, with multiple spring fingers, formed into a circle. Devices can have three, four, or six spring fingers. The mating pin is circular, allowing multiple points of surface contact. These contacts are commonly used on high-reliability connection systems and individual PCB sockets. The main advantage is that the point of contact is always maintained; this is essential for continuous signal transmission. The clip performs extremely well in conditions of vibration and shock. This design provides high durability at low cost. The operating temperature is in line with MIL-Spec parameters of -55 °C to 125 °C. The clip can be inserted into a variety of shells, making the contact very versatile.

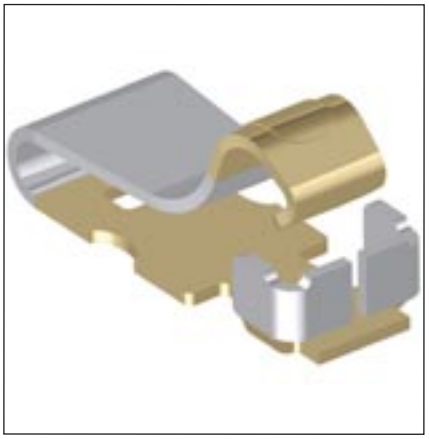
The disadvantage is the limitation on current-handling; therefore, they are not suitable for high-current applications.

Typically, circular stamped contact clips are used across a wide spectrum of applications, particularly when high reliability and low cost are required. These include military equipment, civil and military avionics, critical medical, high-performance industrial, and precision test instruments.

Circular Turned Multi-Fingered Contact

This contact is machined in beryllium copper with the spring fingers (also known as tines) being an integral part of the contact, rather than a subcomponent. The mating pin is circular to ensure contact is made with all of the tines. This one-part design overcomes the current-carrying limitation of the circular stamped contact clip, while at the same time maintaining signal continuity during conditions of vibration at a smaller size.

This style of contact is used in a wide variety of high-reliability applications where small size and light weight are pre-requisites such as UAVs, military portable equipment, and avionics.



Spring contact.

Spring Contact

Individual spring contacts (also known as shield fingers or grounding contacts) are a simple folded metal strip design that can be mated with a variety of flat surfaces. The design is used to connect PCBs to other boards or components, to pass signals and current, or to the chassis for grounding. The advantage is that they offer a low cost of ownership — they are both low-cost to purchase and low-cost to assemble onto a PCB. They are usually supplied on tape-and-reel packaging, thus enabling use of advanced manufacturing processes such as pick-and-place machines.

A disadvantage is a risk of over-compression that can result in permanent set, although there are some

designs that have a "positive stop" to prevent this.

Typical applications include wearables, mobile devices, and antennas.

Spring Loaded Contact

This design comprises a plunger, spring, and barrel. The plunger is held under pressure by the spring contained in the barrel. The mating part is usually a fixed flat surface either as part of a connector or as an individual PCB pad. This design is used when rapid mating and un-mating of the connector is required in applications where there is a risk of variation in the closing mating dimension. It can also be used in "blind mate" applications where the engagement of the connectors cannot be seen, and precise alignment cannot be achieved. The spring loaded contact is also commonly used as a probe on automatic test equipment. Devices have high durability, with the number of operational cycles being 10,000 or more. These features come with a cost that is noticeably higher than that of the spring contact.

Hyperboloid

This is an arrangement of twisted wires to form a hyperbola shape between the two ends of a socket. The mating round pin, when inserted, stretches the wires, putting tension on the pin and creating a good electrical contact. The main disadvantage is the particularly high cost of the contact design.

Spring loaded contact.

This design offers high durability and is used in applications where shock and vibration are expected such as military, avionic, railway, and other rugged applications.

Summary

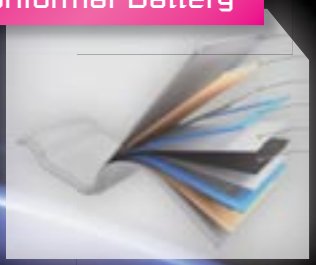
Contact performance varies considerably due to the contact design, as discussed above, and the manufacturer. Great care and consideration should therefore be paid to the selection of technology and supplier, especially if the connector is to be used in harsh and challenging environments. The customer should ensure that they have a full understanding of their performance and environmental criteria, which can also help connector manufacturers guide them to the most suitable connection technology.

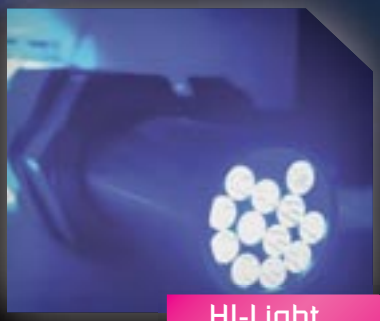
This article was written by Scott Flower, Product Strategy Manager – High-Reliability Connectors at Harwin, Salem, NH. For more information, visit ***http://info.hotims.com/65857-121****.*

SPECIAL AWARDS SECTION

EJBot: Versatile Climbing Robot

Conformal Battery





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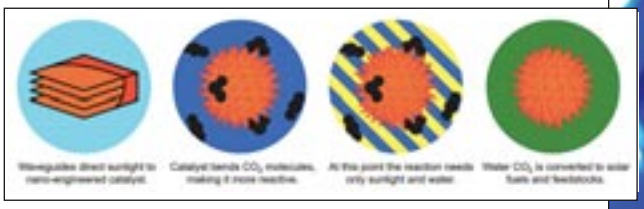
The Create the Future Design Contest was launched 16 years ago by Tech Briefs Media Group (publishers of *Tech Briefs* magazine) to help stimulate and reward engineering innovation. Since then, the annual contest has drawn more than 14,000 product design ideas from engineers, students, and entrepreneurs worldwide. Sponsored by COMSOL, Mouser Electronics, and Tech Briefs Media Group, the 2017 contest rewarded innovation in seven categories: Aerospace & Defense, Automotive/Transportation, Consumer Products, Electronics/Sensors/IoT, Machinery/Automation/Robotics, Medical, and Sustainable Technologies.

In this special section, you'll meet the Grand Prize Winner, as well as the winners and Honorable Mentions in all seven categories, chosen from more than 1,100 new product ideas submitted from 65 countries. To view all of the entries online, visit **www.createthefuturecontest.com**.

GRAND PRIZE WINNER

Winner of $20,000



HI-LIGHT — SOLAR THERMAL CHEMICAL REACTOR TECHNOLOGY FOR CONVERTING CO_2 TO HYDROCARBONS

Xiangkun (Elvis) Cao, Jessica Akemi Cimada da Silva, David Erickson, and Tobias Hanrath, Cornell University; and Jason Salfiand and Clayton Poppe, Dimensional Energy
Ithaca, NY

The extraction and consumption of fossil carbon to run our daily lives accounts for more than 6 billion metric tons of CO_2 emissions each year, driving climate change. Creating high-value products from CO_2 can be achieved using energy from all parts of the solar spectrum to photocatalytically produce liquid hydrocarbons at high temperatures, making CO_2 capture and conversion economical.

This technology enables the conversion of CO_2 back to simple hydrocarbons, e.g. into methanol, which has a typical spot price about six times higher, potentially transforming carbon conversion into a profitable enterprise.

The HI-Light reactor is a solar-thermocatalytic "reverse combustion" technology that enables the conversion of CO_2 and water to methanol and other high-value hydrocarbons. The HI-Light reactor design derives from the concurrent optimization of light-coupling and catalyst availability.

In the HI-Light design, the tubes are internal light-guiding rods with specially designed scattering surfaces that enable deep and efficient penetration of the solar radiation captured from a parabolic light concentrator into the reactor. The reagents and products flow through the shell outside the rods. The optimal energy focused into the reactor interacts with the catalyst to convert incoming sequestered CO_2. Photons with energies lower than those required for the catalytic reaction are used to provide thermal energy, and ultimately the high temperatures required to ensure selectivity and efficiency of the reaction to revert CO_2 to hydrocarbon fuels.

The major challenge of electrocatalysis is lowering the over-potential with breakthroughs in new catalysts. Up to now, product selectivity, lowering faradaic efficiency, and catalyst durability have been hard to achieve. The immense amount of power that it takes to drive the reaction leads to high operating costs. The unique design feature of the HI-Light reactor is the optimized light delivery to both a fixed and fluidized nanostructured catalyst, coupled with solar thermal heating to reach elevated temperatures, thereby enabling faster reaction rates and selectivity of higher hydrocarbons.

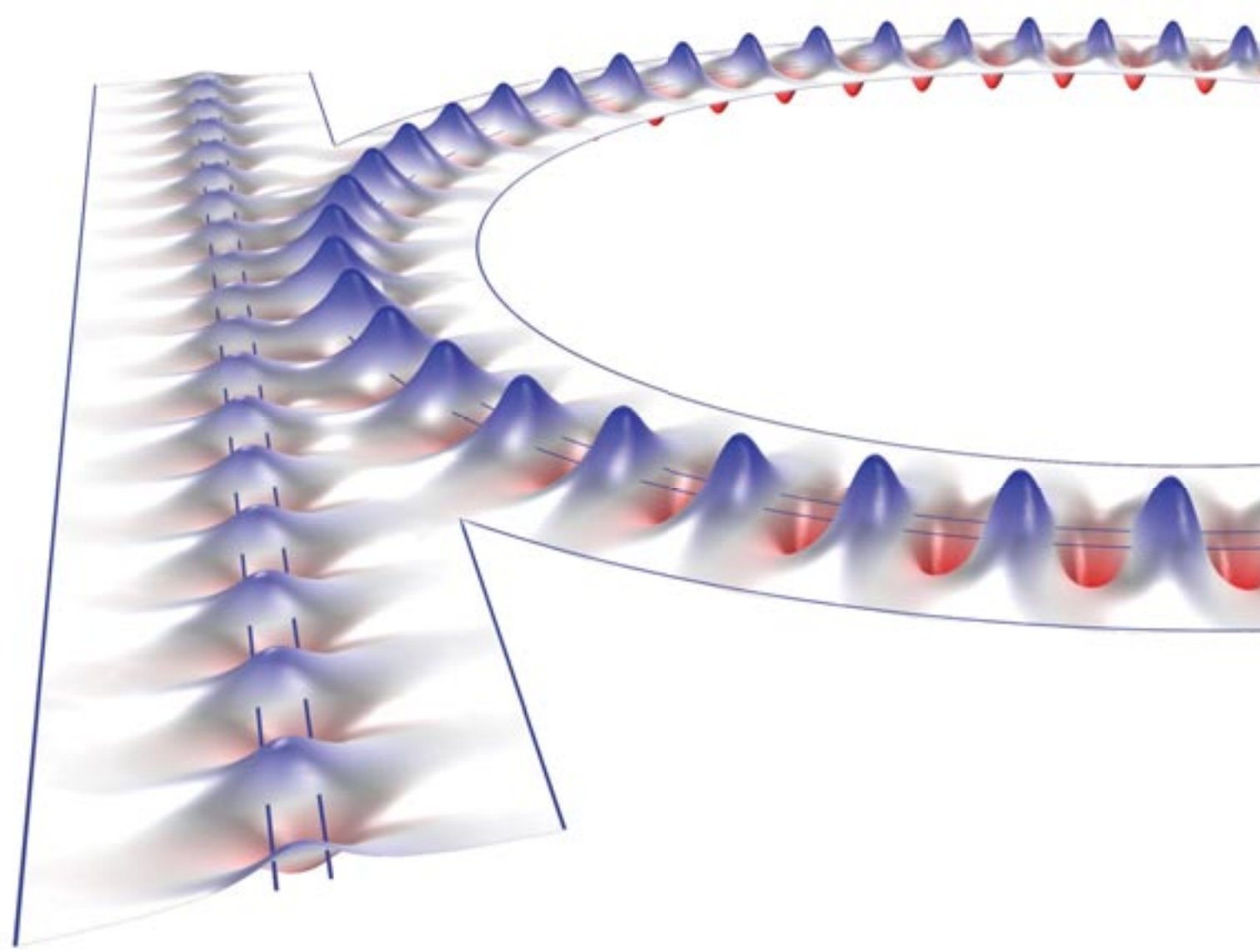
The aim of the business and technical efforts is to demonstrate that the reactor enables substantially improved performance in terms of efficiency, volumetric productivity, and mass of hydrocarbon per mass of catalyst per time, relative to the state-of-the-art.

Advances from the project will contribute significantly to the reduction of energy-related emissions, and will have a positive impact on energy storage. The Cornell team has been working with startup Dimensional Energy to commercialize this technology. In addition to advancing into Round 2 of the $20M NRG COSIA Carbon X-Prize, the team also has had significant interactions with Shell Oil through the Shell GameChanger program.

For more information, visit **http://contest.techbriefs.com/2017/grand_prize**

"I would like to express our greatest gratitude to the judges for choosing our team as the Grand Prize Winner of the 2017 Create the Future Design Contest. It is great recognition for our team. The Cornell team has been working with Dimensional Energy to convert the waste carbon dioxide into liquid fuels and feedstocks that power our economy and fit into a planetary carbon cycle through our unique HI-Light reactor. We will continue to advance our technology, and expect to contribute significantly to the reduction of energy-related emissions, with a positive impact on energy storage. This recognition is not for our team alone, but for the general science community to push forward renewable energy research."

- Elvis Cao



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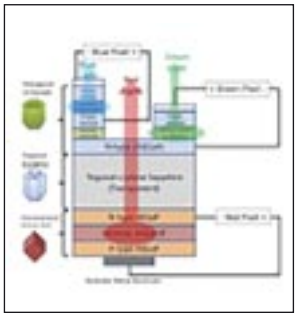


INTEGRATED MULTI-COLOR LIGHT EMITTING DEVICE MADE WITH HYBRID CRYSTAL STRUCTURE

Sang Choi, NASA Langley Research Center, and Yeonjoon Park, National Institute of Aerospace (NIA)
Hampton, VA

Today's LEDs are built with many compound semiconductors with type-I direct bandgap energies of two different crystal structures. While red, orange, yellow, and yellowish-green LEDs are commonly made with III-V semiconductor alloys of aluminum gallium indium phosphide (AlGaInP) and aluminum gallium indium arsenide (AlGaInAs) with cubic zinc-blend crystal structures, the higher-energy colors such as green, blue, purple, and ultraviolet (UV) LEDs are made with III-Nitride compound semiconductors of AlGaInN alloys with hexagonal wurtzite crystal structures. Because the atomic crystal structures are different for red LED and green/blue LEDs, the integration of these semiconductor LEDs as individual R, G, B pixels on one wafer was almost impossible.

NASA Langley Research Center has developed a process for making red, green, and blue LED device structures on the same substrate (wafer) to improve displays. The hybrid crystal LED display device comprises double-sided hetero crystal growth with a hexagonal wurtzite III-Nitride compound semiconductor on one side of c-plane sapphire media, and a cubic zinc-blended III-V or II-VI compound semiconductor on the opposite side.

"Winning first prize in the Electronics Category brings wide exposure and great opportunity for our technology. This multi-color LED will offer a new dimension to current display technology, and it is a great privilege for us to pursue with others the advancement of this technology to the marketplace."

The c-plane sapphire media may be a bulk single crystalline c-plane sapphire wafer, a thin freestanding c-plane sapphire layer, or crack-and-bonded c-plane sapphire layer on any substrate. The bandgap energy and lattice constant may be engineered by changing the alloy composition within the cubic group IV, group III-V, and group II-VI semiconductors, and within the hexagonal III-Nitrides.

For more information, visit **http://contest.techbriefs.com/2017/electronics_winner**

HONORABLE MENTIONS

World's First Cost-Effective Multispectral Sensor-on-Chip Solutions

Tom Griffiths, ams AG, Austin, TX

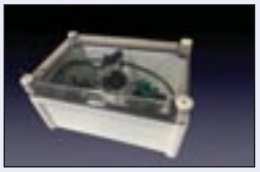
The AS726x cost-effective, multispectral, sensor-on-chip solutions enable chip-scale spectral analysis. They bring the lab to the sample for applications from food safety and product authentication, to routine testing. The multispectral sensors employ a new fabrication technique that enables nano-optical interference filters to be deposited directly on the CMOS silicon die with extreme precision. Onboard intelligence allows the sensors to be calibrated for life.

For more information, visit
http://contest.techbriefs.com/2017/sensor_on_chip

Portable Rapid Sensor for Detection of E. Coli in Water

Parmiss Mojir Shaibani and Amirreza Sohrabi, Roshan Water Solutions, Edmonton, Alberta, Canada

The early detection of pathogens in drinking water can prevent widespread life-threatening infections and catastrophic outbreaks. The VeloCens™ portable sensor detects E. coli in water in one hour. It operates by monitoring the metabolic activity of the bacterial cells and changes in the pH of the local surroundings. It can be used on-site to help decide whether water is safe to use, especially in rural areas.



For more information, visit
http://contest.techbriefs.com/2017/VeloCens

Hearo — Internet of Sound

Hakan Lidbo and Max Bjorverud, Libido Music AB, Stockholm, Sweden

Hearo is an Internet of Sound system, through which any object in the home can be a digital controller. It is taught to identify certain sounds from certain objects with the app; for example, the sound of a spoon on a teacup could make Spotify skip to the next song in a playlist. The sound of the object becomes a digital controller — Hearo doesn't record the sounds or store them online, eliminating additional devices.

For more information, visit
http://contest.techbriefs.com/2017/Hearo

Environmental Sensing in the IoT with BME680

Silvia Mayer and Thomas Block, Bosch Sensortec, Reutlingen, Land Baden-Wurttemberg, Germany

BME680 is a tiny sensor for ambient temperature, relative humidity, barometric pressure, and gas. The sensor measures indoor air quality for applications such as smart homes and IoT for environmental sensing, as well as health monitoring, home automation control, leisure and sports, and smart transportation. It enables battery-driven devices to run for up to two years without battery change.

For more information, visit
http://contest.techbriefs.com/2017/BME680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AIRFOIL PERFORMANCE MONITOR (APM)

John Maris, Puthy Soupin, Ludovic Laberge, and Marie-Hélène Larose
Marinvent Corporation
Saint-bruno, Quebec, Canada

The patented Airfoil Performance Monitor (APM) provides real-time information to pilots regarding the state of the airflow over the aircraft's wings and tail. This information is critical for the prevention of stalls and Loss of Control (LOC), particularly during airborne icing encounters.

According to a 10-year National Transportation Safety Board (NTSB) study, LOC was the leading cause of fatalities in large commercial jet and business jet aircraft, accounting for 4,717 lives lost and 44% of all U.S. business aircraft accidents during a ten-year period. Many LOC events are caused by airfoil stalls that result when the airflow becomes turbulent and separates from the airfoil. This can result in severe aircraft controllability and performance difficulties. Traditional angle-of-attack (AOA) stall-protection systems use horizontally mounted weather vanes that are fuselage-mounted and cannot detect the state of the airflow over the wing. In contrast, APM detects the flow separation caused by an impending stall at its source.

"Marinvent Corporation is tremendously honored that its patented Airfoil Performance Monitor (APM) was recognized as the winner of the Aerospace & Defense Category. We are certain that this special recognition will significantly increase public awareness of the problem areas identified by the NTSB, while highlighting the role that APM can play in drastically reducing future accidents and fatalities."

APM uses miniature pressure transducers to measure air turbulence that has been shown to correlate closely to stall proximity, regardless of icing. APM has the demonstrated capability to drastically reduce stall-related LOC accidents, with significant lifesaving potential.

APM has equal application to manned and unmanned vehicles of all sizes. APM can be used to directly monitor and optimize aircraft cruise performance, resulting in significant gain in fuel efficiency and reduction in greenhouse gases. The design is mature and production-ready, based on flight-quality, commercially available sensors and electronic components.

For more information, visit **http://contest.techbriefs.com/2017/aerodef_winner**

HONORABLE MENTIONS

Breathing System for Divers Based on Separation of Dissolved Air from Water

Alan Bodner, Like-A-Fish, Tsafon, Israel

Based on the amount of dissolved oxygen that exists in seawater, the human oxygen consumption rate, and the amount of energy required to release dissolved oxygen in sufficient amount, a non-nuclear submarine could supply the needs of oxygen for its crew by extracting the oxygen from the water. This method can replace the current air supply system (storage in cylinders) with the advantage of much longer underwater capacity.

For more information, visit
http://contest.techbriefs.com/2017/breathing_system

Hybrid Miller Cycle Rotary HCCI Engine for RQ-7 Class Drones

Roderick Newstrom, Garland, TX

This engine design eliminates spark plugs or diesel fuel injectors via Homogeneous Charge Compression Ignition (HCCI). Magnets, combined with coils in the radial housing, effect a motor/generator for starting, reverse, rapid acceleration, power generation, hybrid operation, and occasional silent running. Ignition delay is minimized, and the stroke and inertial loads associated with the rapidly moving piston are reduced.

For more information, visit
http://contest.techbriefs.com/2017/rotary_engine

Space Exploration for All Using FemtoSats

Jekan Thangavelautham, Aman Chandra, Mercedes Herreras-Martinez, Andrew Warren, and Erik Asphaug, Arizona State University, Tempe, AZ

Significant advances in nanometer-scale, low-power, low-cost, high-reliability electronics have enabled the SunCube FemtoSat platform containing either 27 3 x 3 x 3-cm cubes, or nine 9 x 3 x 3-cm cube spacecraft. The components can be mass-produced, enabling anyone to launch a spacecraft starting at nearly 1/40th the launch price of CubeSats.

For more information, visit
http://contest.techbriefs.com/2017/femtosats

Ultra-High-Speed, Magnetically Levitated Reaction Wheels for Small Satellites

Arda Tuysuz, ETH Zurich, Zurich, Switzerland

A magnetically levitated reaction wheel with an integrated electrical drive, magnetic bearings, and sensors allows for a compact system for small-satellite attitude control. The same materials are utilized for both the magnetic bearings and the rotational drive, enabling ultra-high-speed operation. Low-speed reaction wheels using ball bearings can be replaced with this reaction wheel with minimum effort.

For more information, visit
http://contest.techbriefs.com/2017/reaction_wheel

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Congratulations to the Aerospace & Defense Category Winner:
Airfoil Performance Monitor (APM)
– *John Maris (Team Lead), Marinvent Corporation, Quebec, Canada*

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EJBOT: VERSATILE CLIMBING ROBOT FOR INDUSTRIAL VESSEL INSPECTION

Dr. Mohamed Gouda Alkalla and Mohamed Fanni
Mansoura University
Mansoura, Ad-daqahliyah, Egypt

The EJBot is a propeller-type climbing robot for climbing various types of structures to inspect industrial vessels made of various materials, including non-ferromagnetic material. The inspection process includes capturing images of important spots that are prone to corrosion, as well as measuring the vessel's wall thickness.

The design consists of two coaxial upturned propellers mounted on a mobile platform with four standard wheels. A new hybrid actuation system that consists of propeller thrust forces and standard wheel torques is the adhesion system for this climbing robot. This system generates the required adhesion force to support the robot on the climbed surfaces.

Experimental tests to check the robot's capabilities of climbing different surfaces — such as smooth, rough, flat, and cylindrical surfaces like those on an actual vessel — were successfully completed. The robot stops accurately on the climbed surface at any desired location for inspection purposes, and it overcomes significant obstacles up to 40 mm.

"It was a great pleasure participating in this contest. I was delighted when I received the award of First Prize in the Machinery/Automation/Robotics Category. This win helps my EJBot Climbing Robot to be recognized internationally, and certainly facilitates communicating with industrial companies in the future."

- Dr. Mohamed Gouda Alkalla

This proposed climbing robot is needed for petrochemical and liquid gas companies in which a regular inspection of welds and the wall thickness is required. The interaction between the human and the vessels is dangerous due to the harmful environment inside these vessels. EJBot robot will save the cost of inspection of vessels, as well as protect the health of technicians.

For more information, visit **http://contest.techbriefs.com/2017/machinery_winner**

HONORABLE MENTIONS

Synchronous Reluctance Machine (SRM)

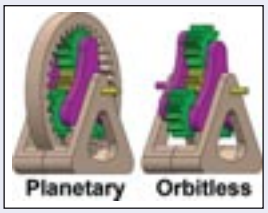
Douglas Richard, DDU Magnetics, Lynwood, IL

SRMs have great potential in wind turbine generators or tractive drive motors. This unique geometry eliminates cogging torque without complex software, using prime numbered stator armature coils. It comprises only four sub-assemblies, and can be retrofitted inside existing DC brushed (and/or AC induction/synchronous) frames.

For more information, visit
http://contest.techbriefs.com/2017/SRM

Orbitless Drive

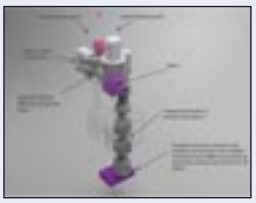
Leo Stocco, Orbitless Drives Inc., Vancouver, British Columbia, Canada



The Orbitless drive is the first new low-ratio drive since the planetary drive, and features torque splitting and co-axial drive shafts that spin in a common direction. It offers lower production cost and lower internal speeds, providing higher efficiency and longer bearing life for applications in automated factories, electric vehicles, medical devices, and other motorized products.

For more information, visit
http://contest.techbriefs.com/2017/orbitless_drive

Development of Multi-Material 3D Printer Using Fused Deposition Modeling



Dr. Jing Yuen Tey and Dr. Yogeswaran a/l Mohan, University Tunku Abdul Rahman, Selangor, Malaysia

This fused deposition modeling (FDM) printer has a compact mixer that takes in two different materials to produce the desired mixing ratio of the polymer material. This can produce unique mechanical properties; for example, with Nylon as a base matrix polymer and carbon fiber as a filler, varied stiffness in the material can be achieved.

For more information, visit
http://contest.techbriefs.com/2017/FDM_printer

Single Sleeve Mounting Pulleys, Gears, and Sprockets on Keyless Shaft

Tad Staniszewski, Asymmetric Fasteners Inc., Hackettstown, NJ

Traditionally, drive elements like gears, pulleys, sprockets, and similar devices are affixed to rotating shafts using a variety of different methods. The Torksleeve A2 (TSA2) is a single cylindrical sleeve whose exterior is threaded with an asymmetric thread. The sleeve can be threaded into a component from either side, providing secure vibration-resistant bidirectional movement, and repeated mounting and dismantling of components.

For more information, visit
http://contest.techbriefs.com/2017/torksleeve

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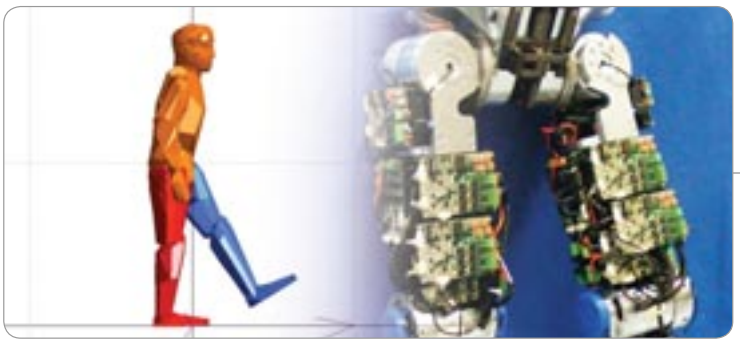

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ARTERIAL EVERTER

Jeffrey Plott, Adeyiza Momoh, Ian Sando, Brendan McCracken, Mohammed Tiba, Kevin Ward, Jeffrey Kozlow, and Paul Cederna
University of Michigan
Ann Arbor, MI

Microvascular anastomosis is the surgical joining, or coaptation, of small (sub-centimeter) veins and arteries with the aid of loupe or microscope magnification. This is accomplished using a microanastomotic coupling device (Synovis GEM Coupler) that reduces complication rates, improves patency rates, and substantially reduces the time necessary to complete the coaptation compared to manual suturing.

Arterial microvascular anastomoses are currently accomplished with standard manual suturing techniques — the thick wall of the artery prevents them from being stretched over the rings of a coupler. As a result, arterial microanastomoses performed by manual suturing takes about 25 minutes in the operating room, versus about 5 minutes using a coupling device (for veins).

The Arterial Everter is used in conjunction with the coupler to replace traditional vessel suturing, and enable rapid anastomosis of arteries ranging from 1.5 to 4 mm in diameter. The average time to perform the anastomosis was significantly less when using the everter/coupler compared to manual suturing (6:35 minutes vs. 25:09 minutes, $p < 0.001$).

"It is very exciting to be recognized as the Medical Category winner. This device is just one example of the strong collaboration between engineering and medicine at the University of Michigan, along with the great support of the Coulter Translational Research Partnership Program. It took the efforts of many different people and groups to get the Arterial Everter to where it is today. Our goal has always been to create something that will ultimately improve the lives of patients, and I am thrilled to see it moving rapidly in that direction."

The Arterial Everter consists of a stainless steel rod over-molded with medical-grade silicone using traditional injection/compression molding. It will reduce leak rate, risk of vessel injury, vessel kinking, and time under anesthesia for the patient, along with being technically easier and faster for the doctor. The use of the coupler rings for arteries also adds significant clinical value because the blood flow through the anastomosis can be monitored using the Flow Coupler system.

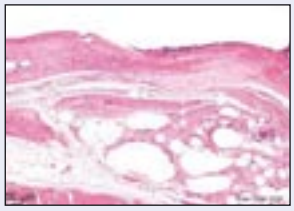
Target users are surgeons, ENTs, and others who perform microsurgery and reconstruction. By analyzing the cost savings of sutures and the drastic reduction in operating time, a hospital could expect to save about $1,000 per anastomosis using the Arterial Everter.

For more information, visit **http://contest.techbriefs.com/2017/medical_winner**

HONORABLE MENTIONS

Electroactive Material for Wound Healing

NASA Langley Research Center's Technology Gateway, Hampton, VA



This device uses electrical activity to facilitate wound healing while protecting the wound. The bandage is made of an electroactive material stimulated by the heat of the body and the pressure of cell growth; no external power source is required. The material is fabricated from PVDF, a thermoplastic fluoropolymer that is highly piezoelectric when poled.

For more information, visit
http://contest.techbriefs.com/2017/wound_healing

Kaleyedos Imaging Device (KID): A Telemedicine Solution to Retinopathy of Prematurity

Erica Schwarz, Sami Messai, Becca Miller, Seony Han, Richard Chen, Aditya Murali, and Prerna Singh, Kaleyedos, San Francisco, CA

Retinopathy of Prematurity (ROP) is a disease that affects premature infants and is the leading cause of childhood blindness. The KID streamlines the infant retinal imaging process, providing a low-cost, telemedicine solution to ROP. The compact, wireless device is designed to be maneuverable in an infant incubator. Images taken by the device are automatically uploaded to a cloud server where they are remotely accessible for grading from anywhere in the world.

For more information, visit
http://contest.techbriefs.com/2017/KID

High Visibility Biopsy Needles

Muhammad Sadiq, Ian Quirk, and Mike Irvine, Active Needle Technology, Abingdon, Oxford, UK

This innovation ensures the visibility and positional accuracy of biopsy needles. A high-frequency oscillation is applied to the needles, causing them to vibrate by microscopic distances. The oscillations are visible when imaged in Doppler ultrasound mode; the color Doppler image precisely locates the needle. Benefits include shorter procedures, fewer repeat procedures, lower procedure cost, and patient well-being.

For more information, visit
http://contest.techbriefs.com/2017/biopsy_needles

Quartet™ H2O LDD Actively Cooled Lateral Surgical Fiber Optic

Stephen Griffin, InnovaQuartz LLC, Phoenix, AZ

Infrared surgical lasers are incompatible with right-angle, off-axis-delivery fiber optics. The Quartet H2O LDD is designed with multiple coolant conduction channels formed within the active end of a fiber optic device similar to a heat exchanger coil without crossing the optical path, thereby avoiding interaction with the therapeutic laser energy.

For more information, visit
http://contest.techbriefs.com/2017/quartet

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AUTOMOTIVE/TRANSPORTATION CATEGORY WINNER

Winner of an HP Workstation

HEAVY DUTY AFTERMARKET SUPER TRUCK

George Sturmon, Ed Murray, Josh Medling, Susan Schmidt, and Glen Harris
Enviro-Cool
Sullivan, MO

The Heavy Duty Aftermarket Super Truck patented system delivers up to 10% reduced fuel consumption, under-hood heat reduction, and sound reduction. This aftermarket upgrade does not affect the engine or body aerodynamics. This platform truck is designed for aftermarket efficient technologies to collaborate on and deliver a "used super truck" that is affordable for today's fleets and owners.

The Advanced Engine Cooling System uses a central radiator plenum, two electric fans, and hood ductwork to transfer hot radiator air outside the body, not into the engine compartment. The system uses a full cowl induction hood scoop to supply cool air to the engine compartment and engine air intake system. Then, hot engine compartment air is transferred out through the exit ducts.

This system produces 50% reduction in under-hood temperature using only 2 horsepower (HP) to drive the electric fans, compared to 60 to 80 HP for the original equipment fan system. There is a 50% reduction in fan noise, with fuel savings up to 10%. The system can idle on electric fans using minimal HP and far less fuel than the original equipment fan assembly.

"We've been working on this technology for over ten years, so winning the Automotive/Transportation category is very exciting for our team, and adds a lot of credibility to the Aftermarket Super Truck Platform and Modular Class 8 Hybrid Powertrain we are developing. Considering under-hood thermodynamics hasn't been a strong point in the industry, this recognition significantly helps our mission."

The system optimizes any heavy truck, converting a fleet's aging assets into "better-than-new" Super Trucks — along with partner and combined affiliate company upgrades. Although licensed shops could retrofit the system in a few days, OEMs could implement the upgrade on assembly lines with greater efficiency and cost savings.

The system provides fewer emissions, less downtime, increased truck life, increased available horsepower, more efficient combustion, fewer engine failures and towing fees, less maintenance cost, and a return on investment in less than three years.

The average retail price for used Class 8 trucks has plunged 22% in the past two years, prompting fleets to keep existing assets longer, which increases maintenance costs.

For more information, visit **http://contest.techbriefs.com/2017/auto_winner**

HONORABLE MENTIONS

SHOT Lightweight Engine Starting System Without Battery/Starter

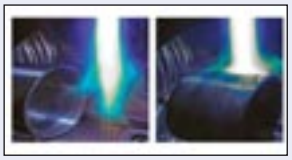
Michel Bernier, BRP, Quebec, Canada/Ski-Doo Engineering Team – USA, Canada, and Austria

The SHOT starting system meets a mountain snowmobiler's need for easy starting without adding significant weight. SHOT enables a lightweight, easy-to-maneuver, and easy-to-start snowmobile by eliminating the battery, starter motor, solenoid, ring gear, and cables. The resulting pushbutton start saves the rider's energy by eliminating the rope start.

For more information, visit http://contest.techbriefs.com/2017/shot

Plasma Deposition of Metal in Composite Panels

Erik S. Weiser, Roberto J. Cano, Brian J. Jensen, and Stephen J. Hales, NASA Langley Research Center; and Joel Alexa, Lockheed Martin, Hampton, VA



This technique prepares metal/composite hybrid laminates, also known as fiber metal laminates (FML), by depositing metal directly onto fabric using a plasma deposition process, eliminating the need for separate foils and providing a better interlayer bonding. Various fabrics and metal alloys can be used for ballistic protection, automotive structures, composite doors and windows, and aeronautics and aerospace applications.

For more information, visit http://contest.techbriefs.com/2017/plasma_deposition

Lightweight, Wear-Resistant, Metal Matrix Composite Brake Rotors

Lori Bracamonte and James Withers, ATS-MER, LLC, Tucson, AZ

Cast iron automobile brake rotors are heavy and suffer from limited lifetimes and excessive wear in the form of dust. This new, lower-temperature, hot pressing technique eliminates porosity and defects, as well as wear and dust generation. Due to the lighter weight and reduced inertial forces, lower CO_2 emissions are also realized. The Al-SiC MMC brake rotors offer significant environmental benefits, a more comfortable ride, and elimination of the need to replace the rotors over the life of the vehicle.

For more information, visit http://contest.techbriefs.com/2017/mmc_rotors

RADIALcvt (Continuously Variable Transmission)

Jan Naude, Varibox CVT Technologies, Johannesburg, Gauteng, South Africa

The RADIALcvt is a multi-parallel power path type of Continuously Variable Transmission (CVT) using traction drive technology to optimize the factors contributing to high mechanical efficiencies in traction drives. It has only one friction drive interface in series in a parallel power path, and at least six parallel power paths. The CVT does not have any hydraulic control.

For more information, visit http://contest.techbriefs.com/2017/radial_cvt

CONSUMER PRODUCTS CATEGORY WINNER

Winner of an HP Workstation

HONORABLE MENTIONS

GAIA

Brent Chase, GAIA, Columbia, MD

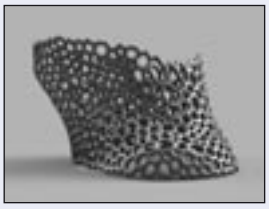
Hypersensitivity is a common trait of those with autism. Weighted, heavy vests that mimic a hug are used to combat this. GAIA smart apparel is lightweight and can be worn under clothing to avoid attention. It monitors biometrics of a user such as heart rate, skin conductivity, and blood to determine the user's stress level. Through machine learning, the shirt generates a threshold for stress indicators. Once the threshold is surpassed, the device initiates compression of the user, simulating a hug.

For more information, visit http://contest.techbriefs.com/2017/GAIA

Impact Absorbing Gel Infused Exoskeleton (IAGIES)

Melissa Chavez, Justin McGinnity, Cody Piercey, and Tanil Ozkan, PhD, Texas A&M University, College Station, TX

The IAGIES (Impact Absorbing Gel Infused Exoskeleton) is a 3D-printed neck mesh exoskeleton. This customizable neck brace distributes stress around the neck optimally through a hollow Voronoi network. Pressure around the neck is uniformly dispersed when the hollow network is filled with DivGel™, an energy absorbing gel. The exoskeleton optimizes helmets, body armor, and protective gear.



For more information, visit http://contest.techbriefs.com/2017/IAGIES

SignAloud

Thomas Pryor, SignAloud, Seattle, WA

SignAloud is a pair of gloves that can translate sign language into a verbal form instantaneously and in an ergonomic fashion. The gloves are a communication tool for people who may have trouble speaking and for those who use sign language. When wearers sign, the central computer associates their hand positions and gestures to a word or phrase that is verbally spoken.

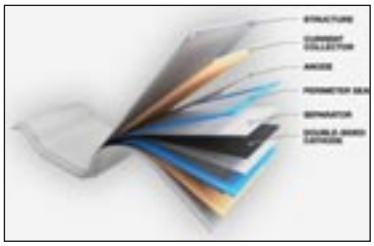
For more information, visit http://contest.techbriefs.com/2017/signaloud

SkyRunner

Stewart Hamel, SkyRunner, LLC, Shreveport, LA, USA

SkyRunner's technology transforms an all-terrain vehicle into an FAA-certified light-sport aircraft in a matter of minutes. The two-engine vehicle — one for off-road and one for flight — uses ram-air parafoil wing technology to reach air speeds of 40 mph at maximum regulated altitude of 10,000 feet. Once airborne, only two flight controls are required: a single throttle lever to climb/descend, and foot pedals for left/right turns.

For more information, visit http://contest.techbriefs.com/2017/sky_runner



CONFORMAL BATTERY

Russell Kittel, Krista Smith, Kathryn Chamberlain, Steve Risser, Christopher Jackson, and Megan Moore
Battelle
Columbus, OH

Today's highly mobile world is very dependent upon portable power, which means batteries or other electrochemical devices are the primary power source. The energy needed for many devices and applications leads to the batteries consuming a significant portion of the mass and volume allocated to the device, and also imposes significant constraints on the shape and size of the device. Since batteries take up space, one of the most obvious approaches is to have them contribute to the mechanical aspects of the structure. The Conformal Battery approach allows for the battery to be integrated into the structural components of the final product.

Removing the outer battery packaging and using an advanced separator allows the battery to have a thinner profile and enables it to be shaped into many different geometries. The Conformal Battery can be integrated into a product housing without impacting overall rigidity and strength. In addition, the battery is fire-safe.

"We are honored to have been selected Consumer Products Category award winner. This award provides validation that the consumer market is excited to remove the design constraints associated with traditional batteries. We expect the award win will spark conversations with potential commercialization partners, and accelerate the entrance of conformal batteries into the marketplace."

The electrochemical device may be integrated into a composite or polymer panel suitable for uses such as structural load-bearing panels or sheets for aircraft wings or fuselage, composite armor, unmanned underwater vehicles, torpedoes, missile bodies, consumer electronics, etc.

The conformal battery is a mirrored stack design centered on a dual-sided anode. From the anode moving outward, the components are the safety separator, cathode, and outer containment layer. The Conformal Battery has been developed using mostly commercially available materials, enabling a seamless manufacturing process. The design was created to fit seamlessly in current composite material fabrication processes for ease of implementation into final consumer products and beyond.

The Conformal Battery can be used in power-integrated, lighter-weight military gear designed to better aid soldiers; in lower-profile, body-contoured pacemakers for a more comfortable patient experience; or in advanced power tools.

For more information, visit **http://contest.techbriefs.com/2017/consumer_winner**

SUSTAINABLE TECHNOLOGIES CATEGORY WINNER

Winner of an HP Workstation

ENERGY SAVING FILTER FOR REMOVAL OF HEAVY METALS FROM WATER

Volodymyr Khranovskyy, R. Yakimova, Ivan Shtepliuk, P. Lima de Carvalho, and A. Pinto
Talent Molecule LDA
Braga, Portugal

Pollution by heavy metals (HMs) is a crucial environmental issue. With the modern growth of chemical, mining, energy, tanning, and dye industries, residual HMs — such as Hg, Pb, Cd, Cr, and others — are discharged into the ambient air. These toxic contaminants end up in potable water. Since they are invisible and tasteless to humans, they bio-accumulate in organisms, causing chronic diseases and death around the world.

"The entire team is delighted to be the Sustainable Technologies category winner. Our design is on a scale that is invisible to the human eye, but it's critical for performance. With our product, materials science meets design on the nanoscale for environmental solutions — saving human lives with nanomaterial design."

Researchers at Linkoping University (Sweden) developed a novel nanomaterial that attracts heavy metal ions in aqueous solutions. The material is called functionalized graphene oxide (FGO, patent pending). Originating from carbon, it is only one atomic layer thin, and therefore has the highest possible surface area, which makes it an ideal absorbent. A unique approach was developed for the nanomaterial processing, and a filtering unit with efficiency of more than 95% for HM removal was designed.

Unlike traditional water-cleaning technologies, this filtering unit is optimized for low-cost, zero energy consumption, with no water waste and high flow rate. The product is a dynamic flow filter with a capacity for 10,000 liters of average contaminated water (50 mcg/L). The filtering system can be adapted for highly contaminated water, high water flows, or both.

For more information, visit **http://contest.techbriefs.com/2017/sustainable_winner**

HONORABLE MENTIONS

Pollution-Free Paper (Self-Erasing Ink Enables Reuse)

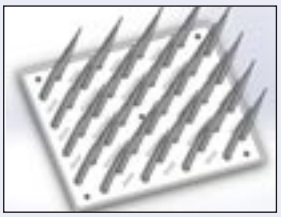
Carl Yee, Blue Planet Ink, San Diego, CA

Paper-Saver™ ink is a disappearing ink for inkjet printers. The water-based ink erases itself after three weeks as it absorbs carbon dioxide from the air, allowing the paper to be reused. All the sheets in a stack of paper self-erase; the top sheet in a stack of paper erases fastest because it has the most airflow. The ink is sold as third-party replacement ink cartridges.

For more information, visit http://contest.techbriefs.com/2017/paper_saver

ecoSPEARS: A Non-invasive Solution to PCB Pollution in Contaminated Waterways

Samuel Johnson, Sergie Albino, and Ian Doromal, ecoSPEARS, Winter Springs, FL

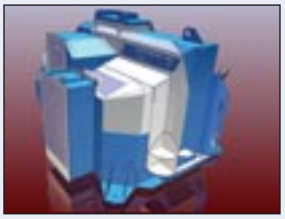


ecoSPEARS is a technology conceptualized by NASA to bring a sustainable, long-term solution to polychlorinated biphenyl (PCB) remediation in worldwide water supplies. The SPEARS are 3D-printed using polymer plastic. The hollow interior of the SPEARS is then lined with resin to reinforce its structural integrity, and is filled with ethanol. This allows for the polymer molecules to widen when placed within marine sediment, drawing the hydrophobic PCB molecules into the polymer, and ensnaring them within the ethanol.

For more information, visit http://contest.techbriefs.com/2017/eco_spears

MicroEVAP™ Water Purification System

Karen Sorber, Micronic Technologies, Wise, VA



The MicroEVAP water purification system processes polluted water from any source with a low-pressure, low-temperature, tornado-induced, rapid-evaporation technology. It requires no chemical pre-treatment or membranes, is self-contained, and requires no onsite waste heat supply. The current system design can purify a range of contaminated water types at an estimated throughput of 1,500 gallons per day. It has been demonstrated to remove 95% of the contaminants at 95% throughput efficiency.

For more information, visit http://contest.techbriefs.com/2017/micro_evap

SPIRP – Solar Powered Irrigation Resonance Pump

Sue Becconsall and Alec Becconsall, Longcroft Engineering; and John Allport, Simon Malins, and Goodarz Khodabakhsi, University of Huddersfield, West Yorkshire, UK. **For more information, contact Sue Becconsall at sue@longcroftengineering.co.uk**

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Piero Aversa
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R&D Manager, Fisher and Paykel Healthcare
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Pierluigi Benedini
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Extremely Large Telescope Dome and Main Structure, European Southern Observatory
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Irvine, CA

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Asst. Dean Engineering Tech., ECPI University
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Regulatory Policy Head, Digital Medicines and Devices, Novartis
San Carlos, CA

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Robert Taylor
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TOP TEN MOST POPULAR ENTRIES

Visitors to the Create the Future Design Contest web site were invited to vote for their favorite entries. Each wins Nanodots Magnetic Constructors from Nano Magnetics.

VSSUT Student Satellite
Apurwa Masook, Bodhisattwa Sanghapriya, Jaswasi Sahoo, Sovan Panda, Sudarshan Samal, and Tatwamsiddha Nanda, Idea Innovation Cell, Sambalpur, Odisha, India
https://contest.techbriefs.com/2017/entries/8109

Hoisting Device Combined with the Hydraulic Dump System of a Pickup Truck Bed
Shailesh Parkhe, Shahnavaz Abdulla Shah, Sandip Bhausaheb, Lokhande Ganesh, and Jamnadas Ghule, Chandwad, Maharashtra, India
https://contest.techbriefs.com/2017/entries/8116

MEDDIAR Medical Diary
Mayank Talwar, Nayan Sharma, and Jatin Rana, Dronacharya College of Engineering, Gurgaon, Haryana, India
https://contest.techbriefs.com/2017/entries/8337

Future Dustbin
Nilaabh Vinay, Gugale Arjun, and Vikram Soni, Creative Minds, Pune, Maharashtra, India
https://contest.techbriefs.com/2017/entries/8058

Netmory
Mikhael Lerman, Manestate, San Jose, CA
https://contest.techbriefs.com/2017/entries/7630

Space Gravity Suit
Georgios Profitiliotis, Elena Veli Giorgos, Ntalis Vasilapostolos Ouranis, and Vicky Stefanouli, NTUA, Athens, Greece
https://contest.techbriefs.com/2017/entries/8527

Chassis System that Reduces Hill Accidents
Manoj Sharma, Pantnagar, Uttarakhand, India
https://contest.techbriefs.com/2017/entries/7579

(24/7) From Solar Thermal-to-Electrical Energy
Marwan Sallouta, Abu Dhabi, Abu Zabi, United Arab Emirates
https://contest.techbriefs.com/2017/entries/7895

Groundnut Decorticator and Separator
Rahulkanth Sh, Saran R, Santhosh B, Raghul A, Easwari Engineering College, Chennai, Tamil Nadu, India
https://contest.techbriefs.com/2017/entries/8493

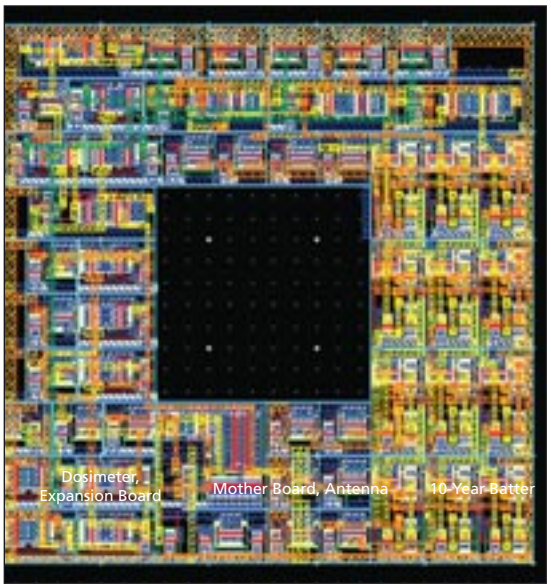
Advanced Space Debris Disposal System
Ritesh Deokar, Anish Gorantiwar, Kunal Nalamwar, Krishna Hundekari, Rohit Gujarathi, and Akashay Verma, MIT Pune, Pune, Maharashtra, India
https://contest.techbriefs.com/2017/entries/8500

Single Event Upset Suppression System (SEUSS)

This technique can be used in electronic devices in applications where extreme design flexibility is required.

Fermi National Accelerator Laboratory, Batavia, Illinois

Electronic devices are getting smaller and more energy-efficient, meaning that they are more susceptible to single event upsets (SEUs) — malfunctions caused by particles in the atmosphere interfering with electronic systems. The need increases as these devices get smaller, since particles that cause these upsets can even come from the packages that house the devices. This is especially prevalent in the aerospace industry, since working at higher altitudes means increased exposure to cosmic ray particles.



SEUSS is a latch that can behave like any known latch.

There are two widely used SEU hardening techniques: tech hardening and design hardening. Tech hardening involves making changes to the fabrication of the chip to reduce SEU occurrences. These fabrication processes can cost billions of dollars to develop.

The Single Event Upset Suppression System (SEUSS) is a latch that suppresses these single event upsets. SEUSS gives electrical engineers freedom of design, since it can behave like any known latch (SR latch, D latch, T flip flop, JK flip flop, etc.). It offers single event upset tolerance while maintaining flexibility in design, and saves money in the process.

SEUSS cells are designed to be immune to SEUs. CMOS transistors are configured to operate as a SEU-tolerant SR latch. The SEUSS cells come in two different variations. One version emulates a cross-coupled NOR gate SR flip-flop (SEUSSNor); the other emulates a cross-coupled NAND gate SR flip-flop (SEUSSNand). This flexible device, when configured as a SEU-tolerant SR latch, can be converted into any known type of latch.

One benefit of the SEUSS latch is that it can be fabricated in any modern integrated circuit process that provides complementary transistors. Another benefit is that scaling is not required to make the design functional. The SEU tolerance of the invention is not affected by any external logic that may be added.

The SEUSS technology can be set or reset either synchronously or asynchronously; therefore, redundant circuitry can be added to the invention to increase its SEU tolerance.

For more information, contact Aaron G. Sauers at asauers@fnal.gov; 630-840-4432.

Integrated Three-Dimensional Module Heat Exchanger for Power Electronics Cooling

National Renewable Energy Laboratory, Golden, Colorado

Critical elements in the operation of electric drive systems are power electronics and power semiconductor packages. Improving thermal management of power electronics can help reduce the cost, weight, and volume of electric drive systems, and thus increase market acceptance. The power semiconductor packaging must provide the necessary electrical connections, while at the same time enabling heat removal from the semiconductor devices such as insulated gate bipolar transistors (IGBTs) and diodes.

An integrated three-dimensional module heat exchanger was developed for power electronics cooling. The design is fully integrated with a semiconductor package. Heat transfer happens from the top, bottom, and sides, ensuring maximum cooling. The design is stackable to form common power electronics building blocks, and is scalable and modular.

The integrated module heat exchanger consists of the following elements: cooling fins, heat spread plate, semiconductor package, space for bus bars, and control electronics or distributed capacitors. Optional features include heat spread tip fins and thermal insulators. Designs for liquid- and air-cooled systems are included as well. Preliminary finite element analysis has shown significant benefits relative to volume and cost when compared to existing cooling technologies for power semiconductor packages.

While the design was based on the needs of vehicle systems manufacturers, application of the technology is not limited. Other applications include variable speed motor drives for energy efficiency, solar power and microscale grid power electronics, wind power generation electronics, and others.

For more information, contact Eric Payne at Eric.Payne@nrel.gov; 303-275-3166.

Flexible Wearable Electronics Use Body Heat for Energy

This thermoelectric harvester has the material quality of rigid devices inside a flexible package.

North Carolina State University, Raleigh, North Carolina

Interest in wearable electronics for continuous, long-term health and performance monitoring is rapidly increasing. The reduction in power levels consumed by sensors and electronic circuits, accompanied by the advances in energy harvesting methods, allows for the realization of self-powered monitoring systems that do not have to rely on batteries.

For wearable electronics, thermoelectric generators (TEGs) offer the unique ability to continuously convert body heat into usable energy. For body harvesting, it is preferable to have TEGs that are thin, soft, and flexible. Unfortunately, the performance of flexible modules reported to date has been far behind that of their rigid counterparts. This is largely due to lower efficiencies of the thermoelectric materials, electrical or thermal parasitic losses, and limitations on leg dimensions posed by the synthesis techniques.

A flexible thermoelectric energy harvester was developed that has the potential to rival the effectiveness of existing power wearable electronic devices, using body heat as the only source of energy. The thermoelectric harvester provides the material quality of rigid devices, yet provides similar or better efficiency. Flexible electronics offer superior contact resistance — or skin contact — as well as the ergonomic and comfort considerations to the device wearer.

Liquid metal in the flexible thermoelectric device allows for self-healing — rigid devices do not have this ability. (Mehmet Ozturk, NC State University)

A key challenge to developing a flexible harvester is connecting thermoelectric elements in series using reliable, low-resistivity interconnects. A liquid metal of gallium and indium — a common, non-toxic alloy called EGaIn —

was used to connect the thermoelectric "legs." The electric resistance of these connections is very low, which is critical since the generated power is inversely proportional to the resistance — low resistance means more power.

Using liquid metal also adds a self-healing function. If a connection is broken, the liquid metal will reconnect to make the device work efficiently again. Rigid devices are not able to heal themselves. Future work will focus on improving the efficiencies of these flexible devices by using materials and techniques to further eliminate parasitic resistances.

For more information, contact Mehmet Ozturk at mco@ncsu.edu; 919-515-9594.

Device for and Method of Computer Intrusion Anticipation, Detection, and Remediation

National Security Agency, Ft. George G. Meade, Maryland

Initially, relatively powerful computers were constructed as unique mainframes operated by larger corporations on isolated networks. Then, computers with modest amounts of computing power were made available to individuals as standalone personal computers. The computing power of personal computers and the applications for which they could be used were increased by networking them with other computers throughout the world using ancillary devices (e.g., servers, routers, links, switches, hubs, etc.). An arrangement into which computer and ancillary devices are configured is called a topology. There are many different types of topologies (e.g., bus, ring, star, tree, mesh, etc.).

Networking over a public network is less secure than an isolated network due to the accessibility of a network by a hacker. Typically, a hacker inserts software (malicious code or malware) into a computer network to not only provide incorrect data, but to influence, or take control of, the command and control structure of the network.

Prior art intrusion detection systems monitor computer networks or systems for attempts to load malware onto a computer, or violations of network security policies. Examples of malware include computer viruses, ransomware, worms, Trojan horses, spyware, and rogue security software. Three types of malware detection methods are currently being used: signature-based methods, anomaly-based methods, and protocol analysis methods.

These systems have a very narrow view into intrusion attempts, and are either backward-looking or use a fiction about average computer network traffic or benign computer activity. Therefore, there is a need for a computer security device and method that not only takes a wider view of intrusion detection, but also addresses the issue of malware that has successfully avoided detection and is operating on a computer.

This invention enhances electronic network security in the same way that radar improved weather forecasting — by providing advanced information to experts who can then determine what, if any, protective action must be taken.

This technology anticipates network intrusion attempts, detects actual attempts, and detects both existing and new malware. Improving on existing technology, the system remedies intrusions by changing network topology, countering computer traffic associated with the various phases of intrusion, and countering the source of the computer traffic. Intrusion attempts are considered broadly, in the context of a wide range of information over a longer period of time, and over many dimensions (space, intrusion-attempt choreography, type of actor, and number of actors).

The method provides electronic network security by establishing a network topology, including multiple devices, where the network includes a command and control layer and a transport layer. The command and control layer is changeable by the transport layer, and vice versa. All phases of an intrusion attempt are monitored to anticipate an intrusion, prevent an intrusion, and remedy a successful intrusion. An assessment of the threat is made in multiple dimensions. The topology of the network may be changed in accordance with the threat assessment.

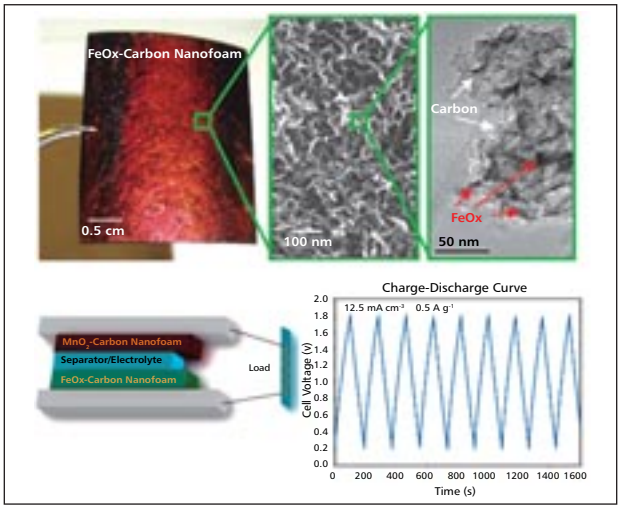
For more information, contact the National Security Agency Technology Transfer Program Office at tech_transfer@nsa.gov; 866-680-4539.

High-Energy-Storage Capacitor

Applications include hybrid-electric systems, bridge and/or backup power, and energy recovery.

Naval Research Laboratory, Washington, DC

A method was created for electroless deposition of conformal ultrathin (<20 nm) metal oxides on the high-surface-area walls of commercial carbon nanofoam papers, typically 0.1–0.3 mm thick. The resulting ultrathin metal oxides rapidly take up and release electrons and ions, thereby storing energy at 300–600 Farads per gram of oxide, while the carbon nanofoam paper serves as a three-dimensional current collector and defines a pre-selected porous electrode architecture.



Nanoscale metal oxide coatings on 3D carbon nanoarchitectures.

The high surface-to-volume ratio of oxide-painted carbon nanofoam enables footprint-normalized capacitances of 1–10 F·cm^{-2} addressable within tens of seconds — a time scale of relevance for hybrid electric vehicles. Pairing MnOx–carbon nanofoam with FeOx–carbon nanofoam yields an energy-storage device with an extended operating voltage in mild aqueous electrolytes (~2 V). This device provides technologically relevant energy and power density, while also being low-cost, safe to operate, and environmentally benign. Device-ready electrode structures exhibit up to 10-fold increased electrochemical charge storage.

The combination of high-performance electrode materials and aqueous electrolytes results in energy-storage devices that are composed of inexpensive components, safe to operate, environmentally friendly, and relevant in energy and power density.

For more information, visit the NRL Technology Transfer Office at www.nrl.navy.mil/techtransfer.

Flexible, Printable Electronics for Sensor Arrays

This new 3D-printed device responds to mechanical stresses by changing the color of a spot on its surface.

Massachusetts Institute of Technology, Cambridge, Massachusetts

Printable electronics — flexible circuitry that is deposited on some type of plastic substrate — has been a major area of research for decades. But the ability to print the substrate itself greatly increases the range of devices the technique can yield.

The choice of substrate limits the types of materials that can be deposited on top of it. Because a printed substrate could consist of many materials interlocked in intricate, but regular patterns, it broadens the range of functional materials that printable electronics can use. Printed substrates also open the possibility of devices that, although printed as flat sheets, can fold themselves up into more complex, three-dimensional shapes.

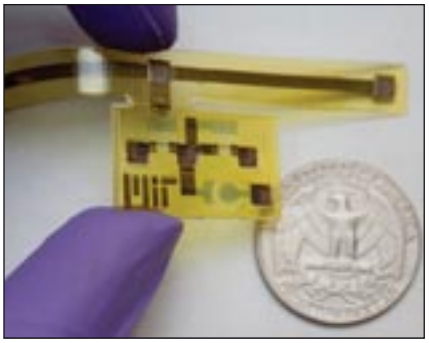


Figure 1. The new device responds to mechanical stresses by changing the color of a spot on its surface. (Subramanian Sundaram)

Researchers have designed and built a device that responds to mechanical stresses by changing the color of a spot on its surface. This technology demonstrates the feasibility of flexible, printable electronics that combine sensors and processing circuitry, and can act on their environments. The device was inspired by the golden tortoise beetle (or goldbug), an insect whose exterior usually appears golden, but turns to reddish-orange if the insect is poked or prodded; that is, mechanically stressed.

The new device is approximately T-shaped, but with a wide, squat base and an elongated crossbar (Figure 1). The crossbar is made from an elastic plastic, with a strip of silver running its length; electrodes were connected to the crossbar's ends. The base of the T is made from a more rigid plastic. It includes two printed transistors and what the researchers call a "pixel" — a circle of semiconducting polymer whose color changes when the crossbars stretch, modifying the electrical resistance of the silver strip (Figure 2).

The transistors and the pixel are made from the same material — the transistors also change color slightly when the crossbars stretch. The effect is

more dramatic in the pixel because the transistors amplify the electrical signal from the crossbar. Demonstrating working transistors was essential because large, dense sensor arrays require some capacity for onboard signal processing.

The researchers used a custom 3D printer with two different print heads — one for emitting hot materials and one for cool — and an array of ultraviolet light-emitting diodes. Using ultraviolet radiation to "cure" fluids deposited by the print heads produces the device's substrate. A copper and ceramic heater was added to deposit the semiconducting plastic. The plastic is suspended in a fluid that's sprayed onto the device surface, and the heater evaporates the fluid, leaving behind a layer of plastic only 200 nanometers thick.

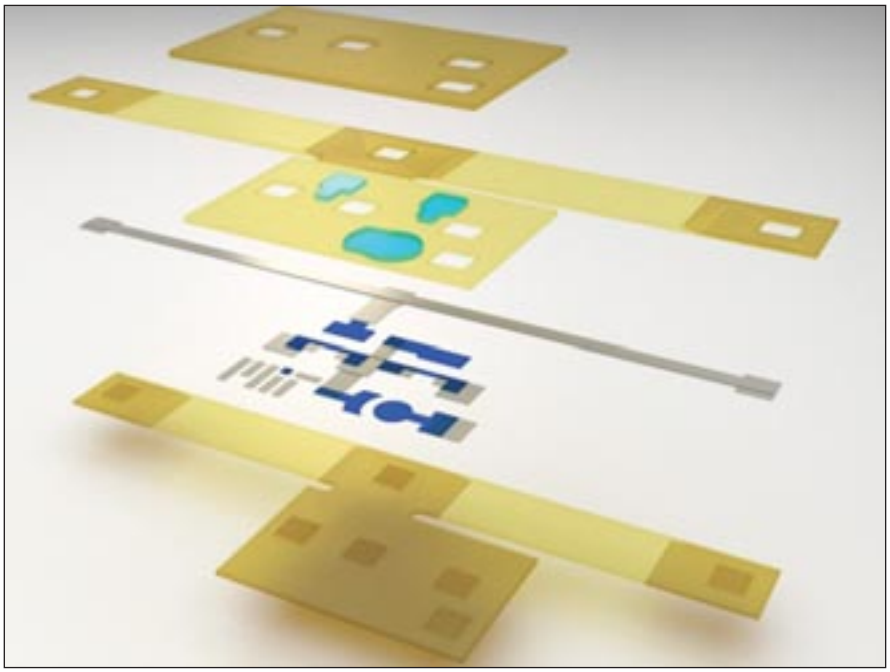


Figure 2. The components that make up the printable device. (Subramanian Sundaram)

In a standard transistor, there is an insulator between the gate and the semiconductor to prevent the gate current from leaking into the semiconductor channel. The transistors in the new device instead separate the gate and the semiconductor with a layer of water containing a potassium salt. Charging the gate drives potassium ions into the semiconductor, changing its conductivity. The layer of saltwater lowers the device's operational voltage, so that it can be powered with an ordinary 1.5-Volt battery.

For more information, contact Abby Abazorius at abbya@mit.edu; 617-253-2709.

Manufacturing & Prototyping

Interim, In-Situ Additive Manufacturing Inspection

This method enables real-time inspection of printed parts in aerospace, automotive, and medical applications.

Marshall Space Flight Center, Alabama

Researchers at NASA's Marshall Space Flight Center have developed a novel method for interim, in-situ dimensional inspection of additively manufactured parts. Additive manufacturing processes currently have limited monitoring capabilities, offering users little to no options for mitigating the high levels of product and process failures.

This technology uses both infrared (IR) and visual cameras to allow users to monitor the build in real time, and correct the process as needed to reduce the time and material wasted in parts that will not meet quality specifications. The technology is especially useful for the in-process inspection of a part's internal features (e.g., fluid channels and passages) that cannot be easily inspected once the print is complete. The technology has the potential to enable the implementation of a closed-loop feedback system, allowing systems for automatic real-time corrections.

The technology combines different types of cameras strategically placed around the part to monitor its properties during construction. The IR cameras collect accurate temperature data to validate thermal math models, while the visual cameras obtain highly detailed data at the exact location of the laser to build accurate, as-built geometric models. Furthermore, certain adopted techniques (e.g., single to grouped pixel comparison to avoid bad/biased pixels) reduce false positive readings.

Interim inspection improves the quality of parts with intricate internal features like these fuel channels.

NASA has developed and tested prototypes in both laser-sintered plastic and metal processes. The technology detected errors due to stray powder sparking and material layer lifts. Furthermore, the technology has the potential to detect anomalies in the property profile caused by errors due to stress, power density issues, incomplete melting, voids, incomplete fill, and layer lift-up. Three-dimensional models of the printed parts were reconstructed using only the collected data, which demonstrates the success and potential of the technology to provide a deeper understanding of the laser-metal interactions. By monitoring the print, layer by layer, in real time, users can pause the process and make corrections to the build as needed, reducing material, energy, and time wasted in non-conforming parts.

NASA's Technology Transfer Program offers commercial licensing agreements to ensure its pioneering research finds secondary uses that benefit the economy, create jobs, and improve quality of life. For more information about licensing, please contact Clark Darty at ronald.c.darty@nasa.gov, or 256-544-2728.

Optofluidic 3D Printing

Lawrence Berkeley National Laboratory, Berkeley, California

Optofluidic three-dimensional printing enables advancements and innovation in optical fibers and biomedical devices. This 3D printing approach uses axial plane optical microscopy (APOM) technology.

In this approach, axial light patterns are projected in the microfluidic resist flows by reversely utilizing the unique optical path of APOM. By changing the light pattern and maintaining constant photoresist flows, the projected ultraviolet light pattern becomes a cross-section of photopolymerized 3D structures. The result is a higher-resolution, higher-throughput technology than currently available.

Unlike traditional optical lithography-based 3D printing approaches, such as sterolithography (SL) and two-photon lithography (2PL), the optofluidic 3D printing technology allows high throughput with high resolution, and eliminates batch-sized processes that limit product size. Other optofluidic lithography approaches are free from batch-sized processes, but production is limited to 2D shapes, and channel wall materials are extremely limited.

Applications include structured optical fibers, biomedical devices, optoelectronics, and fiber photonics.

For more information, contact ipo@lbl.gov; 510-486-6467.

Diffusion-Bonded CVC SiC for Large UVOIR Telescope Mirrors and Structures

Marshall Space Flight Center, Alabama

In 2012, the National Research Council called for a new generation of astronomical telescopes to enable discovery of habitable planets, facilitate advances in solar physics, and enable the study of faint structures around bright objects by developing high-contrast imaging and spectroscopic technologies to provide unprecedented sensitivity, field of view, and spectroscopy of faint objects. Large-aperture, lightweight mirrors for UV, Optical and IR (UVOIR) telescopes answer this need. NASA requires low-cost, ultra-stable, large-aperture, normal incidence mirrors with low mass-to-collecting-area ratios. Potential UV/optical missions require 4- to 8- or 16-meter monolithic or segmented primary mirrors with active/passive alignment and control of normal-incidence imaging systems with <10 nm RMS surface figures.

In all cases, the most important metric for an advanced optical system (after performance) is affordability or areal cost (cost per m^2 of collecting aperture). Current normal incidence space mirrors cost $4 to $6 million per m^2 of optical surface area. Trex's Phase I research effort seeks a cost reduction for precision optical components by 5 to 50 times, to less than $1 million to $100,000 per m^2.

The labor, schedule, risk, and cost drivers for the large-aperture glass (ULE), metallic (beryllium), and ceramic (zerodur and silicon carbide) mirrors of modern times are machining, lightweighting, and polishing. Concerning the latter, one of the hidden costs of large-diameter mirror polishing is the iterative metrology process of polish, measure, polish, measure, until requirements are achieved. These costs amplify as the diameter of the mirror increases, and the required surface figure error and surface finish of the mirror decrease. For instance, a single 1.5-meter-diameter lightweight ULE primary mirror for the EUV telescope of a high-altitude balloon experiment costs as much as $10 million.

Current silicon carbide telescope technology is limited by the obtainable surface figure accuracy of reaction-bonded silicon carbide (RB-SiC), thermal stability, and CTE (coefficient of thermal expansion). Trex CVC SiC surpasses RB-SiC in all relevant material properties, including achievable surface figure accuracy.

Trex, in collaboration with Advanced Bonding Technology (ABT), has developed a hybrid joining process whereby CVC SiC components are bonded together to make large optical assemblies or complex structures with the same thermal performance as the base SiC material — a type of additive manufacturing. No additives, adhesives, or bonding agents are used to affect bonding that would influence CTE or elastic modulus of the joint region. This technology will enable cost-

effective production of multimeter mirror assemblies by substantially polishing simple CVC SiC plate structures, then bonding the plates together using various support structures. This same approach can be used to build telescope structures (e.g., Surrier truss or optical benches).

ABT developed a hybrid joining process whereby two or more CVD SiC articles (not to be confused with Trex CVC SiC) can be bonded together without the use of bonding agents or additives to produce a bond with the same thermal performance as the base SiC material. Component SiC parts are pre-machined to the desired dimensions and fixtured in a manner so as to yield the desired final structure. Normal high-temperature furnaces are used to facilitate the bond. Early feasibility demonstrations for a CVC SiC solid-state bonding process clearly showed the capability to make large complex mirrors and structures from small, simply shaped, and easily manufactured parts (i.e. additive manufacturing). The CVC SiC bonding technology will be competitive with glass and beryllium mirrors where the requirement for ultra-stability exists.

Low-cost, lightweight, dimensionally stable SiC mirrors have use in complex telescopes for astronomy, imaging, and remote sensing applications, including optical instruments/telescopes that enable imaging, surveillance, and reconnaissance missions for police and paramilitary units, firefighters, power and pipeline monitoring, search and rescue, atmospheric and ocean monitoring, imagery and mapping for resource management, and disaster relief and communications. The dual-use nature of complex telescopes will bring affordability to national defense missions as well.

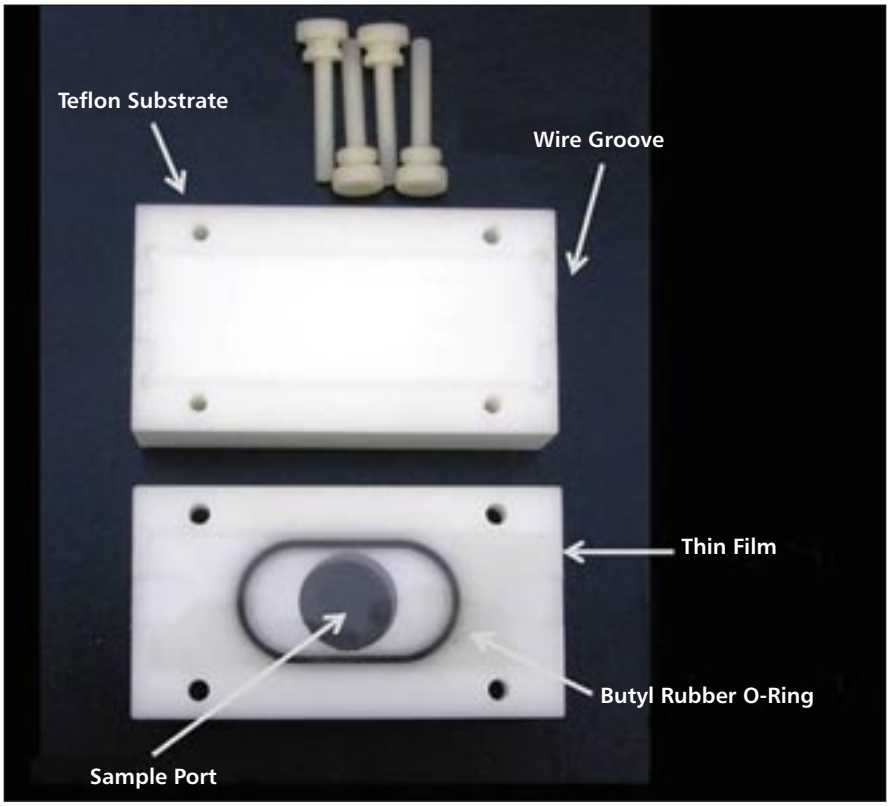
This work was done by Lauren Bolton, Bill Goodman, and Fred Styer of Trex Enterprises Corp. for Marshall Space Flight Center. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact Clark Darty at Ronald.C.Darty@nasa.gov.*** *MFS-33377-1*

Sample Holder for Evaluating Thin Film Sensor Materials in Gaseous Environments

Thin film technology is used for a wide variety of applications, including optics, coatings, electronics, and sensors.

John F. Kennedy Space Center, Florida

Thin film gas sensors are small, lightweight, and relatively easy to operate; however, the testing of these thin film gas sensors is difficult in harsh environments due to the exposure of critical components to the harsh environment. A need exists for the ability to test thin film gas sensor materials for their response to analytes of interest in a variety of environments, including harsh environments. Currently, a sample holder does not exist that will



The thin film sensor material sample holder includes a two-part Teflon housing and a sample port with butyl rubber o-ring.

allow the testing of thin film gas sensor materials in harsh environments. Many of the thin film gas sensors require electrical and mechanical connections in order to operate. Harsh environments tend to degrade many of these connections, compromising sensor performance and shortening sensor lifetime. A sensor holder that provides exposure of the thin film sensor material to the harsh environment, while protecting the electrical and mechanical connections, is needed. The advantages of such a sample holder are that the sensors can be used in a wider range of environments (temperature, humidity, etc.), and a wider range of analytes can be evaluated (hydrazine, ammonia, hydrogen, etc.).

A thin film sensor material sample holder was developed. All components of the holder are made of inert materials, providing excellent resistance to most chemicals. Teflon is widely known for its chemical resistance. Butyl rubber has excellent resistance to many harsh chemicals, including hydrazine, methanol, hydrogen fluoride, acetone, and nitric acid.

The thin film sensor material sample holder is comprised of the following components: two-part Teflon housing (substrate), four Teflon screws, and butyl rubber o-ring. The two-part Teflon housing was designed as follows. The housing was grooved for thin film placement and wire feedthrough. Next, the sample port was designed with butyl rubber o-ring, providing approximately 7.5 cm^2 sample area. The two-part Teflon housing is joined using four Teflon screws.

In the current embodiment, the thin film sample is placed in the sample holder, the wire leads are placed in the wire groove, and the two-part housing is joined using the Teflon screws. The sample holder is then attached to a sample chamber with a receptacle matching the sample port on the holder. The sample chamber can be filled with any analyte of interest. The atmosphere in the chamber can be changed at any time, providing the ability to sample a wide variety of environmental conditions (various temperature/humidity/analyte combinations).

This work was done by Tracy Gibson and Steven Parks of ASRC Aerospace for Kennedy Space Center. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact KSC-DL-TechnologyTransfer@mail.nasa.gov.***
KSC-13534

Method for Inflating Uniformly Stiff Tubular Booms

Applications include ultra-lightweight aircraft, structural and insulation material, mobile housing, and portable stretchers for remote use.

Marshall Space Flight Center, Alabama

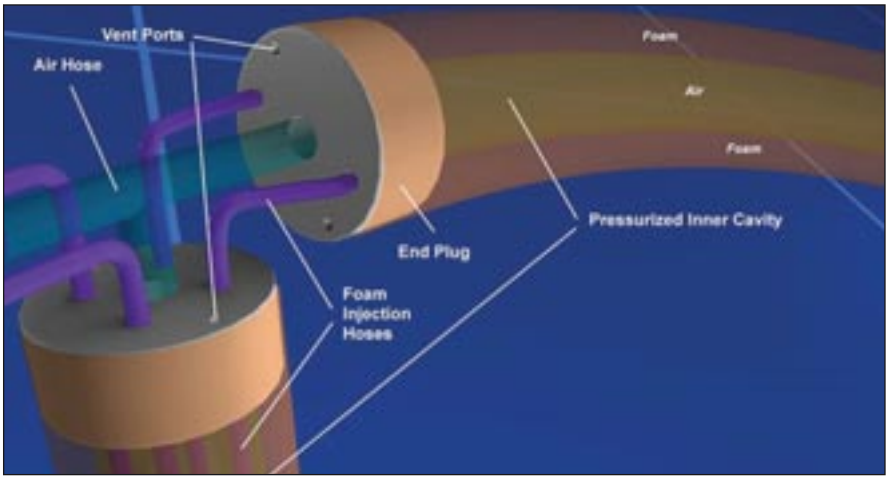
NASA's Marshall Space Flight Center (MSFC) developed a foam-rigidized, inflatable, tubular space boom that can be transported, deployed, and inflated at remote locations. The lightweight device consists of an inner and outer sleeve and, in its non-pressurized state, can be accordion-folded into a small storage canister. This allows for simple and compact transportation at a low cost.

The boom has a unique gas venting mechanism, allowing excess air and gas bubbles that form during the foam injection to escape without affecting the end product's hardened shape. The technology was initially created to build light, rigid structures for in-space applications, but can be used in other environments due to its naturally portable design, low weight, and low packaging volume requirements. Given its tubular shape, multiple boom structures can be combined to create complex structures such as a tripod, wall, or large rectangular prism.

The tubular boom has already been trialed and tested. Several articles have been fabricated at MSFC and tested for deployment, foam injection, and structural properties. The device consists of an inner bladder and an outer sleeve. These can be constructed with several materials, including polyimide film or a robust fabric with polymer lining. The tube includes two ends that are capped by lightweight polymer end plugs. The front-end plug has two or more input ports, and the back-end plug has two or more output ports. The first input leads to the internal bladder, where pumped-in air creates a core pressure. The second input leads to the outer sleeve, where liquid foam is injected and hardens.

As the foam enters, outputs at the back of the structure serve two purposes. First, they enable any residual air that remains in the outer sleeve to escape once the injection begins. Second, they vent any trapped gas formed while the foam cures, allowing the material to fill the tube and create a uniformly stiff structure. Once this process is finished, the internal pressure is released, and the boom is operational. The boom is thus able to retain its rigid structure without the need to sustain any internal pressure. Scalability is a major benefit of this technology, given that the boom diameter, wall thickness, and foam density can be customized for specific design requirements.

NASA's Technology Transfer Program offers commercial licensing agreements to ensure its pioneering research finds secondary uses that benefit the economy, create jobs, and improve quality of life. For more information about licensing, please contact Clark Darty at ronald.c.darty@nasa.gov or 256-544-2728.



Foam is injected between the inner and outer polyimide sleeves, while the inner cavity is pressurized. After the foam cures to rigidity, pressure is released, and the boom holds its shape.

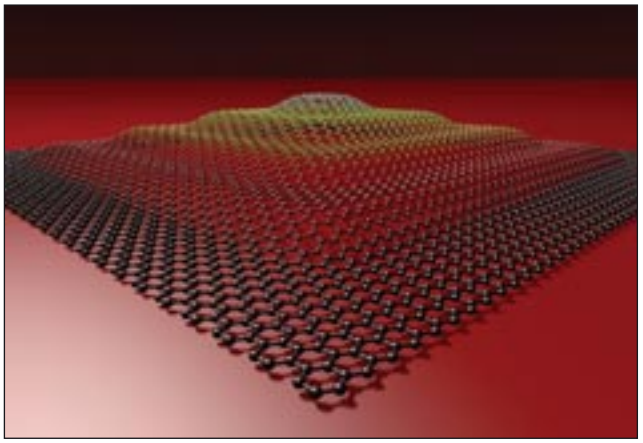
Forging Graphene into Three-Dimensional Shapes

Laser light is used to make 3D graphene objects.

Academy of Finland, Helsinki, Finland

Graphene is a relative to graphite, which consists of millions of layers of graphene, and can be found in common pencil tips. Since graphene was isolated in 2004, researchers have learned to routinely produce and handle it. Graphene can be used to make electronic and optoelectronic devices such as transistors, photodetectors, and sensors.

A process was developed that enables graphene, a single-atom-thin layer of carbon, to be forged into three-dimensional objects using laser light. A pyramid with a height of 60 nm — about 200 times larger than the thickness of a graphene sheet — was fabricated using the process. The pyramid was so small that it would easily fit on a single strand of hair.



A pyramid made from graphene. A similar structure was made experimentally by using laser irradiation in a process called optical forging.

The optical forging technique resembles forging metals into 3D shapes with a hammer. In this case, a laser beam is the hammer that forges the graphene into 3D shapes. The technique is fast and easy to use, and does not require any additional chemicals or processing.

When the irradiated graphene was first examined, researchers expected to find traces of chemical species incorporated into the graphene, but there were none. After more careful inspection, it was concluded that it was purely structural defects, rather than chemical doping, that were responsible for such changes on the graphene.

The novel 3D graphene is stable and has electronic and optical properties that differ from normal 2D graphene. Optically forged graphene can help in fabricating 3D architectures for graphene-based devices.

For more information, contact Mika Pettersson at mika.j.pettersson@jyu.fi; +358 50 310 9969.

Piezoelectric Actuator with Dual Horns Separately Controllable to Drive Miniature Vehicles Along a Single Axis

The technology enables miniature vehicles to operate in extreme environments for space, military, and industrial uses.

NASA's Jet Propulsion Laboratory, Pasadena, California

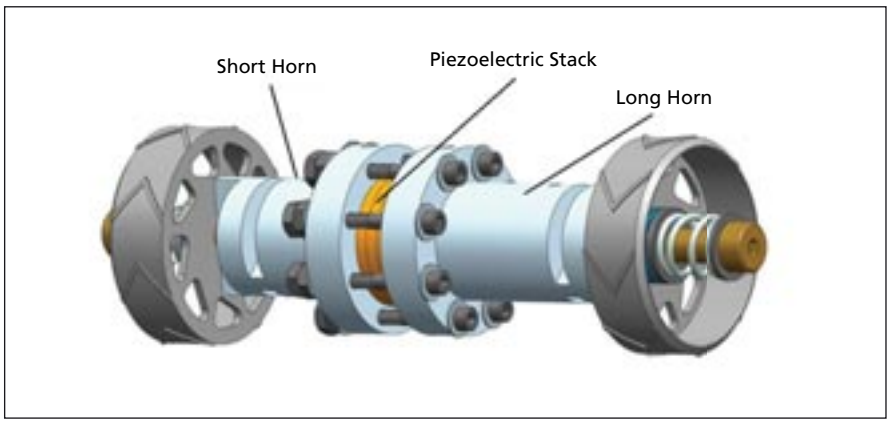
Actuators are a critical driver of all the mechanisms used in space, and improvements of their operation mechanism enhance mission capabilities. The disclosed invention is a new type of actuator that simultaneously drives dual mechanisms (e.g., rotors, wheels, etc.) at opposite sides of a piezoelectric stack using the generated vibrations. The actuator consists of dual-sided horns and is capable of operating ratcheting mechanisms through walls.

The problem that was addressed is the need to drive miniature vehicles through walls while operating along a single axis and using a single motor. The use of more than one actuator that drives each of the two wheels on the opposite sides, or the use of a gear train, requires greater mass and complexity due to the need to use motors on each wheel and have additional drive electronics.

The actuator was designed using a piezoelectric stack as a transducer to produce vibrations, and rather than a horn on one side and a backing on the other, the stainless steel backing used for pre-stressing the stack was replaced with a second horn. Thus, the pre-stress backing was converted to an additional actuator on the other side of the transducer. Further, the dual-horn actuator was designed based on the piezo-ratcheting motor, providing actuation on both sides of the piezoelectric stack. This design allows rotation of wheels with no moving parts besides the rotors.

The two horns are not made identical, allowing steering capability where the use of different driving frequencies leads to changing the relative speed of the wheels along the drive axis. Also, the horns are designed to be sufficiently similar to allow operating them well within the same range of frequencies, while causing one to outperform the other. By controlling the frequency, the direction of travel of a rover driven by these horns is controlled. The piezoelectric stack was made of lead zirconate titanate (PZT) with multiple steel backing plates and clamping screws.

This work was done by Yoseph Bar-Cohen, Stewart Sherrit, Xiaoqi Bao, Mircea Badescu, Phillip E. Walkemeyer, and Grayson T. Adams of Caltech for NASA's Jet Propulsion Laboratory. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov.***



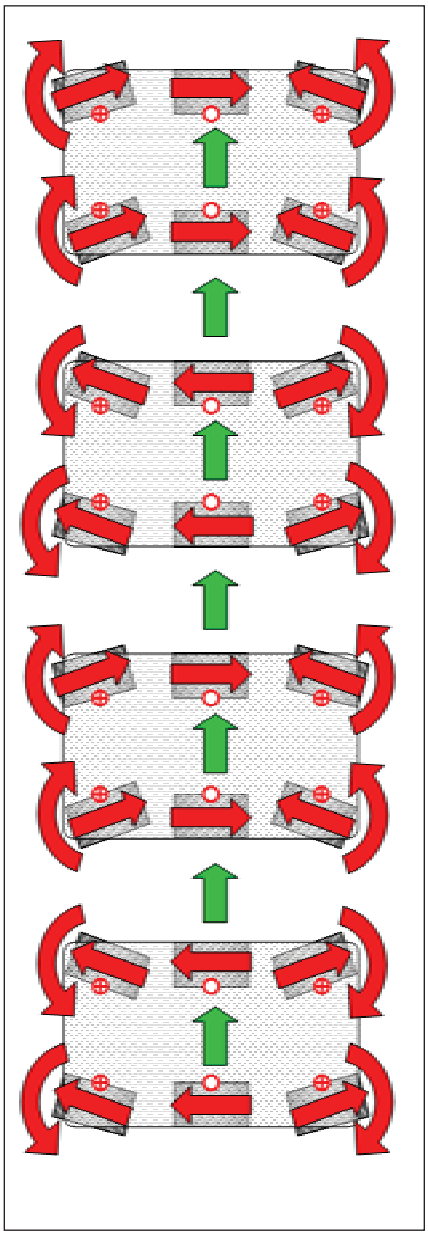
The dual-horn actuator was designed on a piezo-ratcheting motor, providing actuation on both sides of the piezoelectric stack. This design allows rotation of wheels with no moving parts besides the rotors.

Crab Crawl Maneuver for Independently Steerable Wheeled Platforms

This method enables a mobile robot to go sideways when it does not have a transverse steering capability.

Lyndon B. Johnson Space Center, Houston, Texas

An industrial-class excavator was developed for use on the Moon and perhaps on Mars. The model mobility platform uses Ackerman Steering with active drives on all six wheels, and steering on the corners. A faulty sequence of wheel steering and driving commands resulted in undocumented behaviors in a simulation and rendering program that appear to have actual applicability to surface operations. Quite by accident, it was discovered that by applying power and steering to the wheels in a complex pattern, the excavator could move laterally, hard to starboard. The intended command was "reverse," and the execution was a seemingly random



The Crab Crawl maneuver of sideways propulsion.

turning and driving of all of the simulated six wheels. The faulty behavior was employed to remove the robotic platform when it was stuck on rocks, and enabled the platform to "scoot" sideways, successfully disentangling from the rocks. The method drove the wheels in the direction of the intended motion, while steering them in a sweeping motion, and the apparent motion resembles swimming.

In the figure, the green arrows depict the robotic vehicle's direction of motion, while the red arrows depict the direction of driving wheels at the surface, and the sweep or steering motion applied to the steering motors. This alternating steerage of the driving wheels clears the vehicle of protruding obstacles. Ultimately, the long-term solution was to increase the torque available to the drive wheels.

This may not be practical with a platform deployed at a distant location, so the Crab Crawl maneuver may be worth further investigation as a hardware feature.

This work was done by a team lead by Gary Rodriguez of sysRAND Corporation for Johnson Space Center. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact jsc-techtran@mail.nasa.gov.***
MSC-25012-1

Continuous Diagnostic System Predicts Industrial Robot Faults

This early warning system for industrial robots notifies operators of potential problems.

Saarland University, Saarbrücken, Germany

Robots in production lines work with micrometer precision, unless a component fails. If, for example, the linear actuator used to precisely position a car body in front of an assembly robot is damaged, the robotic arm will no longer be able to position the car door exactly. The result is a misaligned door.

A system was developed comprising intelligent sensors that continuously collect a wide array of measurement data from inside plant machinery, and compare the signal patterns against those for normal operating conditions. If the system detects a difference in the patterns that indicates a potential fault, it immediately notifies the equipment operator about what remedial measures should be taken. This helps engineers plan maintenance more effectively, and protects them from unpleasant surprises and unexpected production losses.

The system subjects robots to what is effectively a continuous medical checkup. The human equivalent would be equipping a person with an activity tracker, a continuous digital ECG, and

Researchers test the smart condition monitoring system on an electro-mechanical cylinder. (Oliver Dietze)

blood pressure monitor so their state of health could be analyzed at any time. The system enables operators to continuously visualize the current condition of industrial robots, and provide advanced warning of potential damage.

Sensors are installed inside the machines, and interact with each other and with existing process sensors. Industrial equipment will begin to make a different noise, or will vibrate or overheat, long before it actually fails. The trick is that the characteristic manner in which a machine hums or vibrates during normal operation is different than that observed when something has changed within the machine; these differences can be very subtle and undetectable to normal senses.

The sensors can detect these slight changes, and can assign them automatically to specific fault profiles. Signal patterns, such as the frequency of vibrations, alter during common damage or fault states. The research team examined the patterns in thousands of measurement datasets and identified those associated with particular types of damage or mechanical wear. That information is fed to the sensors, transforming them into smart devices that detect the signal differences on their own. This essentially eliminates the need for an external analyzer, as the system is able to perform the analysis itself.

The goal of the research is to develop a set of sensors and modules that will allow companies that operate industrial robots to put together a fitness check specifically tailored to the needs of their plant or equipment. The customized sensors can either be integrated into the machinery when it is being made, or can be retrofitted. Initially, the sensors spend their time collecting baseline data that reflects the normal operating state of the machine. Once that has been done, the system is ready to continuously compare the current operational data with those typical sensor signal patterns associated with incipient equipment failure or damage. The system can also be used for quality control purposes by analyzing whether production machinery was operating properly during a manufacturing process.

For more information, contact Dr. Andreas Schütze at schuetze@lmt.uni-saarland.de; +49 (0)681 3024663; or visit www.lmt.uni-saarland.de.

Health & Biotech

Smartphone Camera Measures Heart Health

California Institute of Technology, Pasadena, California

Currently, a 45-minute ultrasound scan is required to provide detailed information about heart health. Researchers have discovered a method by which a smartphone camera can noninvasively provide the same information.

By simply holding a smartphone to a patient's neck for a minute or two, the technique can infer the left ventricular ejection fraction (LVEF) of the heart by measuring the amount that the carotid artery displaces the skin of the neck as blood pumps through it. LVEF represents the amount of blood in the heart that is pumped out with each beat. In a normal heart, this LVEF ranges from 50 to 70 percent. When the heart is weaker, less of the total amount of blood in the heart is pumped out with each beat, and the LVEF value is lower. LVEF is a key measure of heart health — one upon which physicians base diagnostic and therapeutic decisions.

To test the smartphone app, clinical trials were conducted with 72 volunteers between the ages of 20 and 92 at an outpatient magnetic resonance imaging (MRI) facility. MRI is the gold standard in measuring LVEF, but is seldom used clinically due to its high cost and limited availability. LVEF is most commonly measured using an ultrasound machine during a procedure known as echocardiography; however, LVEF requires a trained technician, an expensive ultrasound machine, and up to 45 minutes of a patient's time.

The measurements made by the smartphone during trials had a margin of error of ±19.1 percent, compared with those done in an MRI. By way of comparison, the margin of error for echocardiography is around ±20 percent.

The app works because the walls of arteries are almost completely elastic — they expand and contract with each beat of the heart. That expanding and contracting can be measured and described as a waveform that encodes information about the heart. For the study, the team used an iPhone 5, but any smartphone with a camera will work. The technique could be developed to diagnose heart valve diseases like aortic stenosis, and coronary artery blockages.

For more information, contact Robert Perkins at rperkins@caltech.edu; 626-395-1862.

Independent Navigation for the Visually Impaired Using a Wearable, Vision-Based Feedback System

The system could be used in conjunction with, or as an alternative to, a cane to give visually impaired users more information about their environments.

Massachusetts Institute of Technology, Cambridge, Massachusetts

Automatic navigation systems have been developed previously to aid the visually impaired, but these devices have not been as reliable and easy to use as a cane — the type of metal-tipped cane that visually impaired people frequently use to identify clear walking paths. These canes, however, have drawbacks. First, the obstacles they come in contact with are sometimes other people. Second, they can't identify certain types of objects, such as tables or chairs, or determine whether a chair is already occupied.

Researchers have developed a new system that uses a 3D camera, a belt with separately controllable vibrational motors distributed around it, and an electronically reconfigurable Braille interface to give visually impaired users more information about their environments. The system could be used in conjunction with, or as an alternative to, a cane.

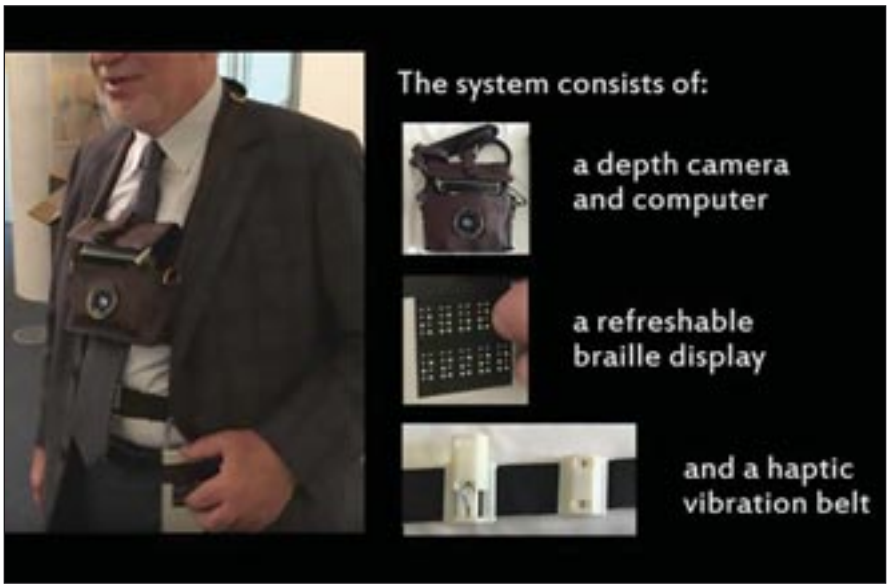
Tests were conducted with blind users who sought a device that did not infringe on their other senses, so the researchers chose not to use audio. They found that the one area of the body that is the least used for other senses is around the abdomen.

The system consists of a 3D camera worn in a pouch hung around the neck, a processing unit that runs proprietary algorithms, the sensor belt that has five vibrating motors evenly spaced around its forward half, and the reconfigurable Braille interface worn at the user's side.

The key to the system is an algorithm for quickly identifying surfaces and their orientations from the 3D camera data. The researchers experimented with three different types of 3D cameras that used three different techniques to gauge depth, but all produced relatively low-resolution images — 640 pixels by 480 pixels — with both color and depth measurements for each pixel.

The algorithm first groups the pixels into clusters of three. Because the pixels have associated location data, each cluster determines a plane. If the orientations of the planes defined by five nearby clusters are within 10 degrees of each other, the system concludes that it has found a surface. It doesn't need to determine the extent of the surface or what type of object it's the surface of; it simply registers an obstacle at that location and begins to buzz the associated motor if the wearer gets within 2 meters of it.

Chair identification is similar, but a little more stringent. The system needs to complete three distinct surface identifications



New algorithms power a prototype system for helping visually impaired users avoid obstacles and identify objects. (Photo courtesy of the researchers)

in the same general area, rather than just one; this ensures that the chair is unoccupied. The surfaces need to be roughly parallel to the ground, and they have to fall within a prescribed range of heights.

The belt motors can vary the frequency, intensity, and duration of their vibrations, as well as the intervals between them, to send different types of tactile signals to the user. For instance, an increase in frequency and intensity generally indicates that the wearer is approaching an obstacle in the direction indicated by that particular motor. But when the system is in chair-finding mode, a double pulse indicates the direction in which a chair with a vacant seat can be found.

The Braille interface consists of two rows of five reconfigurable Braille pads. Symbols displayed on the pads describe objects in the user's environment; for instance, a "t" for table or a "c" for chair. The symbol's position in the row indicates the direction in which it can be found; the column it appears in indicates its distance. A user adept at Braille should find that the signals from the Braille interface and the belt-mounted motors coincide.

In tests, the chair-finding system reduced subjects' contacts with objects other than the chairs they sought by 80 percent, and the navigation system reduced the number of cane collisions with people loitering around a hallway by 86 percent.

For more information, contact Abby Abazorius at abbya@mit.edu; 617-253-2709.

ECTemp™

Army Medical Research and Materiel Command, Fort Detrick, Maryland

The health and fitness industry strives to provide customers with the best technologies and features available to help users train in the right zone and duration for best results. Core body temperature is a factor in this analysis, but has been largely unavailable due to the invasiveness of accurate sensors, and the variation between skin temperature and core body temperature. An accurate estimate of core body temperature is also valuable for occupations in which heat stress and heat illness are risk factors. Because of the difficulty in directly measuring core body temperature, a practical alternative was developed.

In most applications, a person's initial core body temperature can be assumed as 98.6 °F at the person's resting heart rate. From that or an alternative starting point, ECTemp utilizes a mathematical process to calculate the change in core body temperature based on heart rate time series data; no temperature sensor is needed. Field testing has demonstrated accurate temperature estimates using ECTemp even when operated 24/7 for several days. With this new capability, a worker can be alerted if and when a predicted core body temperature exceeds a predetermined threshold, thus avoiding potential heat illness or undue stress.

The easy-to-implement algorithm can be incorporated in commercial heart rate monitors to provide a value-added feature. Core body temperature can be displayed in real time on many devices such as wrist-worn displays, smartphones, or heads-up displays. ECTemp can be used during activity for real-time data and/or post-activity for analysis.

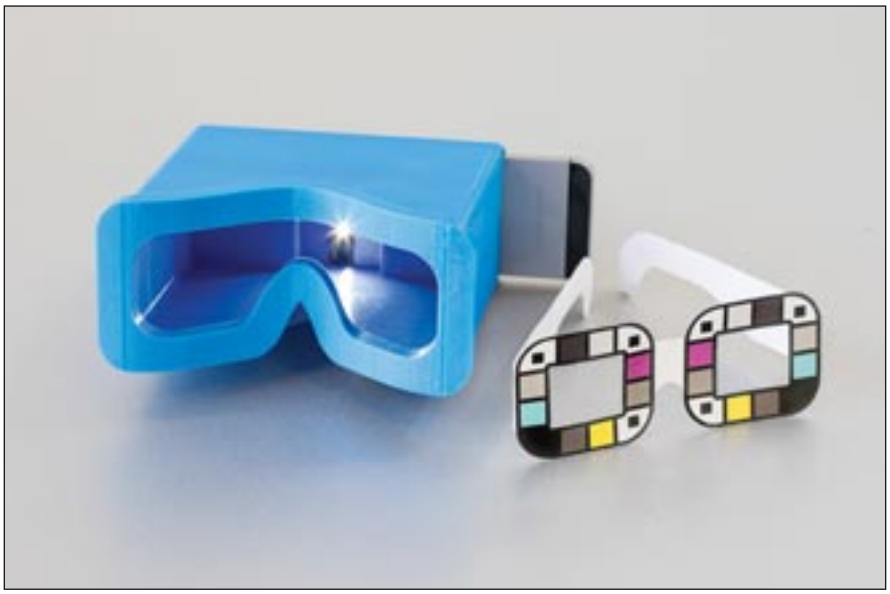
For more information, contact USArmy.Detrick.MEDCOM-USAMRMC.List.ORTA@mail.mil; 301-619-0033.

App Enables Smartphone Camera to Screen for Pancreatic Cancer

This technology detects signs of jaundice, an early detector of pancreatic cancer and other diseases.

University of Washington, Seattle, Washington

The five-year survival rate of pancreatic cancer is one of the worst — 9 percent — in part because there are no obvious symptoms or non-invasive screening tools to catch a tumor before it spreads. One of the earliest symptoms of pancreatic cancer, as well as other diseases, is jaundice, a yellow discoloration of the skin and eyes caused by a buildup of bilirubin in the blood. The ability to



Two different accessories were tested for BiliScreen: a 3D-printed box to control lighting conditions, and glasses that help the app calibrate colors. (Dennis Wise/University of Washington)

detect signs of jaundice when bilirubin levels are minimally elevated — but before they're visible to the naked eye — could enable an entirely new screening program for at-risk individuals.

An app was developed that could allow people to easily screen for pancreatic cancer and other diseases by snapping a smartphone selfie. BiliScreen uses a smartphone camera, computer vision algorithms, and machine learning tools to detect increased bilirubin levels in a person's sclera, or the white part of the eye. In an initial clinical study of 70 people, the BiliScreen app — used in conjunction with a 3D-printed box that controls the eye's exposure to light — correctly identified cases of concern 89.7 percent of the time.

The blood test that doctors currently use to measure bilirubin levels — which is typically not administered to adults unless there is reason for concern — requires access to a healthcare professional, and is inconvenient for frequent screening. BiliScreen is designed to be an easy-to-use, non-invasive tool that could help determine whether someone ought to consult a doctor for further testing. Beyond diagnosis, BiliScreen could also potentially ease the burden on patients with pancreatic cancer who require frequent bilirubin monitoring.

In adults, the whites of the eyes are more sensitive than skin to changes in bilirubin levels, which also can be an early warning sign for hepatitis or the generally harmless Gilbert's syndrome. Unlike skin color, changes in the sclera are more consistent across all races and ethnicities. Yet, by the time people notice the yellowish discoloration in the sclera, bilirubin levels are already well past cause for concern.

BiliScreen uses a smartphone's built-in camera and flash to collect pictures of a person's eye as they snap a selfie. The team developed a computer vision system to automatically and effectively isolate the white parts of the eye, which is a valuable tool for medical diagnostics. The app then calculates the color information from the sclera — based on the wavelengths of light being reflected and absorbed — and correlates it with bilirubin levels using machine learning algorithms.

To account for different lighting conditions, the team tested BiliScreen with two different accessories: paper glasses printed with colored squares to help calibrate color, and the 3D-printed box that blocks out ambient lighting. Using the app with the box accessory led to slightly better results.

Next steps include testing the app on a wider range of people at risk for jaundice and underlying conditions, as well as continuing to make usability improvements — including removing the need for accessories like the box and glasses.

Watch a video demo of the system on Tech Briefs TV at www.techbriefs.com/tv/BiliScreen. For more information, e-mail uwbiliscreen@gmail.com.

ScienceOrganizer: A Scientific Knowledge Management and Remote Experimentation Tool

Ames Research Center, Moffett Field, California

The ScienceOrganizer system was designed to facilitate the work of geographically distributed NASA science teams by supporting the organization, administration, documentation, and execution of science projects and missions. The capabilities of ScienceOrganizer include the ability to conduct and monitor working experiments; locate, utilize, and publish experimental datasets; develop and share scientific software models; store scientific project information; document the scientific process; and co-visualize scientific data. Users access ScienceOrganizer through an intuitive Web-based interface that enables them to upload, download, and centrally organize project information including data, documents, images, and scientific records associated with laboratory and field experiments.

ScienceOrganizer features a "threaded" information repository that maintains explicit links capturing semantic relationships among information resources. Threading enables users to locate, track, and organize inter-related pieces of scientific data. Additional capabilities include the ability to collaboratively view and annotate images in the repository, and to initiate experiments and collect data from remote instruments.

This work was done by Richard Keller of Ames Research Center and Michael Compton of Recom Technologies, Inc. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact 1-855-627-2249 or ARC-TechTransfer@mail.nasa.gov.*** *ARC-15069-1*

Knowledge Preservation Management

Y-12 National Security Complex, Oak Ridge, Tennessee

The Knowledge Preservation Management (KPM) system allows for the capture, management, and Web-based access of manufacturing operations information. KPM also captures retirees' knowledge via transcript-enabled videotaped interviews, and with video data-mining advanced search capabilities. Access to this information is available directly to the operator on the factory floor or in an office, providing a complete, on-demand knowledge management and training capability.

KPM captures and manages video, animation, process maps, work instructions, and any other associated information digitally. It allows for information configuration control and long-term archival of a knowledge base, and can be access-controlled.

The efficient, transcript-based, jump-to-frame video data mining and retrieval system can be used by manufacturing and industrial companies, government agencies, and research and development entities.

For more information, contact the Office of Technology Commercialization and Partnerships at OTCP@y12.doe.gov; 865-241-5981.

Desktop Status

Goddard Space Flight Center, Greenbelt, Maryland

The purpose of the Desktop Status application is to collect processor, memory, and storage usages of a computer running the Microsoft Windows 7 operating system, and record these data with time stamps to files at a user-defined time interval. A graphical user interface (GUI) captures users' inputs and displays them on a plot for informational purposes. Microsoft Windows' Task Manager program, a prior art that is included in the Windows operating system, has the capability to collect processor and memory usages and display them on a graph, but cannot write the raw data values to files with time stamps at regular time intervals.

The Desktop Status software is a standalone application developed using the C/C++ programming language with Qt for the integrated development environment (IDE), Qt libraries, and Microsoft Visual Studio 2013 or MinGW for the compiler. The Desktop Status application is generally built using the model-controller-view design pattern by grouping the source code into two categories: logic and graphics. The logic portion is responsible for collecting usage of each existing processor, memory, and storage space using Microsoft Windows API (application programming interface), time tagging them, and writing these to files at a user-defined time interval. It also passes the collected data to the graphics portion for displaying on a plot. The graphics portion contains a

scatter plot for displaying the system resource usages and a numerical spinner for specifying user-defined time intervals. A Network Countdown Time Protocol (NCTP) is used for time-synchronizing and displaying Earth and countdown times for informational purposes.

The Desktop Status application is unique due to the following capabilities combined into one standalone application: collecting the system resource usages on a Microsoft Windows 7 computer, graphical display for rendering data values, data recording, and using NCTP for timing synchronizing. The benefit of the Desktop Status application is to allow the user to obtain the system resource data in raw values for further analysis, such as generating a comprehensive graph for a report.

This work was done by Nathan Riolo of NASA Wallops Flight Facility for Goddard Space Flight Center. ***NASA is seeking partners to further develop this technology through joint cooperative research and development. For more information about this technology and to explore opportunities, please contact Scott Leonardi at Robert.S.Leonardi@nasa.gov.*** *GSC-17405-1*

Development of Automated Structural Health Monitoring for Composite Overwrapped Pressure Vessels

Composite overwrapped pressure vessels are becoming common in water filtration and automotive applications, as well as in fuel, SCUBA, and fire extinguisher pressurized tanks.

Lyndon B. Johnson Space Center, Houston, Texas

Virtually all NASA spacecraft use composite overwrapped pressure vessels (COPVs) to reduce the weight disadvantage of metal pressure vessels. However, these composite structures are more susceptible to damage than metal PVs, are difficult to inspect, have large burst pressure variability, and are susceptible to stress rupture when maintained at pressure. Over the past few years, NASA's Johnson Space Center (JSC) White Sands Test Facility (WSTF) has developed novel analysis methods that show promise for assessing the structural health of composite overwrapped pressure vessels. These methods and industry standard methods have been integrated into specialized software for automated analysis, thus significantly increasing throughput to the point where real-time assessments of structural health may be determined. Adaptive analysis methods have also been developed to provide modal analyses at specified points in a structure's life, including loading, unloading, and dwells. Together, these enhancements increase the utility and ease of use for acoustic emission testing.

Supporting the development of smart structures, including the "Smart COPV" project, this software is being phased through its current post-test analysis function into an *in-situ* structural health monitoring (SHM) tool. In simple terms, the adaptation transforms the technology from a difficult-to-understand measurement into the equivalent of a "check engine" light for a structure. If hazardous conditions are identified, crew will be alerted with instructions. Data may then be streamed to NASA JSC WSTF via the Tracking and Data Relay Satellite System (TDRSS) ground terminal adjacent to the facility for expert evaluation. If imminently hazardous conditions exist, the system may be configured to relieve a small amount of pressure for hazard mitigation.

Adaptive methods allow the software to analyze data per standard and proprietary methods automatically with little initial tuning. Pressure profiles are composed of load, unload, and dwell segments. This feature allows the software to perform segment-dependent modal acoustic emission analysis techniques automatically. Additionally, burst pressures may be predicted with good accuracy using proprietary methods developed at WSTF. Data from representative COPVs and tensile specimens were analyzed, producing trends that are advantageous to project burst pressures that are unique to each test article evaluated.

This work was done by Regor L. Saulsberry, Charles Nichols, Douglas Weathers, Jonathan M. Tylka, Kenneth L. Johnson, and Donald J. Roth of Johnson Space Center; and Jess M. Waller and Joshua Simmons of Jacobs Technology Inc. ***This software is available for use. To request a copy, please visit https://software.nasa.gov/software/MSC-25421-1.***

APPLICATION BRIEFS

Injection Molding Service Saves Time and Money for Spring Manufacturer

Proto Labs
Maple Plain, MN
www.protolabs.com

As products get smaller, their components need to follow suit, and springs are no exception. In a variety of industrial applications, flat-wire wave springs are replacing traditional coil springs. The reason is that a wave spring is half the height of a coil spring, yet can often perform the same job as the coil spring — deflect the same amount of weight under the same load — saving valuable space and, in most cases, weight as well.

Smalley Steel Ring — a Lake Zurich, IL-based wave spring manufacturer that serves aerospace, automotive, oil and gas, medical, and other industries — offers more than 10,000 standard rings and springs, as well as custom designs in diameters ranging from 4 to 3,000 mm (0.165 to 120 inches). While the capabilities of wave springs are becoming more widely known, the company has long equipped its sales force with a small demonstration device — a handheld "comparator" — that clearly shows the relative size and performance of a wave spring compared with a larger, but functionally equivalent coil spring.

Smalley's comparator, a sales demo device.

"Comparators have been a great way to demonstrate the advantages and benefits of wave springs," said Lane Persky, Smalley marketing manager. "But they were complicated and costly to manufacture, so we only made a small number of them to distribute to our salespeople."

Smalley would eventually turn to Proto Labs for help with this cost issue when, more recently, the company considered redesigning the comparator to reduce costs and, as Persky explained, "use them as 'giveaways' to prospective customers. We were looking to go from about 20 of the original comparators, which each cost about $100 to produce, to an initial run of 1,000 redesigned comparators at a target cost of about $1 each."

The project to design the new comparator was headed by Senior Research and Development Engineer Ben Moskalik, who noted that the original comparators each consisted of 23 parts, many of them individually machined or purchased. The most costly single part was a linear bearing that allowed smooth compression of the springs. Developers hoped that injection molding would allow multiple parts to be combined and a number of individual fasteners eliminated, simplifying production and significantly reducing costs.


Proto Labs' injection molding service reduced the number of components needed for Smalley's new comparator. The new design required just seven pieces; the original comparators each consisted of 23 parts.

The new comparator, as designed, would require just seven parts. Smalley engineers created initial prototypes on an in-house 3D printer, but while the resulting parts approximated the shape of the designed components, the printing process was slow, the resin was nothing like the material that would be used for molded parts, and it tended to absorb moisture, affecting its performance. In addition, the rough

surface texture resulting from the layering process caused moving parts to bind instead of sliding smoothly, hampering functionality testing of the new device. Smalley sought out assistance from Proto Labs.

The same CAD models that had been used to print parts in-house were uploaded to ProtoQuote, Proto Labs' online quoting and design for manufacturability (DFM) analysis engine. ProtoQuote flagged potential moldability problems including a couple of features in which walls were too thick for effective molding, and would be subject to cosmetic defects like sink.

Based on Proto Labs' DFM analysis, a redesigned CAD model with thinner walls was resubmitted. The new CAD models raised no red flags with ProtoQuote, and met Smalley's requirements without the moldability problems. With a few additional iterations by Smalley engineers — some post heights were reduced — the CAD model was uploaded for production of injection molds.

One of the important decisions Smalley had to make was the choice of resin for the molded parts. Proto Labs sent resin sample "tiles" to help with choices of feel, finish, and color. With input from Proto Labs, the company chose Lustran ABS 433, a general-purpose grade of ABS that has a high impact resistance and glossy appearance. The hard material and glossy finish allowed elimination of the separate linear bearing in the original comparator, and reduced friction between moving parts.

The completed comparator requires just seven parts: three molded parts made by Proto Labs, a wave spring, two retaining rings made by Smalley, and a purchased coil spring that matches the performance specs of the wave spring, which was chosen for comparison purposes. Smalley ordered 1,000 injection-molded pieces from Proto Labs that the company assembled into the new comparators.

This article was written by Greg Kagan, contributing writer for Proto Labs, Maple Plain, MN. For more information, visit ***http://info.hotims.com/65857-122****.*

New on the MARKET

Product of the Month

WinSystems, Arlington, TX, released the PPC65B series IP65-rated panel PC in a thin, fanless design with an operating temperature range from -20 to +70 ºC. The panel PC offers a rugged design for extreme environments and industrial IoT applications. The PCs accommodate panel and VESA mounting configurations; when mounted properly, the sealed front bezel provides protection against ingress from dust and moisture for industrial control applications. They support Linux and Windows 10 operating systems, use the 1.9-GHz Quad-Core Intel® Atom™ processor, and include up to 8 GB of RAM. High-resolution graphics at 1024 × 768 and 1280 × 1024 are accessed via a five-wire resistive touchscreen. The rugged design also incorporates a SATA controller with 2.5" HDD/SSD and input power of 12-24V DC. Optimal connectivity and I/O for embedded systems is achieved through two Gigabit Ethernet ports, a USB 2.0 port, and a USB 3.0 port. The series also includes options for expansion with RS-232/422/485 and USB.

For Free Info Visit http://info.hotims.com/65857-120

Product Focus: Test Instruments

Infrared Thermometer

OMEGA Engineering, Norwalk, CT, offers the OS768-LS laser infrared thermometer that verifies surface temperatures with a non-contact micromachined thermopile, and a type K thermocouple input. It features an infrared measurement range to 1800 °C (3272 °F), dual laser points for the target spot size, a high/low temperature audible alarm, and USB function. The non-contact infrared measurement is suited for non-reachable situations to provide instant readings, and the thermocouple is suited for high-precision measurement of contact surfaces, gases, and liquids.

For Free Info Visit http://info.hotims.com/65857-100

Oscilloscope

Saelig, Fairport, NY, introduced the Cleverscope CS448 isolated, high common-mode rejection ratio (CMRR), four-channel, 200-MHz, 14-bit oscilloscope. It was designed to measure high-voltage, fast-slew-rate signals such as those in a full or three-phase power electronic switching bridge. It includes a built-in, isolated, 65-MHz signal generator to provide stimulus signals, and eight isolated, 100-Mb/s logic inputs to measure digital control signals. Two of the scopes can be slaved to make an 8-channel oscilloscope with coherent sampling.

For Free Info Visit http://info.hotims.com/65857-101

Data Recorder

The SLICE IP68 data acquisition system from DTS, Seal Beach, CA, captures physical signals in challenging environments such as shock, water, and dust exposure. It measures 60 × 60 mm for embedding in most test articles. The device features onboard signal conditioning, supporting external sensors such as bridge and IEPE transducers for gathering acceleration, displacement, strain, pressure, temperature, and voltage measurements. Data direct-writes to 16-GB internal flash memory.

For Free Info Visit http://info.hotims.com/65857-102

Power Calibrator

Yokogawa Meters & Instruments Corp., Newnan, GA, announced the LS3300 AC power calibrator that produces a wide range of AC power outputs for the calibration of power meters and other power measuring instruments. The device can calibrate AC voltage, current, and power, as well as test both phase difference and power factor. Features include the ability to output currents of up to 62.5 A for extended periods of time. Three units can be synchronized to output currents of up to 180 A.

For Free Info Visit http://info.hotims.com/65857-103

PXI Remote Control Modules

National Instruments, Austin, TX, offers PXI remote control and bus extension modules with PCI Express Gen 3 connectivity. The PCIe-8398 host interface card communicates over a transparent PCI Express Gen 3 ×16 link to either the single-port PXIe-8398 or dual-port PXIe-8399 remote control module to offer up to 13.7 GB/s of sustained data throughput. A second port on the PXIe-8399 can be used to daisy-chain additional chassis, enabling direct interface of multiple PXI Express chassis to a single host computer.

For Free Info Visit http://info.hotims.com/65857-104

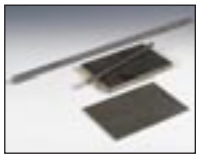
PXIe Chassis

Marvin Test Solutions, Irvine, CA, announced the GX7100e, GX7205, and GX7215 PXI Express chassis for general-purpose and high-bandwidth test applications. The chassis offer a combination of PXIe, hybrid slots, and PXI-1. The three models support integral smart functions such as system power supply, slot temperature, and fan speed control/monitoring, as well as PXI trigger mapping.

For Free Info Visit http://info.hotims.com/65857-105

Glass-Ceramic

Aremcolox 502-400 machinable glass-ceramic from Aremco Products, Valley Cottage, NY, is used to produce thermally insulative and high dielectric components and fixtures used in electrical and electronics applications to 700 °F. Features include electrical resistance; compressive and flexural strengths of 40,000 and 15,000 psi, respectively; dielectric strength of 400 Volts per mil; dielectric constant of 6.9 at 1 MHz; and thermal conductivity of 2.88 Btu-in/hr-ft^2-°F (0.41 W/m-K).



For Free Info Visit
http://info.hotims.com/65857-107

USB Data Acquisition

DATAQ® Instruments, Akron, OH, released model DI-2108-P USB data acquisition (DAQ) system with 16-bit ADC resolution, programmable gain, and ChannelStretch™ channel expansion technology. It provides eight analog input channels, each with 2.5-, 5-, and 10-Volt unipolar and bipolar programmable measurement ranges. It provides seven digital ports, each configurable as an input or a switch. Two ports can be programmed as counter and frequency measurement inputs.

For Free Info Visit
http://info.hotims.com/65857-108

Handheld Laser Scanner

The ModelMaker H120 handheld laser scanner from Nikon Metrology, Brighton, MI, incorporates a blue low-speckle laser, Nikon optics, and a field-of-view width up to 120 mm. It features a point resolution of up to 35 µm and frame rate of more than 450 Hz, even when measuring materials such as carbon fiber, gloss black, reflective, or multi-colored parts. With 2,000 points per scan line, very small scratches and abrasions can be identified on a surface.

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COMSOL, Inc.

Free Info at http://info.hotims.com/65857-737

DC SOURCE/ CALIBRATOR SIMULATES THERMO-COUPLES

The Krohn-Hite Model 526 DC Source/Calibrator is used in thermocouple simulation as well as many other applications. Voltages from ±100nVdc to ±110Vdc can be output with a stability of ±5ppm along with currents from ±100nA to ±110mA. Resolution is 1ppm. The Model 526 is also a perfect replacement for the obsolete Analogic 8200. http://www.krohn-hite.com/htm/calibrators/PDFAD/526Data.pdf

Krohn-Hite

Free Info at http://info.hotims.com/65857-738

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Master Bond

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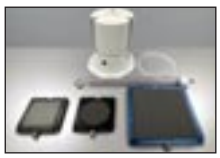

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FACILITY FOCUS

Naval Research Laboratory

The Naval Research Laboratory (NRL) began operations in 1923 as the United States Navy's first modern research institution, and it continues today as one of the Navy's premier R&D resources. NRL's early 20th Century founders knew the importance of science and technology in maintaining naval power and preserving national security.

During the years since World War II, NRL has conducted basic and applied research pertaining to the Navy's environments of Earth, sea, sky, space, and cyberspace. Investigations have ranged widely, from monitoring the Sun's behavior, to analyzing marine atmospheric conditions, to measuring parameters of the deep oceans. Detection and communication capabilities have benefitted from research that has exploited new portions of the electromagnetic spectrum, extended ranges to outer space, and provided a means of transferring information reliably and securely, even through massive jamming.

Submarine habitability, lubricants, shipbuilding materials, firefighting, and the study of sound in the sea have remained steadfast concerns. Recent explorations have been within the fields of virtual reality, superconductivity, biomolecular science and engineering, and nanotechnology.

NRL has pioneered naval research into space, from direction of the Vanguard project (America's first satellite program), to inventing and developing the first satellite prototypes of the Global Positioning System (GPS). Today, NRL is the Navy's lead laboratory in space systems research, as well as in fire research, tactical electronic warfare, microelectronic devices, and artificial intelligence.

NRL operates as the Navy's full-spectrum corporate laboratory, conducting a broadly based multidisciplinary program of scientific research and advanced technological development directed toward maritime applications of new and improved materials, techniques, equipment, systems and ocean, atmospheric, and space sciences and related technologies.

Sailors assigned to Mobile Diving and Salvage Unit (MDSU) 1 conduct a safety walk-through before recovering the test vehicle for NASA's Low-Density Supersonic Decelerator (LDSD). The LDSD project investigates and tests breakthrough technologies for landing future robotic and human Mars missions, and safely returning large payloads to Earth. (U.S. Navy photo: Chief Mass Communication Specialist John M. Hageman)

NRL is now focusing its research efforts on new Navy strategic interests in the 21st Century, a period marked by global terrorism, shifting power balances, and irregular and asymmetric warfare. While continuing its programs of basic research that help the Navy anticipate and meet future needs, NRL also moves technology rapidly from concept to operational use when high-priority, short-term needs arise for pathogen detection, lightweight body armor, contaminant transport modeling, and communications interoperability, for example.

Technology Milestones

In the late 1940s, NRL led in developing instruments and techniques for taking weather-related measurements. By 1952, NRL developed a balloon-borne meteorological station for collecting data on temperature, pressure, and humidity over remote ocean areas. Today, NRL's Monterey site is the only scientific center in the Navy wholly dedicated to atmospheric research, conducting research to provide local, regional, and global atmospheric analysis and prediction, as well as the development of automated weather interpretation systems to support Naval Operations; that is, the effect of atmospheric changes on naval communications and weapons systems.

The NAVSTAR Global Positioning System (GPS) Program is a Department of Defense program to provide precise navigation data to military and civilian users by means of a constellation of 24 satellites. NAVSTAR is based on NRL's TIMATION research program begun in 1964. NRL conceived the idea of the time-based navigational system, which led to the Global Positioning System.

NRL invented the first modern U.S. radar. The invention of radar and the developments that flowed from it are among the foundations of modern military power. Radar plays a major role in the operation of civilian transportation systems, weather forecasting, astronomy, and automation, among other uses. Before the development of radar, Navy ships could track other ships or aircraft only by using optical techniques, sound ranging, or primitive radio.

In 1937, NRL developed the first Identification Friend or Foe (IFF) system in the United States. Since 1979, NRL has collaborated with the Air Force and Army to develop new IFF systems, which are urgently needed to make efficient use of beyond-visual-range weapon systems.

NRL also has made extensive discoveries in materials science. In 1959, while researching chemical flame extinction, NRL scientists discovered a dry chemical agent still used globally for fire protection operations, and starting in the early 1960s, NRL fire suppression research led to one of the most far-reaching benefits to worldwide aviation safety: the development of aqueous film-forming foam for use in potentially catastrophic fuel fires.

NRL developed the Microassay on a Card (MAC), a portable, handheld immunoassay about the size of a credit card that can

A UH-1 Huey helicopter, equipped with a Navy-funded Autonomous Aerial Cargo/Utility System (AACUS) sensor suite, conducts integrated flight testing. The AACUS program is developing a capability that, when installed in existing rotary-wing aircraft, enables autonomous flight, obstacle avoidance, approaches, landings, and takeoffs to and from unprepared landing sites. (U.S. Navy photo by John F. Williams)

The Navy Sea Systems Command (NAVSEA) has funded the Navy Clothing and Textile Research Facility (NCTRF) to develop the next generation of protective gear for emergency responders to steam line ruptures aboard submarines. (U.S. Navy photo by John F. Williams)

detect a wide variety of substances in the environment. NRL's fiber-optic biosensor uses antibodies, lectins, and antibiotics on the surface of an optical fiber to detect environmental pollutants and hazardous chemical or biological materials.

NRL's explosive and contraband detector uses nuclear quadrupole resonance to detect nitrogenous explosives or narcotics carried in luggage, mail, small cargo, or on a person. The Lab's surface acoustic wave sensor system was developed to detect and identify gases, and is currently used to monitor hazardous chemical vapors, chemical warfare agents, potential fires, and environmental pollutants.

Current and Future Research

In April 2001, in a departure from traditional working relationships among Laboratory scientists, NRL established an Institute for Nanoscience to conduct multidisciplinary

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NRL researchers and Penn State University (PSU) developed autonomous soaring algorithms used to keep unmanned sailplanes aloft for sustained flight durations, a benefit aimed at improving the availability of 24-7 Information, Surveillance, and Reconnaissance (ISR) mission data. This image captures a view taken from a tail-mounted camera onboard the PSU aircraft. (Penn State photo)

research at the intersections of the fields of materials, electronics, and biology. While still belonging organizationally and performing research for their respective divisions, scientists may also be part of the Nanoscience Institute.

NRL has a long history of research and significant contributions in unmanned and autonomous systems dating back to the mid-1920s. NRL's Dragon Eye is an affordable, expendable, hand-launched, 5.5-pound miniature surveillance plane with the radar signature of a bird. Carried by U.S. Marines in a backpack, this airborne sensor platform provides small-unit reconnaissance, battle damage assessment, and threat detection capabilities. It has been deployed with the 1st Marine Expeditionary Force in support of Operation Iraqi Freedom.

In March of 2012, NRL opened the Laboratory for Autonomous Systems Research. This facility brings together scientists and engineers from diverse backgrounds to tackle common challenges in autonomy research at the intersection of their respective fields. The facility supports highly innovative multidisciplinary research in autonomous systems, including intelligent autonomy, sensor systems, power and energy systems, human-system interaction, networking and communications, and platforms. The Laboratory provides unique facilities, simulated environments (littoral, desert, tropical), and instrumented, reconfigurable high-bay spaces to support integration of science and technology components into research prototype systems.

NRL is providing improved capabilities in areas such as sensors, communications, and intelligence systems for homeland defense and the war on terrorism. NRL's Specific Emitter Identification technology identifies any radar by its unique characteristics with such a high degree of accuracy that the radar is "fingerprinted." In fact, it can distinguish between identical models produced off the same assembly line. The National Security Agency selected it as the national standard. Its uses go beyond that of traditional military requirements. Coast Guard vessels, naval warships, and aircraft use it to monitor the movement of materials used in weapons of mass destruction (WMD).

Three days after the September 11 terror attacks, NRL designed an interoperable communication infrastructure that provides assured communication capabilities to military and civilian authorities. The Infrastructure Linkage and Augmentation System (InfraLynx) allows first responders to communicate when local infrastructure is destroyed. It was deployed by the Office of Domestic Preparedness during the 2002 Winter Olympics in Salt Lake City and Super Bowl XXXVII. InfraLynx has also supported counter-terrorism training and WMD preparedness drills.

Work with NRL

As the Navy's corporate laboratory, NRL draws on the powerful resources of a combination of scientific expertise and modern facilities. It is the mission of the Technology Transfer Office (TTO) to facilitate the implementation of the NRL's innovative technologies in products and services to benefit the public. To carry out this mission, TTO engages with commercial entities to develop strategic partnerships, building a collaborative bridge between government and industry.

There are two primary mechanisms by which the NRL TTO transfers its technologies to the public sector: Patent License Agreements and Cooperative Research and Development Agreements (CRADAs).

NRL has an extensive portfolio of patents covering important technological developments in a wide variety of scientific and engineering disciplines. NRL is authorized by the Navy to negotiate licenses for the commercial use of NRL's patented technologies.

Visit ***https://www.nrl.navy.mil*** *for more information on NRL. Learn more about working with NRL by visiting the Technology Transfer Office at* ***https://www.nrl.navy.mil/techtransfer/.***

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Mineral Analyzer Shakes Answers Out of Soil and Rocks

Sample analysis technology on the Curiosity rover is used by industries from mining to medical.

On the Curiosity rover, a tool called CheMin (Chemistry and Mineralogy) is helping scientists determine what minerals make up the Martian landscape, and whether single-celled or more complex organisms could once have thrived there. CheMin sends an X-ray beam through tiny samples of Martian soil or rock, recording how the beam scatters as it bounces against atomic planes of the different minerals contained within. The technique, called X-ray powder diffraction (XRD), has been around for a long time, but the tools commonly used were not practical for a robotic mission millions of miles from the nearest human hands.

"To do powder diffraction and get good data, you need to have roughly a million grains of the same type within the volume you're analyzing," said Philippe Sarrazin, who was the lead developer of CheMin at Ames Research Center. Technicians would grind a fine powder with grains just 10 to 50 microns in diameter, press it into a flat cake between two pieces of plastic, and put it in a massive XRD machine. On Mars, however, everything relies on very precise motions and very heavy equipment.

The biggest problem was that to make the instrument smaller, the sample chamber also had to be smaller. But since traditional XRD still requires a million grains to get enough data points, that meant the grains needed to be even smaller as well. NASA engineers first considered making grains smaller than one micron in diameter. The task proved basically impossible: by the time you ground the material that finely, even if you could do so reliably on Mars, you'd ruin the crystalline structure you were attempting to analyze.

Then they stumbled onto a game-changing discovery. When you vibrate a bed of grains, it flows in a predictable, cyclical pattern. It's called granular convection, and it had been seen before, but no one had ever thought to apply it to XRD. The CheMin team realized this phenomenon could solve the problems they were encountering. Because they were able to see grains from so many different orientations, they could use fewer, bigger grains — about the texture of sand. When the drill operates on Mars, it creates samples that are about 150 microns and less. All the sample-handling instrument had to do was pour the dirt into a sieve and shake that into the CheMin sample chamber.

Sarrazin filed for a patent covering the vibration technique; shortly afterward, he left NASA to form his own company, inXitu, but his work on the instrument continued. Ames granted inXitu two Small Business Innovation Research (SBIR) contracts to pursue the project, which was now destined to travel to Mars on Curiosity. Although the vibration concept worked, there were still a number of practicalities to figure out, including how to vibrate the sample at high intensity without vibrating everything else at the same time. The design for CheMin was completed at Jet Propulsion Laboratory, and the instrument is successfully analyzing samples gathered during Curiosity's trek across Mars. Sarrazin was able to use the work he did for CheMin to create a product for his new company. inXitu's XRD mineral analyzer was small, easy to use, and extremely rugged, and the company could sell it at a fraction of the cost of other instruments.

(Left) NASA's Curiosity rover uses an XRD device called CheMin to analyze minerals in the Martian soil. The key innovation of CheMin was that it didn't require samples to be finely ground into powder; in fact, the rock grains need only to be small enough to fit through the screen installed on Curiosity (right), through which the rover funnels the samples it collects with its robotic arms.

In commercial mining, XRD can give detailed information about the minerals found on-site, which the geologist or mine manager can then use to make important decisions about the plan for the mine. The Terra portable, rugged device, based on technology used in CheMin, provides answers far more quickly than if samples must be sent back to a central laboratory.

His new design, which can be used in the field, requires the user to take a hammer and knock out a rock fragment; the hammer is then used to crush it. Then it's poured into the sample cell; the XRD analysis is a one-button operation. The unit can be used by anyone in the field, eliminating the need for a highly trained technician to perform the XRD analysis, or the long wait for a sample to be sent to a lab.

Olympus Scientific Solutions America (Waltham, MA) bought inXitu and now sells the XRD device in two models: TERRA and BTX II Benchtop. One of their largest markets is oil and gas exploration. By analyzing the minerals the drill is encountering, you can determine when you've hit the "pay zone" of oil or gas.

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Supplement to *Tech Briefs*

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ON THE COVER

One of the biggest challenges in applying optical thin-film coatings is maintaining accurate layer thickness. Variations in thickness affect all coatings, but any coating with a slope is more affected because the change in thickness will cause the slope to move, changing the transmission and reflection values. The way to combat that problem is to use an effective process monitoring system. To learn more, see the feature article on page 2.

(*Image courtesy of PG&O*)

Optical Monitoring System *Enables* Greater Accuracy In Thin-Film Coatings

The challenges in achieving greater accuracy in optical thin-film coatings, both historically and in today's coating processes, are many and deserve our scrutiny. The "old" way of designing and manufacturing coatings was to use a thin-film design software like TFCalc, which included analysis, optimization, results, optical data, and coating files. In this instance, one would create a design using high-, medium-, and low-index materials to come up with a theoretical design (Figure 1). The design of the coatings would be the easy part; the hard part comes in replicating the design thickness and the material indexes inside the coating chamber each and every time.

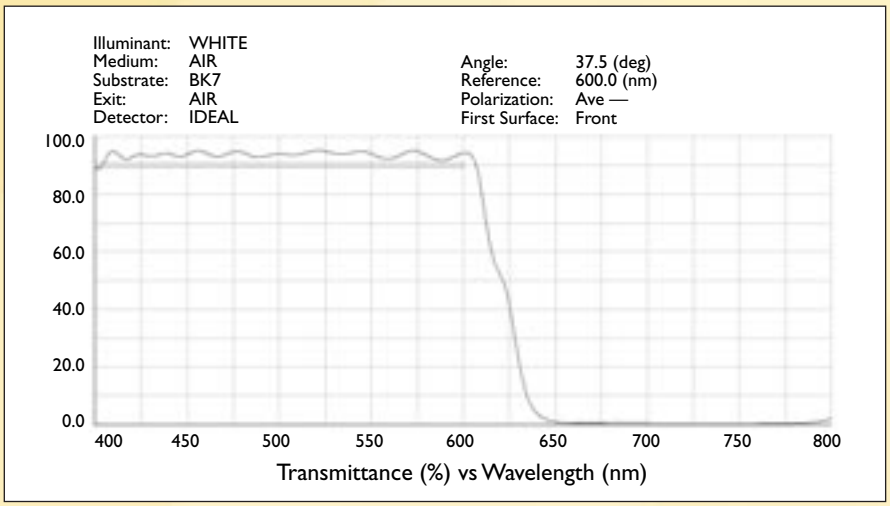

Figure 1. Graph shows optical design curve using TFCalc software.

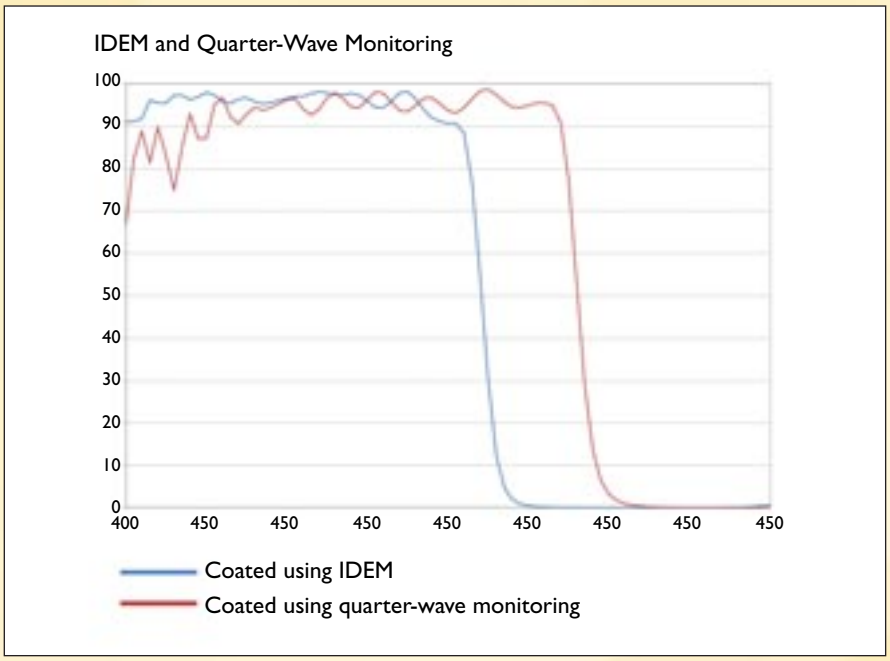

Figure 2. Red line indicates optical monitoring with overshoots using quarter-wave monitoring; the blue line is the coating curve using the new IDEM monitoring system.

All coatings are impacted when the layer thickness is not accurate. Variations in thickness affect all coatings, but any coating with a slope, such as a longwave pass (LWP) and/or shortwave pass (SWP), is often more affected by changes in thickness. Because the change in thickness will cause the slope to move, which in turn, causes the transmission and reflection values to change, it is essential to have an effective process monitoring system in place.

Historically, there have been two ways to monitor the layers when you coat them. One method is to use a crystal to monitor the physical thickness of your layer. The problem with using crystal monitoring is that crystals are very sensitive to temperature and pressure, and therefore, are only accurate to around ±5%. When you consider that most coatings can have as many as 50 layers, and you have an error window of ±5%, you can end up with a coating that is way out of specification.

The second method, and better choice, is to use a quarter-wave monitoring system with overshoots. Based on the layer thickness and work-to-monitor ratios, you can calculate how many quarter waves it would take to achieve the correct layer thickness. This technique is accurate to ±2%, yielding better results than crystal monitoring. However a factor of ±2% can still be problematic, especially over long runs.

Both of these traditional monitoring techniques have a fundamental shortcoming: There is no sure way of knowing if the index dispersion of your material remains the same as your design during the actual process of evaporating your material. If your material index is different, then your coating will not meet the specification.

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The new, real-time optical monitoring system that Precision Glass & Optics (PG&O) has implemented has the capability of calculating the thickness of each layer to within 1 nm of the design thickness. It also accurately shows you what the index dispersion is during the coating process, so you know if and when there is an issue. The new Eddy Company SpectraLock system is an in-situ, full-spectrum optical monitoring and rate control system that allows the production of single and multi-layered thin films with ultra-precision and accuracy that had been previously unattainable.

Index dispersion is the variation of refractive index of a material as a function of wavelength. The new monitoring system is based on this unique technology and is called "index dispersion enhanced monitoring," or IDEM. It produces optical coatings that precisely match the optical design every time, without iteration or error. It gives the user the ability to match the true index dispersion of each deposition material and the individual coating chamber characteristics, making it possible for the thin film design to match the actual coating produced (Figure 2).

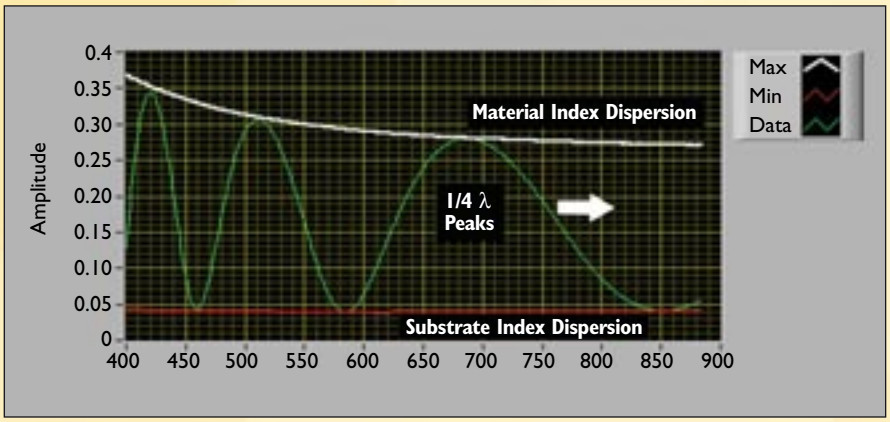

Figure 3. SpectraLock display during calibration process. (Graph courtesy of Eddy Company).

Figure 4. SpectraLock Controller and IDEM software screen capture during monitoring process.

Prior to this innovation, thin film design programs and optical coating systems have used standard materials reference table values for refractive index dispersion in the design and monitoring of the coatings. Unfortunately, the refractive index dispersion for each material in any given optical coating process deviates from the standards by a small amount.

As mentioned earlier, these small errors will multiply with each additional layer applied. In the past, in order to achieve successful results, it has required expert compensation by highly trained specialists. With the IDEM system in place, the coating thickness can be determined from zero up and the index dispersion can be seen from 1nm. In other words, as each optical coating is layered, the IDEM provides rate control and process monitoring throughout each layer.

How It Works

The new IDEM is an automated, full-spectrum optical monitoring system that provides calibration of the exact refractive index dispersion for each material substrate and process you use (Figure 3). Before fabrication of the designed coatings begins, a 2000 nm - 3000 nm calibration layer is deposited on witness chips and sample substrates for each coating process that is to be used. The refractive index dispersion of the coating on each witness chip is measured and the curves are stored for future use. Then the substrate samples are measured to determine the monitor-to-work ratio for each material. These process index dispersions and monitor-to-work ratios are translated and loaded into both the thin film design software program and the SpectraLock controller for precise coating thickness control at each layer (Figure 4).

This is the first commercially available instrument that is capable of measuring in-situ the broadband optical index dispersion produced by the coating machine.

Accuracy With Multiple Coating Layers

Wayne Rodgers, president of Eddy Company, notes, “When developing the IDEM system we were concerned about how many layers we could put on a chip with relative accuracy. So we put a 5-layer coating using 1-layer per chip, 2-layers per chip, 3-layers per chip, up to all 5 layers on one chip. We also ran two interrupted layer coatings. We interrupted it by removing the USB connec-

tion between the computer and the monitor…everything shut down. We reconnected and restarted the process. When we measured these, we got a little bit of a surprise. Prior to the full-spectrum monitoring, we've used single-wavelength monitoring and we've usually gotten within 1 percent from run to run. We assumed that this 1 percent was caused basically by the monitor-to-work ratio change. After these runs and we saw 0.19 percent or 0.2 percent deviation, we then realized the main cause of deviation was the monitoring technique and probably a 0.2 percent is somewhere in the monitor-to-work ratio problems."

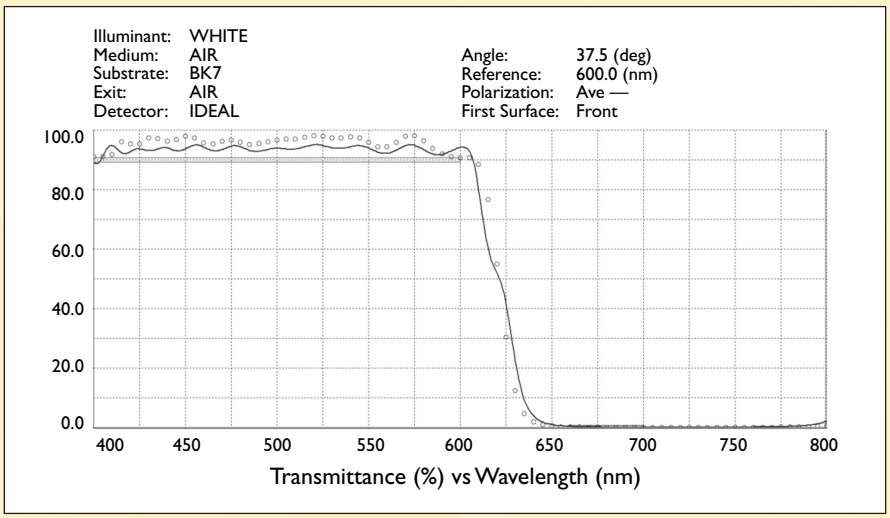

Figure 5. Graph illustrates improved accuracy after the IDEM system was installed at PG&O. The original design curve is shown, with the actual coating data imported, represented by circles and superimposed over the design.

Mr. Rodgers continues, "With this system of index dispersion and the correct monitor-to-work ratio, we can make a 37-layer design and just plain coat it; we measure, and it matches the design. There are no test runs necessary, there's no advantage to even doing a test run, because during the monitoring process we can see if the index dispersion of the material has changed from drift, or other factors."

Conclusion

With the new capabilities available using the index dispersion enhanced monitoring system, the company can now produce optical thin films that perfectly match the design programs and accurately predict the films that the coating chambers produce with optical thickness monitoring and control from 1 nm to over 5,000 nm (Figure 5). This makes the new optical thin films about 10x more precise than ever before.

This article was written by Dan Bukaty, Jr., President, Precision Glass & Optics (PG&O®). For more information, contact Mr. Bukaty at danjr@pgo.com or visit ***http://info.hotims.com/65857-200.***

Line Scan Cameras

What Do They Do? Where Are They Needed?

Area array and line scan cameras are each suited for unique machine vision applications. Area array cameras, for all intents and purposes, are "conventional" cameras that use sensors with two-dimensional pixel arrays. The square or rectangular shaped sensor captures an image in a single pass with the resulting image having a width and height corresponding to the number of pixels on the sensor, for example, 640x480. Because of this, area array cameras are ideal for machine vision tasks where objects are small or have approximately the same size in both dimensions. However, the size of PCBs, LCD panels, and wafers has increased beyond the speed, accuracy, and resolution capabilities of many area array cameras. Line scan cameras offer a better solution.

Line-By-Line

A line scan camera uses a single row of light-sensitive pixels that image across the object, line-by-line, accompanied by high intensity lighting. Resolution is specified in the horizontal axis since the achievable resolution in the vertical direction will depend on the clock rate of the camera and the speed of the web. A completed image is built by stitching together the lines, much like a fax machine. Because only a one-dimensional correction needs to be applied, line scan cameras are much easier to correct for lens shade, photo response non-uniformity (PRNU), or dark signal non-uniformity (DSNU), than an area array camera.

Line scan pixels accumulate photoelectric charges relative to the light from the object imaged onto that pixel. Next, a readout register amplifies, adjusts, and digitizes the charges, all while the next row of pixels is being exposed. The maximum rate at which exposure and readout can occur is the "line rate," calculated in kilohertz (kHz) — the number of lines exposed in one second. In production, the faster an object is moving, the higher the required line rate. To avoid under- or over-sampling an object, a programmable encoder, often connected to a conveyor or web, measures speed and precisely synchronizes the camera in pulses. A predetermined number of lines of the image are then stitched together to form a frame that is analyzed with software. Any defects are recorded on roll maps.

Line scan cameras excel at producing a flat image of cylindrical objects, at imaging very large objects with high resolution and at producing images of objects in continuous movement past a fixed point, such as parts on an assembly line or web applications. Line-scan applications include paper, rolls of metal, fiber, railway inspection, solar cells, textiles, pharmaceuticals, semiconductors, and postal sorting. Another advantage is that the cameras can fit into tight spaces, for example when they must see through rollers on a conveyor to acquire images of the bottom of a part.

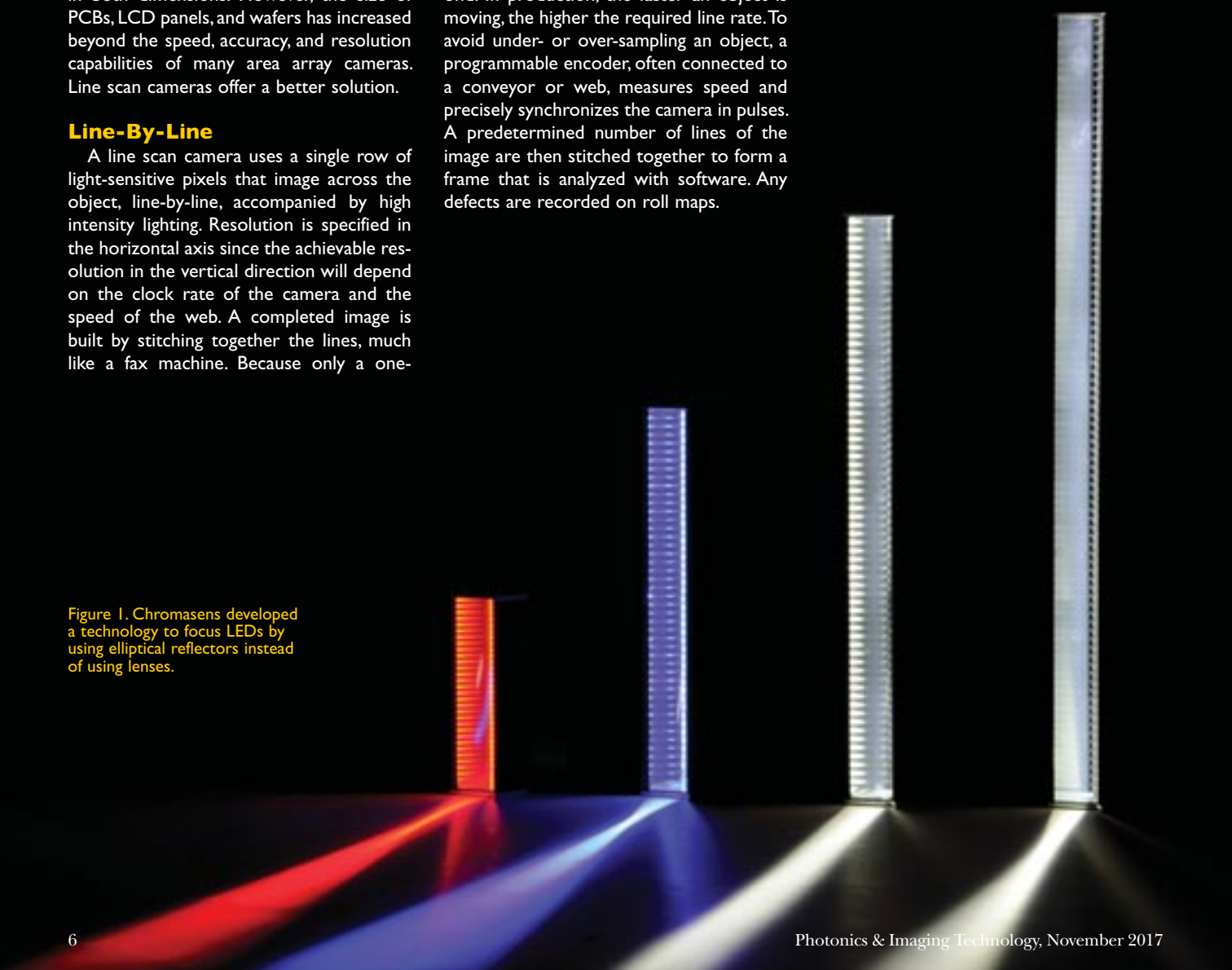

Figure 1. Chromasens developed a technology to focus LEDs by using elliptical reflectors instead of using lenses.

In certain applications demanding both high scan rates and high contrast however, the sensitivity of line scan cameras using single x1 linear sensors can fall short. Increased sensitivity requires multi-line scan cameras. Dual-line scan designs feature two parallel arrays of pixels, capturing twice the number of photons and doubling sensitivity. To improve sensitivity further, time-delay integration (TDI) is frequently incorporated into line scan cameras. TDI-based cameras have several vertical integration stages, resulting in the capture of multiple exposures of the same object. Integrating the output from these stages increases sensitivity.

Color Inspection

Single-line monochrome line scan cameras have linear sensors consisting of multiple pixels in a x1 configuration. To obtain a color image from a single-line scan imager, a linear R-G-B-R-G-B filter can be applied to the sensor with the pixels merged to create a color image. Unfortunately, this approach produces an interpolated image with lower resolution.

A "trilinear" approach calls for each of three arrays to capture one primary color simultaneously but at somewhat different locations on a moving object. The channels are then combined to form a full color image. Spatial correction compensates for the separation — the first and second arrays are buffered to match the third. The downside of using only three channels is relatively low spectral resolution. Manufacturers have improved the performance with image-based color measuring approaches that enable color to be measured on the whole surface of the object, not just on one spot, as with traditional spectrophotometers.

For truly accurate color inspection, line scan cameras with more than three color channels are required. Modern multispectral line scan cameras feature 6 – 12 spectral channels in the 360 – 960 nm range. Multi-channel imaging provides accurate spectral and color output on varying substrates such as paper, plastics, films, and foils.

Color imaging may no longer be enough, however, for inspection where specific wavelengths are required that are either outside the visible spectrum or in between the RGB color bands. Multispectral cameras can be used from near IR up to 960 nm in that case.

Figure 2. Chromasens truePIXA camera offers a combination of high speed and spectral color measurement for each pixel.

3D Line Scan Inspection

Over the past decade, camera manufacturers have introduced several 3D methodologies, ranging from time-of-flight (TOF) analysis and projected pattern correlation, to laser line/triangulation measurements and stereoscopic technologies. Of these, stereo has gained stronger traction, particularly in the semiconductor industry. Components, such as solder balls or pins, which are used to connect wafers and dies, have to be inspected with 3D methods to precisely measure the critical height of the conducting elements. The typical dimensions of such components are about 50 µm, requiring an optical resolution for the inspection systems in the range of at least 5 µm.

The basis of the stereo technology is similar to human vision. Two sensors — in this case, linear sensors — in a stereo configuration are combined into one camera, resulting in two images being acquired of the same object from slightly different perspectives. This serves as the basis for triangulation, which involves an object point projected in both stereo images, and two image points corresponding to the positions of the right and left camera.

Manufacturers are now combining the best of both worlds — line scan with stereo. These cameras have linear sensors up to 8000 pixels in RGB to provide both high resolution and large field of view. Because of the improved accuracy, they open up new 3D applica-

Figure 3. Chromasens truePIXA camera systems permit color measurement on two-dimensional objects, especially for print inspection.

Figure 4. Line scan cameras contain a single row of pixels used to capture data very quickly, so that as an object moves past the camera, a complete image can be reconstructed in software line by line.

tions that are not possible with other approaches in order to detect the most minute of defects. Another advantage is speed — linear sensors have up to 50 kHz line rates even at extremely high resolutions. Finally, this approach results in fewer occlusions — the stereo line scan cameras are oriented perpendicular to the object surface so there are no occlusions in the transport direction.

Conclusion

Compared to manual inspection, machine vision systems employing area-scan cameras offer improved accuracy and far higher consistency. For all their advantages, however, there are limitations to area-scan cameras in more challenging machine vision tasks. Line scan cameras are available today with numerous sensors, speeds, and interfaces so developers can choose the one that best fits their applications.

This article was written by By Dr. Klaus Riemer, Product Manager, Chromasens GmbH (Konstanz, Germany). For more information, contact Dr. Riemer at Klaus.Riemer@chromasens.de or visit ***http://info.hotims.com/65857-201****.*

APPLICATION BRIEFS

Improved Surface Characterization with AFM Imaging

To shrink device size yet still tightly control performance, new technology often requires increasingly stringent surface specifications. Characterization tools, in turn, must keep pace by providing higher resolution, faster throughput, and more functionality. The atomic force microscope (AFM) is well known as a high-resolution imaging technique, but its characterization power and ease of use have increased significantly over the years.

Principles of AFM Operation

Unlike optical and electron microscopes that "see" a surface via transmitted or reflected radiation, the AFM "feels" the surface using a micromachined cantilever with a small tip (Figure 1). With a typical radius of a few nanometers, this tip allows the AFM to sense surface forces with high sensitivity.

The cantilever's position is controlled in three dimensions by a scanner with piezoelectric actuators. Imaging is accomplished by raster scanning the sample (or equivalently, the cantilever) in the XY plane. To improve scanning accuracy, newer AFMs use closed-loop positioning (i.e., sensored feedback) to compensate for piezoelectric hysteresis and creep. Newer AFMs also feature designs with better mechanical stability that reduce thermal drift and noise. As a result, high-resolution imaging can now be performed without vibration isolation or temperature control systems in many settings.

During scanning, the cantilever is monitored with an optical detection scheme. A laser beam is focused onto the cantilever and reflected into a position-sensitive photodiode. The up-down photodiode voltage captures the cantilever's relative vertical position and can be converted to absolute deflection through established calibration procedures. The left-right photodiode voltage can also be acquired and represents the cantilever's relative lateral or torsional motion.

The AFM controller, or control system, includes active feedback to improve sensitivity. The photodiode deflection signal is input to a feedback loop that controls the cantilever position. An example is contact mode, where the tip scans in contact at constant applied force. In this case, the feedback loop works to maintain constant cantilever deflection, and thus force, using the Z piezo actuator to adjust the height of the cantilever base. Images then represent the height change needed at each position. Nearly all AFM modes of operation utilize feedback control, but the variable controlled and the type of data acquired differ depending on the mode.

Several key features of AFMs are apparent from even this brief description. Nearly any type of material can be examined, and samples usually require little or no preparation. Imaging can be performed in an ambient environment or even in liquid. The small tip size provides spatial resolution far exceeding other stylus methods. However, the AFM's field of view is relatively small, typically a few tens of micrometers. Scan speed has also been slow historically (a few minutes per image), but dramatic increases[1] have recently been made (up to several frames per second).

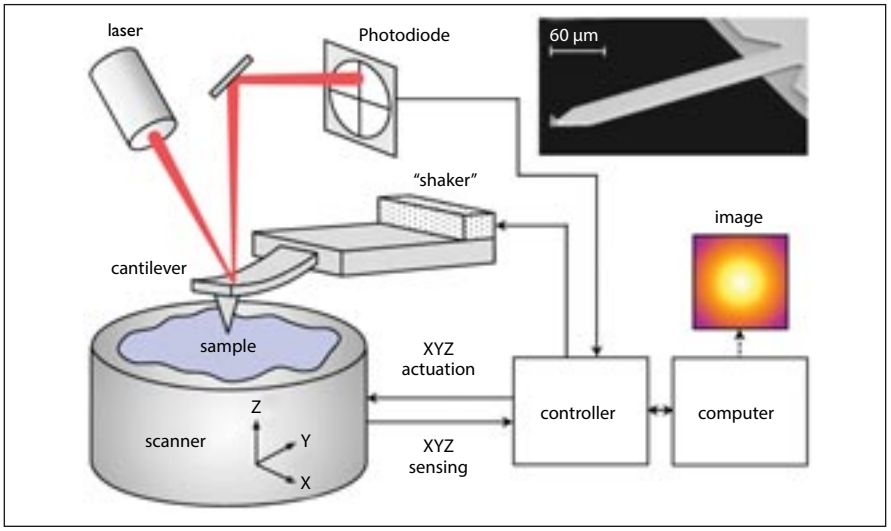

Figure 1. Schematic of AFM components. The SEM image shows a micromachined cantilever.

Imaging Topography on the Nanoscale and Beyond

Since their invention in the 1980s, AFMs have used the above concepts to map surface height variations with nanoscale resolution. These height, or topography, images provide valuable information on many types of structure including roughness, defects, amorphous and crystalline phases, and thin-film nucleation and growth.

Topography was originally acquired in contact mode, described above. However, scanning in contact induces lateral forces that can damage delicate samples, cause excessive tip wear, and require slower scanning. To address these issues, an approach called tapping mode was quickly developed. In tapping mode, the cantilever is oscillated at constant frequency near a flexural resonance (typically from tens to hundreds of kilohertz). Oscillation has traditionally been performed with a piezoelectric "shaker," but photothermal excitation[2] and other alternatives have recently been developed.

In tapping mode, variations in the tip-sample interaction force during scanning alter the cantilever's time-averaged oscillation amplitude. The feedback loop works to keep this amplitude constant by adjust-

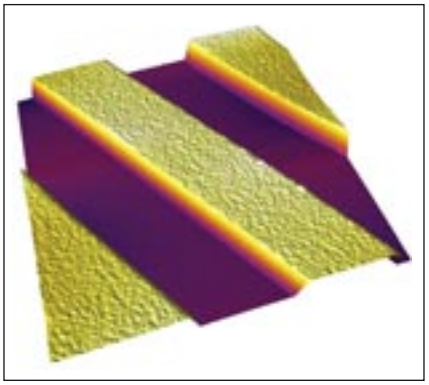

Figure 2. 3D rendering of tapping-mode topography image for a patterned titanium film (yellow) approximately 300 nm thick on silicon (violet). Scan size 10 µm.

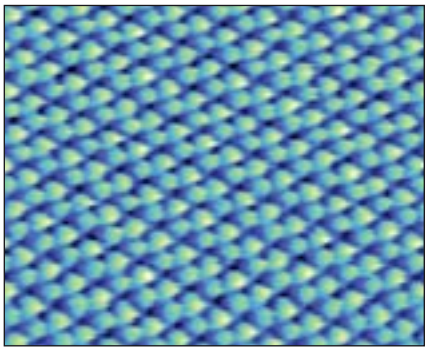

Figure 3. Topography of ß-DBDCS monocrystal imaged in water with tapping mode. The height (color) scale ranges from 0 pm (dark blue) to 700 pm (light green). Scan size 10 nm. Sample courtesy of S. Y. Park, Seoul National University, J. Gierschner, IMDEA Nanociencia, and E. Gnecco, University of Jena.

ing the cantilever's Z position, and the image data represents these adjustments. Because the tip only touches the sample intermittently in tapping mode, lateral forces are greatly reduced and much faster imaging is possible. Tapping mode also yields a second image of cantilever oscillation phase that can provide useful contrast between sample components.

The example topography image in Figure 2 emphasizes that AFM images are 3D surface profiles with quantitative data, not 2D projections subject to interpretation. They thus lend themselves to a wide range of analysis and display options, many of which are pre-programmed in software on newer AFMs. For example, image metrics that correlate with performance or processing variables can be determined quickly and easily.

With an image width of only 10 nm, the topography image in Figure 3 demonstrates the ultra-high resolution possible with today's AFMs. Hardware improvements have enabled spatial resolution sufficient for lattice-scale imaging – resolution similar to, or even better than, the current limit[3] of ~50 pm for high-resolution transmission electron microscopy. Since the tip-sample interaction volume determines AFM resolution, its limits are far smaller than those set by optical and electron diffraction.

Besides higher spatial resolution and other technical improvements, today's AFMs are also easier to use than earlier models. New automated routines – for instance, to align the laser or optimize imaging parameters in tapping mode – greatly reduce setup time. Operation is further streamlined by an extensive range of built-in tools for image display and analysis.

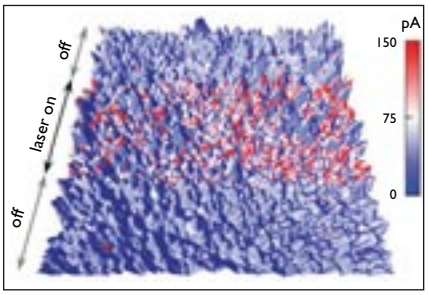

Figure 4. Photocurrent induced in a Eu-doped ZnO film by a blue laser. CAFM current is shown overlaid on 3D topography. Scan size 5 µm.

Imaging Local Material Properties

The AFM's capabilities go beyond imaging topography, however. The same force-sensing concepts can be used to quantify near-surface physical properties on the nanoscale. For many applications, such measurements provide valuable information that imaging morphology alone cannot.

For example, functional properties such as electrical, magnetic, and electromechanical response impact applications ranging from photovoltaics to nonvolatile memory and data storage. To interrogate functional behavior on the nanoscale, a number of AFM modes[4] have been developed based on electrostatic, capacitive, magnetic, and related tip-sample interactions.

AFM modes that probe electrical properties include conductive AFM (CAFM), electrostatic force microscopy (EFM), and Kelvin probe force microscopy (KFPM). The example in Figure 4 shows CAFM evaluation of a photoactive film. The nanoscale information provided by these techniques is often complementary to that obtained by probe station methods, which test a whole device. AFM electrical techniques can also be used to assess uniformity, identify defects, and otherwise assure quality.

Other capabilities for functional characterization are provided by piezoresponse force microscopy (PFM) and magnetic force microscopy (MFM). PFM characterizes static and dynamic electromechanical response of piezoelectric, ferroelectric, and multiferroic materials. In contrast, MFM uses a magnetized tip to assess the magnetic behavior of ferromagnetic and multiferroic materials.

In other applications, mechanical and tribological properties such as modulus, adhesion, and friction are critical for performance and reliability. The AFM's sensitivity to low forces

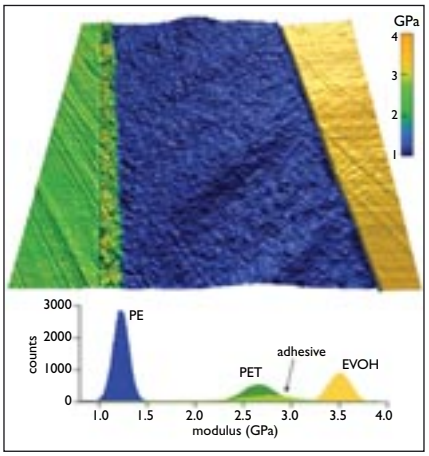

Figure 5. Elastic modulus overlaid on 3D topography for a multilayered polymer film of polyethylene terephthalate (PET, green), polyethylene (PE, blue), ethylene vinyl alcohol (EVOH, yellow), and adhesive (yellow-green). Acquired in AM-FM mode. Scan size 9 µm.

enables mechanical measurements with much higher vertical and lateral resolution than possible otherwise. As Figure 5 shows, today's AFMs provide other nanomechanical techniques[5] besides the classic force curve method. These newer, faster imaging techniques can also measure viscoelastic response, of particular importance for polymers and biomaterials.

This article has briefly reviewed the capabilities of today's AFMs for nanoscale surface characterization. Recent instrumentation advances such as higher spatial resolution, faster imaging rates, and enhanced measurements of physical properties make AFMs more valuable than ever before. Future refinements that extend these capabilities even further will help AFMs keep pace with technology's continuing demands for better device control on smaller length scales.

This article was written by Donna Hurley, a freelance AFM consultant, and Ben Ohler, Director of Marketing at Oxford Instruments Asylum Research (Abingdon, Oxfordshire, UK). For more information, contact Dr. Ohler at Ben.Ohler@oxinst.com or visit ***http://info.hotims.com/65857-202.***

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CoaXPress Blazes Trail for Faster, Higher Quality Machine Vision

Introduced in 2010, CoaXPress (CXP) has become a leading standard for high-end machine vision, as well as life sciences, security, and defense applications. The CXP standard enables sending high-speed asymmetric serial data over long distances using standard 75-ohm coaxial cable. It currently supports speeds up to 6.25 Gb/S per link. However, the use of multiple links allows scaling up of bandwidth to meet the needs of a specific application. In addition, CXP enables control of the camera and supply of 24V at up to 13W of power per cable — all over the same coaxial cable.

One of the driving forces behind rapid adoption of the CXP standard within the machine vision ecosystem is that it allows for the repurposing of coaxial cable in existing analog systems, and provides a cost-effective migration to faster, higher resolution, digital processing. A user need only replace the analog camera and frame grabber to gain CXP transmission rates. Because of the numerous CXP-compliant cameras, cables, frame grabbers, converters, and repeaters currently on the market, machine makers and system integrators are also designing CoaXPress into new solutions. CXP's additional bandwidth gives virtually any vision application the firepower to handle faster production runs and perform finer inspections.

The current version of CXP is 1.1.1, which was adopted in late 2015. The next iteration, CXP 2.0, promises to be a significant upgrade. The final draft of CoaXPress 2.0 is anticipated to be ready towards the end of 2017, with the first certified products expected in 2018. Central to this updated standard is boosting speed to double the data rates — CoaXPress 2.0 will extend machine vision data transfer rates up to 12.5 Gb/S (CXP-12) per link.

Greater speed translates to enhanced flexibility in system design, and the reduction of total system costs. Camera Link (80-bit) can offer a data rate of 850 MB/s, but by comparison, a single CXP-12 link can offer 1500 MB/s. In addition, the real estate requirements on a motherboard are significantly lower for multiple camera solutions.

Because of the globallly increasing adoption of 3D vision techniques, CXP 2.0 includes extensions for 3D imaging. This addition to the standard is especial-

Figure 1. The Aon-CXP single-link CoaXPress frame grabber designed for use with low-cost, compact CXP single-link cameras.

Figure 2. The Mikrotron EoSens CXP+ Series captures 80 frames per second at 25 megapixel resolution. (Photo courtesy of Mikroton).

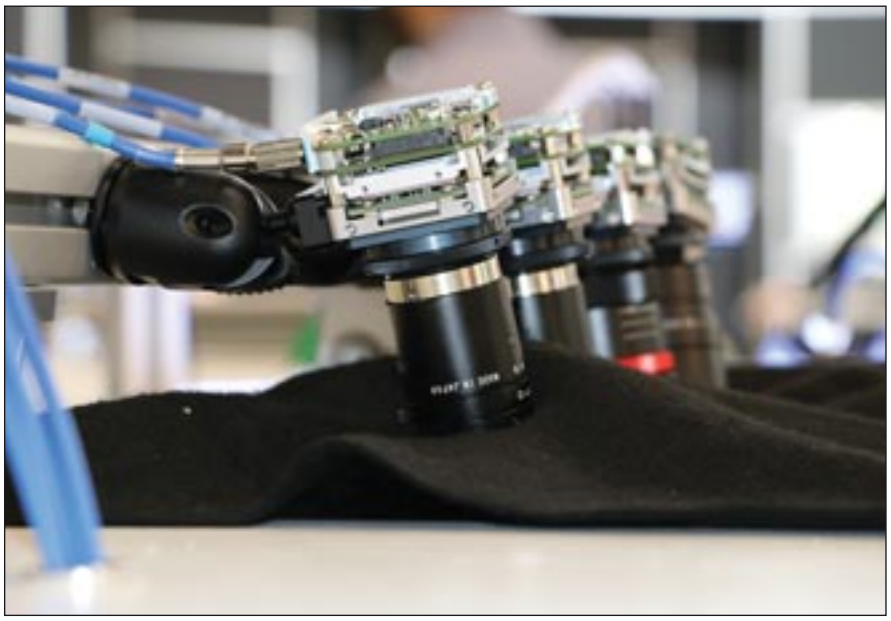


Figure 3. Adimec TMX CoaXPress cameras (photo courtesy of Adimec)

ly timely given that the global 3D vision market is expected to be valued at $2.13 billion by 2022. Growth is attributed to the increasing applications of 3D machine vision in the automotive and electronics industries as well as the broadening of applications that can employ machine vision solutions.

While the jury is still out on what else will be coming in CXP2.0, it is important to note that a variety of new features are being considered. The advantage of being one of the newest standards in machine vision is that we can learn from other standards about what works and what needs improvement.

As price pressures increase due to global competitiveness, productivity remains the key focus for successful manufacturers, with 100% quality assurance being the Holy Grail. Machine vision, with its ability to pinpoint the most minute defect, has long been considered a means for improving quality and therefore, productivity. CXP has improved the machine vision capability for larger manufacturers across a spectrum of industries in high-end inspection applications. The new generation of CXP frame grabbers and single-link cameras is reducing bandwidth requirements and enabling the technology to even be used by smaller manufacturers, who are more cost-constrained.

At the same time as CXP components are improving in performance, their size and cost are decreasing. CXP single-link cameras, new to the market, are replacing traditional, power hungry, large, and expensive CL cameras. Some CXP cameras can have footprints as small as of 29 x 29 mm. These cameras can achieve the current maximum data rates of 6.25 Gb/s despite their size. At this speed, the system can deliver 2MP images at 300 FPS, almost twice the real-world data rate of USB3 Vision cameras, and six times faster than GigE Vision solutions.

Low cost single-link CoaXPress frame grabbers have been launched to take advantage of these new cameras' performance, while still providing all the convenience of a GigE Vision or USB3 Vision camera system. A single-link CXP camera and frame grabber can compete on price while removing USB3 Vision's restriction on cable length. In addition, this combination can provide a host of machine vision features missing from GigE Vision or USB3 Vision camera systems, for example, triggers, encoders, strobe, waveform generators, and quadrature encoder support.

Rather than having to deal with NIC and USB interface troubleshooting, a CXP frame grabber company can write every line of software and firmware designed for their own hardware. In the event of a problem, the company can support their customer to resolve the issue.

Conclusion

CXP is one of the youngest standards in machine vision but has proven itself as a worthy successor to the existing architectures. The CXP interface can evolve to meet the growing demands for larger and faster sensors. For the lower end market, it offers a solution improving upon both USB3 Vision and GigE Vision data rates and real time compatibility. It is anticipated that in time it will come to be accepted as a popular and widely used machine vision standard.

This article was written by Donal Waide, Director of Sales, BitFlow Corp., Boston, MA. For more information, contact Mr. Waide at donal.waide@bitflow.co, or visit ***http://info.hotims.com/65857-203.***

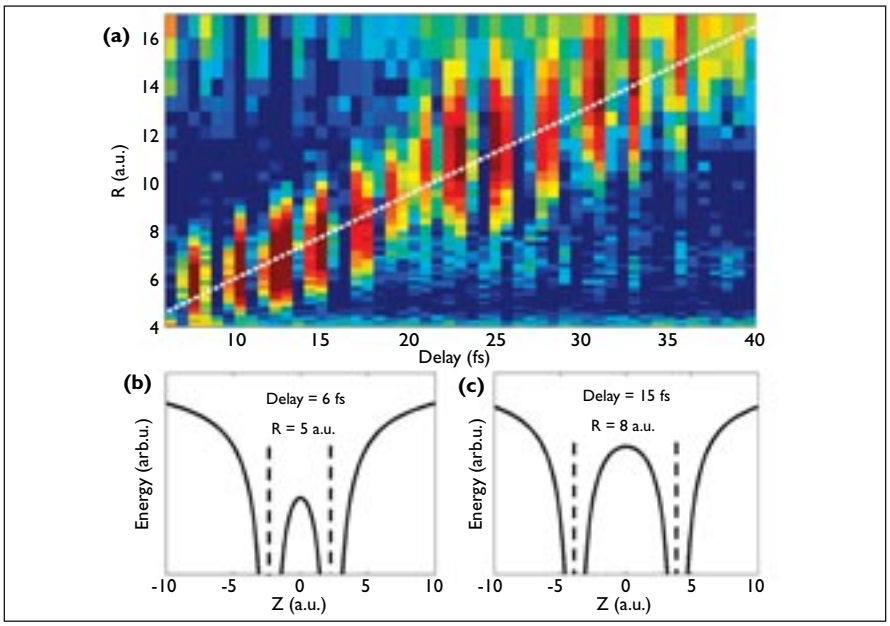
TECH BRIEFS

An Electron Caught in the Act

A super-fast camera captures images of atoms in motion.

Griffith University, Nathan, Queensland, Australia

How fast is an electron? Australian scientists were able to measure it. Australia's fastest camera, located at the Attosecond Science Facility, has revealed the time it takes for molecules to break apart. The experimental research, conducted by Griffith University's Centre for Quantum Dynamics, aims to help in the design of new molecules for materials science or drug discovery.



The graphic indicates the time evolution of the dissociating nuclear wave packets, where the overlaid white dashed line is a linear fit for the peak of the dissociating packets.

Scientists at the facility have been able to measure, in real-time, the time that it took and the separation distance of two atoms when the bond was broken in the simplest diatomic molecule. The result is 15 femtoseconds (10^{-15} seconds) at a distance of 0.5 nanometers. The molecule was made of two protons and one electron that they shared.

That electron sharing is responsible for the chemical bond that binds the protons together to form the molecule. The scientists made that molecule dissociate and observed how soon the electron would 'decide' at which proton it will remain. That is called 'electron localization' or loss of sharing and it signifies a breakage of a chemical bond.

"This allows us to start thinking about how we might engineer a new molecule and is a stepping stone towards looking at that type of reality, particularly in areas like drug discovery," said research leader Igor Litvinyuk. "It's pretty amazing you can do measurements on this sort of timescale. We can even observe processes which are faster than that."

For more information, contact Stephanie Bido, s.bedo@griffith.edu.au

Scientists Demonstrate New Real-Time Technique for Studying Ionic Liquids at Electrode Interfaces

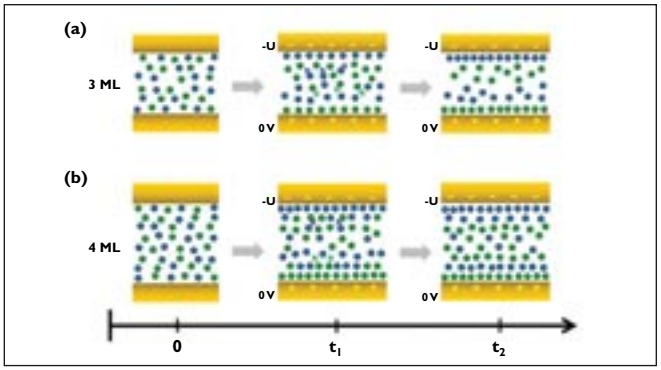
Determining how the ions of the liquid move and rearrange in response to an applied voltage on electrodes is key to optimizing the performance of ionic liquids for energy storage devices.

Brookhaven National Laboratory, Upton, NY

Ionic liquids—salts made by combining positively charged molecules (cations) and negatively charged molecules (anions) that are liquid at relatively low temperatures, often below room temperature—are increasingly being investigated for uses in batteries, supercapacitors, and transistors. Their unique physical and chemical properties, including good ionic conductivity, low flammability and volatility, and high thermal stability, make them well suited for such applications. But thousands of ionic liquids exist and exactly how they interact with the electrified surfaces of electrodes remains poorly understood, making it difficult to choose one for a particular application.

Brookhaven National Laboratory scientists have demonstrated a new method for observing in real time how the ions of such liquids move and reconfigure as different voltages are applied to the electrodes.

When ionic liquid electrolytes come into contact with an electrode, a special structure consisting of alternating layers of cations and anions — called an electric double layer (EDL) — forms at the interface, but tracking the real-time evolution of the EDL, where the electrochemical reactions take place in batteries, is difficult because it is very thin, only a few nanometers thick, and buried by the bulk portion of the ionic liquid.



The team's research showed that the ionic reconfigurations occurring near the gold electrodes (yellow bars) depend on the thickness of the studied ionic liquid films, as illustrated in the above schematic. Anions (green circles) and cations (blue circles) are structured in a checkerboard-like pattern (left) without an applied voltage but rearrange when one of the electrodes is biased (-U). The thicker film (b) has a second layer of cations near the -U electrode.

Until now, scientists have only been able to look at the initial and final EDL structures by using microscopy and spectroscopy techniques; the intermediate structure has been harder to probe. To visualize the structural changes of the EDL and the movement of ions as voltage is applied to the electrodes, the Brookhaven team used an imaging technique called photoemission electron microscopy (PEEM). In this technique, surface electrons are excited with an energy source and accelerated into an electron microscope, where they pass through magnifying lenses before being projected onto a detector that records them. Local variations in the photoemission signal intensities are then used to generate contrast images of the surface.

In this initial demonstration, the team changed the voltage applied to the electrodes, the thickness of the ionic liquid films, and the temperature of the system, all while monitoring changes in photoemission intensity.

They found that the ions move and arrange themselves according to the sign and magnitude of the applied voltage. Cations gravitate toward the electrode with the negative bias to counter the charge, and vice versa for anions. As the difference in potential increases between the two electrodes, a highly dense layer of cations or anions can accumulate near the biased electrode, preventing further ions of the same charge from moving there — a phenomenon called overcrowding — and reducing ion mobility.

For very thin films, the number of ions available for rearrangement is small, so the EDL layer may not be able to form. In the thicker films, more ions are available and they have more room to move around. They rush to the interface and then disperse back into the bulk upon overcrowding to form a more stable structure. The team further explored the importance of mobility in the rearrangement process by cooling the thicker film until the ions virtually stopped moving.

The team plans to continue their research using the new aberration-corrected low-energy electron microscope (LEEM)/PEEM system. This will enable them to study not only the structural and electronic changes, but also the chemical changes of the ionic liquid-electrode interface, all in a single experiment. By determining these unique properties, scientists will be able to select the optimal ionic liquids for specific energy storage applications.

For more information, contact Ariana Tantillo at 631-344-2347.

Novel Techniques Examine Solar Cells with Nanoscale Precision

The new methods will lead to engineering more efficient photovoltaic systems.

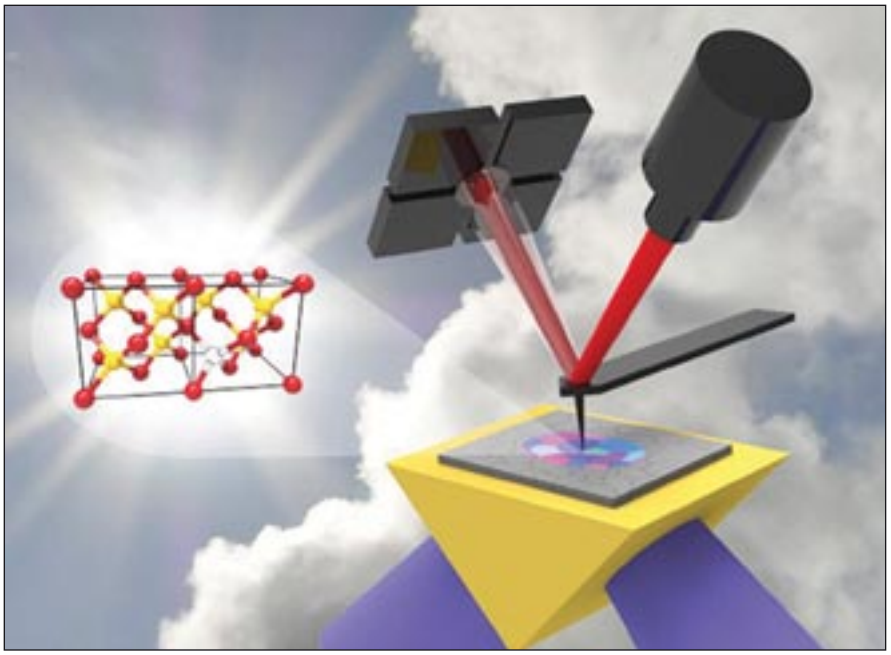
National Institute of Standards and Technology (NIST), Gaithersburg, MD

Researchers at the National Institute of Standards and Technology (NIST) have for the first time examined, with nanometer-scale precision, the variations in chemical composition and defects of widely used solar cells. The new techniques, which were used to investigate a common type of solar cell made of the semiconductor material cadmium telluride, promise to aid scientists to better understand the microscopic structure of solar cells and may ultimately suggest ways to boost the efficiency with which they convert sunlight to electricity.

Even though standard methods to characterize solar cells have long proven useful in guiding their fabrication and design, the available diagnostic tools give only a limited understanding of why the devices operate at sub-optimal efficiency. For instance, although a method known as electron-beam induced current, which analyzes samples using the beam of an electron microscope, provides data on nanoscale variations in solar cell efficiency, it gives little information on the underlying crystal defects and impurities that degrade the efficiency. Two other methods, photoluminescence and cathodoluminescence, which induce light emission from the samples, provide only insufficient or indirect information on the mechanisms of efficiency losses.

In their study, the scientists used two complementary methods that rely on an atomic force microscope (AFM). Photothermal induced resonance (PTIR) provides information on the solar cell's composition and defects at the nanometer-scale by measuring how much light the sample absorbs over a broad range of wavelengths, from visible light to the mid-infrared. The other method, known as direct transmission near-field scanning optical microscopy (dt-NSOM), creates detailed nanoscale images that capture variations in the composition of the solar cells and defects in their structure, by recording how much light is transmitted at specific sites within the cell. That method produces sharper images than PTIR.

The setup for PTIR resembles a finely tuned version of a Rube Goldberg contraption. First, light pulses from a laser illuminate a sample of cadmium telluride. When the sample absorbs the laser light, it heats up and expands. The expansion nudges the sharp tip of an AFM that is in contact with the sample. The tip converts the heat-induced expansion into mechanical motion, causing the cantilever on which it is mounted to vibrate. Finally, the vibration is detected by bouncing light from another laser off the cantilever into the AFM detector.



Schematic of cadmium telluride examined by the photothermal induced resonance technique. (Yoon et al./NIST)

Because the amplitude of the cantilever's vibrations is proportional to the energy absorbed by the cadmium telluride sample, PTIR measurements provide key information about the material. For instance, when the tip is held at one location and the wavelength of the pulsed laser light is varied, information is generated about the spectra of radiation absorbed at different points along the sample, with nanoscale resolution.

When the AFM tip moves over the sample but the laser's wavelength remains fixed, PTIR yields an absorption map of the material, which reveals variations in chemical composition from one part of the sample to the other. The small size of the probe tip provides absorption information with a spatial resolution smaller than the laser wavelength.

In the dt-NSOM technique, light from the sharp tip of an AFM probe illuminates a small part of the sample. A photodetector in contact with the sample then measures the amount of light transmitted through the material as the probe scans over it.

The experiments showed that defects in the crystal arrangement of the material are related to impurities in chemical composition, propagated along and from the boundaries between adjoining crystal grains. The team also demonstrated techniques to measure the spatial variation of so-called deep defects in the cadmium telluride samples. These defects, which cause electrons and holes (positively charged particles) in cadmium telluride and other semiconductors to recombine instead of generating electricity, are one of the key reasons that solar cells do not perform as well as the theoretical models predict.

According to the researchers, these findings will aid solar cell research, leading to a better understanding of a variety of photovoltaic materials, and consequently, engineering them for greater efficiency.

For more information, contact Ben Stein, benjamin.stein@nist.gov.

Optical Probing Deep into the Eye

A simple, low-cost fix improves images obtained with a new optical scanning technique that opens the door to "virtual biopsies."

Stanford Medical, Stanford, CA

Optical coherence tomography (OCT) is a scanning technology commonly used by ophthalmologists to check for eye diseases. A team of scientists has figured out how to retrofit these high-performance machines with off-the-shelf components, increasing OCT's resolution by several-fold, promising earlier detection of retinal and corneal damage, incipient tumors, and more.

The relatively simple, low-cost fix — entailing a pair of lenses, a piece of ground glass and some software tweaks — erases blemishes that have bedeviled images obtained via OCT since its invention in 1991. This improvement, combined with the technology's ability to optically penetrate up to 2 millimeters into tissue, could enable physicians to perform "virtual biopsies," visualizing tissue in three dimensions at microscope-quality resolution without excising any tissue from patients.

The researchers tested the enhancement in two different commercially available OCT devices. They were able to view cell-scale features in intact tissues, including in a living mouse's ear and a human fingertip.

Every year, more than 10 million OCT scans are performed to diagnose or monitor conditions from age-related macular degeneration to melanoma. The technology has also been adapted for endoscopic use in pulmonary, gastrointestinal, and cardiovascular medicine.

Somewhat analogous to ultrasound, OCT penetrates tissues optically instead of with sound waves. The device aims beams of laser light at an object — say, a tissue sample, or a patient's eye — and records what comes back when light bounces off reflective elements within the sample or eyeball. Adjusting the depth of penetration, a user can scan layer upon layer of a tissue and, piling virtual slices of tissue atop one another, assemble them to generate a volumetric image.

But to this day, OCT continues to be plagued by a form of noise that, unlike the random noise generated by any sensing system, can't be washed away simply by repeatedly imaging the object of interest and averaging the results.

The noise generated by OCT, called "speckle," is an inherent feature of the architecture of the object being viewed and the unique properties of laser light.

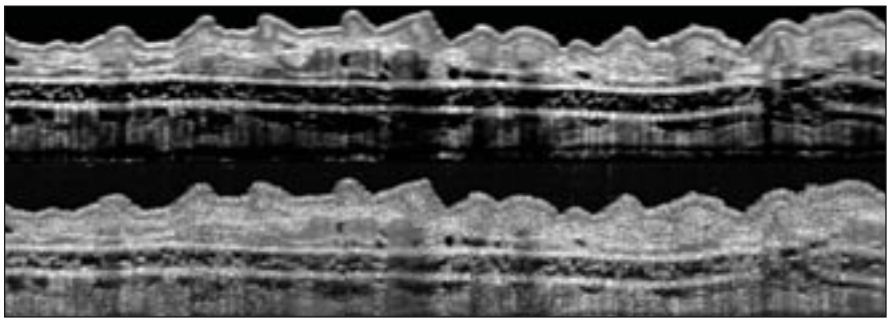
A photon isn't a mere particle. It's also a wave whose power waxes and wanes as it travels. When two waves collide, their combined height at the moment of their collision depends on whether each was at its peak, its trough, or somewhere in between.

The photons comprising a beam of laser light are in phase; they share the same wavelength, with their peaks and troughs occurring in sync. But when these photons bounce off of two separate surfaces — say, two closely situated components of a cell — the lengths of their return routes differ slightly, so they're no longer in phase. In that case, they may cancel each other out, creating a false-black speckle on the resulting image. Or they may reinforce one another, creating a false-white

speckle. If the speckle-generating components' positions are fixed, as is the case in most tissues (circulating blood being one exception), those same speckles will pop up in the same places on every successive OCT scan.

In principle, if you could reach in with a molecular tweezers and move one of those two interfering components just a tiny bit, you would change the speckle pattern. The scientists have found a way to do essentially the same thing, optically speaking.

By positioning a couple of additional lenses in the OCT device's line of sight, they were able to create a second image — a holograph-like exact lookalike of the viewed sample that appeared elsewhere along the line of sight, between the added lenses and the sample. By inserting what they call a "diffuser" — a plate of glass they'd roughened by randomly etching tiny grooves into it — at just the right point in the line of sight and methodically moving it between each round of repeated scans, they achieved the optical equivalent of shifting the geographical relationship of the sample's components just a tiny bit each time they scanned it.



The upper image, showing a section of a mouse's outer ear, is considerably enhanced by the team's refinements compared with one obtained by conventional technology (lower image). (Courtesy of the de la Zerda lab.)

Now, averaging the successive images removed the speckles. The team was able to acquire detailed, essentially noise-free images of a living, anesthetized mouse's ear, its retina and cornea. They were also able to see sebaceous glands, hair follicles, blood vessels, and lymph vessels.

In a scan of a human finger, they saw an anatomical feature never before glimpsed with OCT: Meissner's corpuscle, a nerve bundle responsible for tactile sensations.

For more information, contact Bruce Goldman, goldmanb@stanford.edu.

R&D Effort Produces Magnetic Devices to Enable More Powerful X-ray Lasers

A record-setting magnetic field for a prototype superconducting undulator will significantly improve its performance.

Lawrence Berkeley Laboratory, Berkeley, CA

A team of researchers have designed, built, and tested two devices, called superconducting undulators, which could make X-ray free-electron lasers (FELs) more powerful, versatile, compact, and durable.

X-ray FELs are powerful tools for studying the microscopic structure and other properties of samples, such as proteins that are key to drug design, exotic materials relevant to electronics and energy applications, and chemistry that is central to industrial processes like fuel production.

The development effort was motivated by SLAC National Accelerator Laboratory's upgrade of its Linac Coherent Light Source (LCLS), the nation's only X-ray FEL. This upgrade, now underway, is known as LCLS-II. All existing X-ray FELS, including both LCLS and LCLS-II, use permanent magnet undulators to generate intense pulses of X-rays. These devices produce X-ray light by passing high-energy bunches of electrons through alternating magnetic fields produced by a series of permanent magnets.

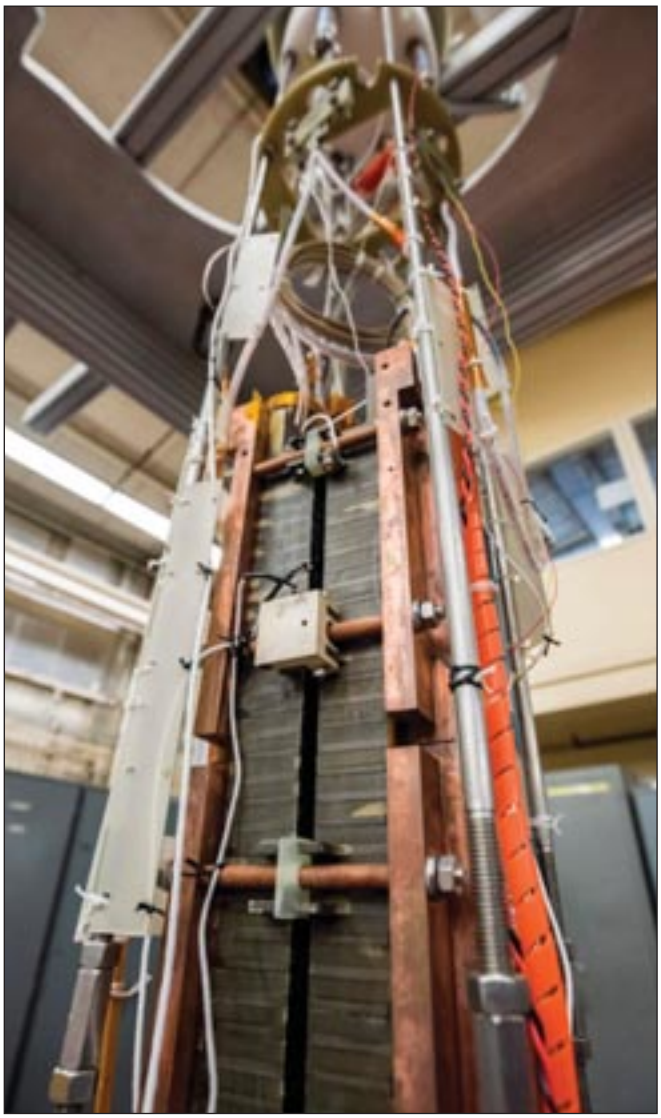
Superconducting undulators (SCUs) offer another technical solution and are considered among the most promising technologies to improve the performance of the next generation FELs, and of other types of light sources, such as Berkeley Lab's Advanced Light Source (ALS) and Argonne's Advanced Photon Source (APS).

SCUs replace the permanent magnets in the undulator with superconducting coils. The prototype SCUs have successfully produced stronger magnetic fields than conventional undulators of the same size. Higher fields, in turn, can produce higher-energy free-electron laser light to open up a broader range of experiments.

Berkeley Lab's 1.5-meter-long prototype undulator, which uses a superconducting material known as niobium-tin (Nb_3Sn), set a record in magnetic field strength for a device of its design during testing at the Lab in September 2016.

Argonne's test of another superconducting material, niobium-titanium (NbTi), successfully reached its performance goal, and additionally passed a bevy of quality tests. Niobium-titanium has a lower maximum magnetic field strength than niobium-tin, but is further along in its development.

Niobium-tin is a brittle material that cannot be drawn into a wire. For practical use, a pliable wire, which contains the components that will form niobium-tin when heat-treated, is used for winding the undulator coils. The full undulator coil is then heat-treated in a furnace at 1200°F. The niobium-tin wire is wound around a steel frame to form tightly wrapped coils in an alternating arrangement. The precision of the winding is critical for the performance of the device. One of the challenges was to maintain precision in its winding despite large temperature variations.



This Berkeley Lab-developed device, a niobium-tin superconducting undulator prototype, set a record in magnetic field strength for a device of its kind. This type of undulator could be used to wiggle electron beams to emit light for a next generation of X-ray lasers. (Credit: Marilyn Chung/Berkeley Lab

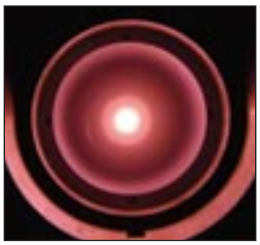
After the heat treatment, the coils are placed in a mold and impregnated with epoxy to hold them in place. To achieve a superconducting state and demonstrate its performance, the device was immersed in a bath of liquid helium to cool it down to about minus 450°F.

Another challenge was in developing a fast shutoff to prevent catastrophic failure during an event known as quenching. During a quench, there is a sudden loss of superconductivity that can be caused by a small amount of heat generation. Uncontrolled quenching could lead to rapid heating that might damage the niobium-tin and surrounding copper and ruin the device. This is a critical issue for the niobium-tin undulators due to the extraordinary current densities they can support. A quench-protection system that can detect the occurrence of quenching within a couple of milliseconds and shut down its effects within 10 milliseconds was developed to address the issue.

For more information, contact Glenn Roberts Jr. 510-486-5582.

NEW PRODUCTS

High-Energy UV lamp



McPherson, Inc. (Chelmsford, MA) introduces the flow-controlled windowless, hollow cathode UV lamp Model 629. This broad-spectrum source emits ionized gas emission lines with little or no absorption by neutral gas. Computer controlled gas flow and constant current power supply improve stability.

The lamp produces excited atoms and ions that emit electromagnetic radiation at wavelengths characteristic of the gas flowing through the system, similarly to inductively coupled plasma (ICP) atomic emission spectroscopy systems. Mirrors can reflect the light to an analytical optical system, a spectrometer, or spectrophotometer. Since there is no limiting window, this UV source works in the more energetic range of wavelengths from double ionized Helium at 30 nanometers up to the visible light range (2 to 40 eV). Molecules of sample media emit radiation at characteristic "fingerprint" wavelengths of the elements involved and the relative intensity of emission indicates concentration of the element within the sample.

For Free Info Visit: http://info.hotims.com/65857-281

High Power Nanosecond Lasers

High-power ultraviolet (355 nm) and green (532 nm) additions to the Coherent, Inc. (Santa Clara, CA) AVIA industrial nanosecond laser family can improve the performance of microprocessing applications. The AVIA 355-55 features a 150 kHz pulse repetition rate, resulting in an average power of 55 watts at 355 nm. The AVIA 532-80 produces 1 millijoule pulse energy, which, together with a maximum pulse repetition rate of 80 kHz, translates into an average power of 80 watts.

These lasers are used for cutting flex substrates and thin printed circuit boards where high lateral resolution is a critical consideration. The higher power will extend cutting capabilities to >200-µm flex and multi-layer materials. It will also enable existing applications to be accelerated to higher throughputs, without affecting edge quality and with minimal peripheral thermal damage. The high pulse energy improves the piercing capabilities for drilling, cutting, and scribing deeper features, and thicker substrates.

For Free Info Visit: http://info.hotims.com/65857-278

Microscopy Camera

Andor Technology (Belfast, Northern Ireland), has announced a new "super-resolution" (SRRF-Stream) microscopy technology, available on its single photon sensitive iXon EMCCD cameras. It can be used with most modern microscopes, with conventional fluorophores at low illumination intensities, thus making it highly compatible with live cell imaging. A resolution improvement from 2- to 6-fold (50-150nm final resolution) can be expected for most datasets.

GPU processing optimization techniques are employed to execute the recently developed SRRF algorithm up to 30x faster than the existing image-based post processing implementation of SRRF. This enables data acquisition and SRRF processing to operate in parallel to process the super-resolution large field-of-view images faster than the camera can acquire data. An EMCCD full field of view super-resolved image can be generated at rates of > 1 Hz, or up to > 10 Hz by using smaller ROI sizes.

For Free Info Visit: http://info.hotims.com/65857-277

Solid-State Light Source Driver/Controller

Innovations in Optics, Inc. (Woburn, MA) introduces the 5500A Solid-State Source Driver/Controller to independently drive, control and modulate as many as 18 different solid-state sources, including combinations of LEDs, LDs, or IR VCSEL arrays. It provides precise, independent, constant current control up to 3A per source channel. Its ground-based design is configured for common cathode LED or LD devices, which allows for multiple channels to be run in parallel for a combined current of up to 54A.

The independent current control to each UV-LED is designed to achieve optimal performance and lifetime by maintaing uniform current density through the entire LED array. Constant current, is selectable from 0A to 3A per channel with 10-bit resolution at a maximum compliance voltage of 6.0 VDC in continuous or pulsed mode, to a minimum pulse width <20 microseconds and a maximum 15 kHz rep. rate.

For Free Info Visit: http://info.hotims.com/65857-279

Time-of-Flight Chipset

Melexis (Tessenderlo, Belgium) is introducing a new Time-of-Flight (ToF) chipset and development kit that enables simple, modular design of 3D vision solutions. It includes the MLX75023 1/3-inch optical format ToF sensor and the MLX75123 companion IC that embeds many of the external components normally required to develop a 3D vision solution. With this high level of integration, designers don't have to be concerned with external FPGAs and ADCs, thereby reducing size, design cost, product cost, and time-to-market.

According to the manufacturer, it offers the world's smallest pixel at QVGA resolution with 63 dB linear dynamic range and sunlight robustness. The companion chip directly interfaces the sensor IC to a host MCU and provides rapid readout of data from the sensor. It is available in automotive grade (-40°C to +105°C) for applications like occupant detection, and industrial grade (-20°C to +85°C).

For Free Info Visit: http://info.hotims.com/65857-275

Thermal Imaging Camera

FLIR Systems, Inc. (Wilsonville, OR) has announced the FLIR ETS320 thermal imaging solution for electronics testing in engineering benchtop environments. It combines a high-sensitivity thermal camera – engineered for imaging PCBs and other electronics – with an adjustable, hands-free table stand to provide consistent, non-contact thermal testing through the entire electronics design, development, and production process. By offering more than 76,000 points of temperature measurement, it has the ability to monitor power consumption, detect hot spots, and identify potential points of failure during product development. The camera's high measurement accuracy and its ability to visualize small temperature differences helps evaluate thermal performance, ensure environmental compatibility, and troubleshoot problems for a wide range of electronic products.

For Free Info Visit: http://info.hotims.com/65857-270

Smart Camera

The EyeCheck EC9000 camera series from EVT (Karlsruhe, Germany) comes preloaded with EyeVision image processing software, and can be upgraded to the Professional version.

The standard camera sensor is a gray-scale CMOS matrix. Options include color sensors, line scan, and thermal imaging sensors. Xilinx SDK for programming FPGAs is also included. There are eight I/Os, including GigE, RS232, and LVDS interfaces, and optionally USB 2.0. The camera comes with an M12 connector and has an IP65 rating. It also includes a mini-PCI-Express card and 2 x Micro-USB connectors.

The integrated EyeVision software offers a graphical, ready-to-use user interface and also a variety of libraries for C/C++ programming. Therefore the camera combines plug-and-play features with versatile programming possibilities.

For Free Info Visit: http://info.hotims.com/65857-271

Line Scan Cameras for Optical Coherence Tomography

The new OctoPlus line scan cameras from Teledyne e2v, (Milpitas CA), have been developed for Optical Coherence Tomography (OCT) applications in healthcare and industrial markets.

Based on new image sensor pixel architecture, it is specifically tuned to provide users with accurate images of the retina and cornea: mapping tissue structure, measuring thickness, and visualising blood flow dynamics for diagnostics. OctoPlus will more than double the eye surface captured in a single scan without sacrificing resolution. Its field of view is 250 percent larger than the Food and Drug Administration (FDA) approved commercial Swept Source OCT (SS-OCT) and it has a +5dB signal-to-noise ratio (SNR). In addition, it saves 60 percent of the power used by previous designs, thereby reducing heat generation, improving stability and increasing maintenance intervals.

For Free Info Visit: http://info.hotims.com/65857-272

Video Management Software

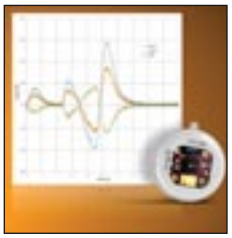
OnSSI (Pearl River, NY) is releasing Ocularis version 5.4, the latest version of the company's industry Video Management Software (VMS). New features include support for H.265 compression and increased SQL server flexibility.

Mobile enhancements include ability to send video directly to Ocularis via cell phone or tablet; "one tap" capture of JPEG images for sharing of snapshots; trigger capability to move a PTZ camera, release a door, initiate an alarm, or turn on lights; alert/event badge counter. Web enhancements include triggers for individual and global cameras and sharing of AVI exports via a direct link.

The three available models are: Professional, for organizations operating multiple locations with small to mid-sized camera counts; Enterprise, for a wide range of mid to large IT-centric organizations; and Ultimate, for large organizations with extended command and control needs.

For Free Info Visit: http://info.hotims.com/65857-276

Pyroelectric Detectors



Laser Components (Bedford, NH) is introducing the LD2100 series pyroelectric detector, with differential outputs. This is advantageous since pyroelectric crystals simultaneously generate positive and negative charges on opposite faces. The detector not only gives you double the signal compared to a single-ended detector when used with a differential amplifier, but the noise only increases by √2, which produces an improvement in signal to noise ratio of around 1.4. In addition, since differential inputs cancel out external common-mode noise signals, they are well suited for critical environments. And wiring is simplified, since the signal outputs can be connected directly to the inputs of a differential AD converter.

Pyroelectric detectors are used in NDIR and FTIR spectroscopy, IR laser-based measurement technology, pyrometry, and flame and fire detection. They are highly sensitive as thermal detectors from short to long IR wavelengths.

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