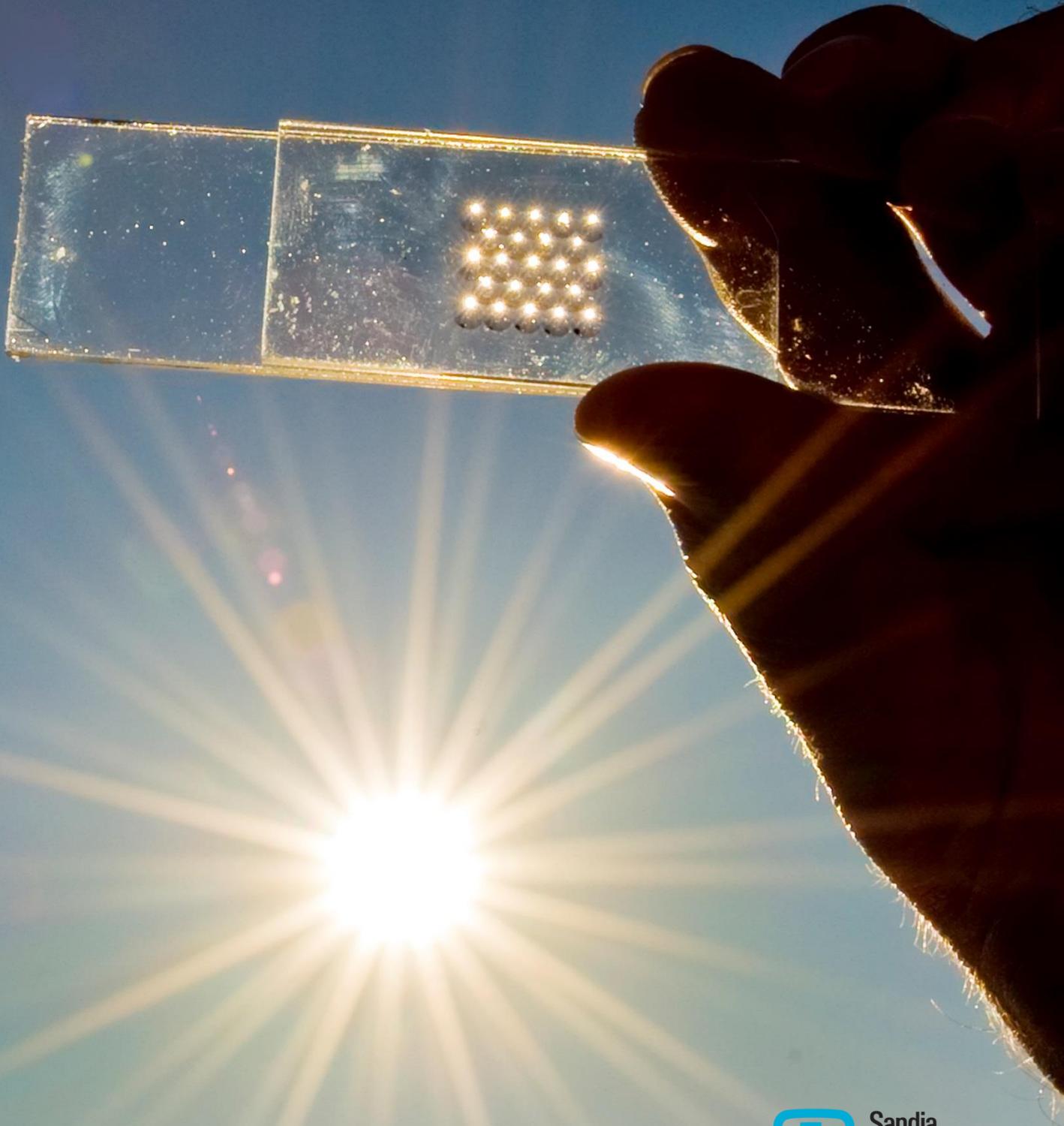


Sandia's INNOVATION MARKETPLACE

A QUARTERLY UPDATE OF AVAILABLE TECHNOLOGIES FOR INDUSTRY



April 2014 • Vol 1, Issue 2



Welcome to Sandia National Laboratories' Intellectual Property Showcase

Sandia's Innovation Marketplace is a quarterly e-magazine published by Sandia National Laboratories. This publication highlights exceptional opportunities for licensing Sandia's intellectual property, including patents, copyrights (generally software), trademarks, and mask works. Listings within should not be construed as an offer to license technology. All licenses are subject to negotiation and availability of the intellectual property for licensing. This publication is intended for indications of interest only.

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Leverage World-Class Technology and Research

For more than 60 years, Sandia has delivered essential science and technology to resolve the nation's most challenging security issues. A strong science, technology, and engineering foundation enables Sandia's mission through a capable research staff working at the forefront of innovation, collaborative research with universities and companies, and discretionary research projects with significant potential impact.

The Best and Brightest

In keeping with our vision to be the nation's premier science and engineering laboratory for national security and technology innovation, we recruit the best and the brightest, equip them with world-class research tools and facilities, and provide opportunities to collaborate with technical experts from many different scientific disciplines. The excitement and importance of our work, an exemplary work environment, partnerships with academia, industry, and government, and our record of historic contributions help us attract exceptional staff. Our employees are recognized by their professional peers for their outstanding contributions.

To discuss licensing opportunities, please send inquiries to: ip@sandia.gov

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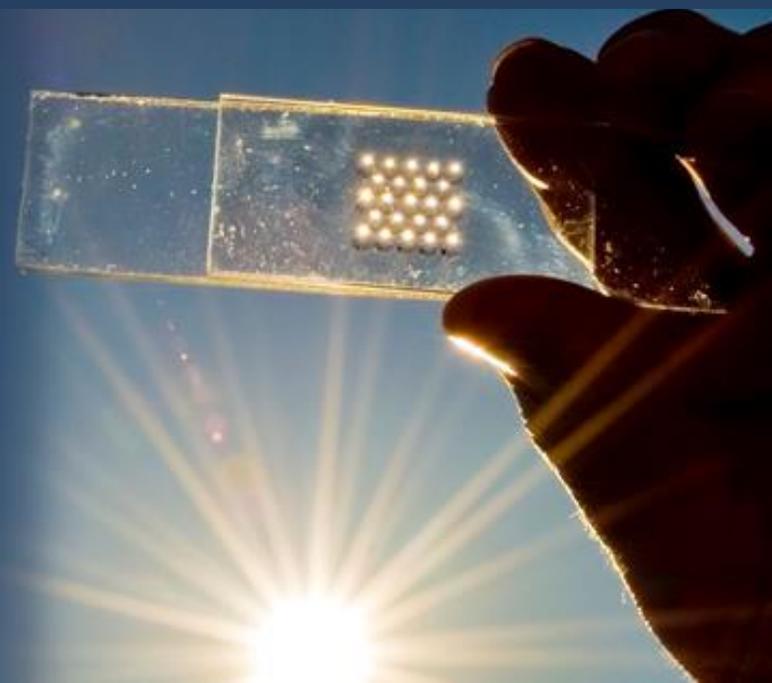
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ON THE COVER

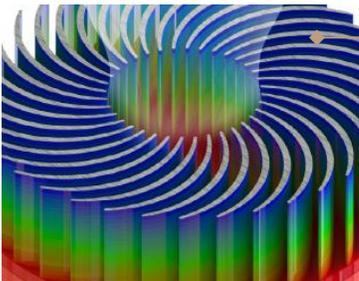
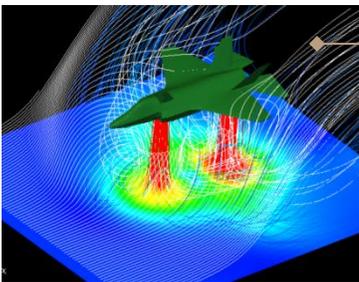
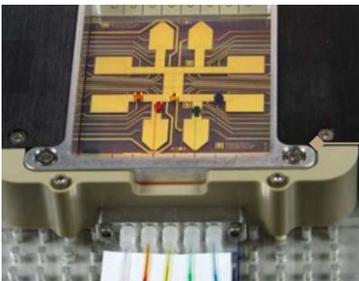
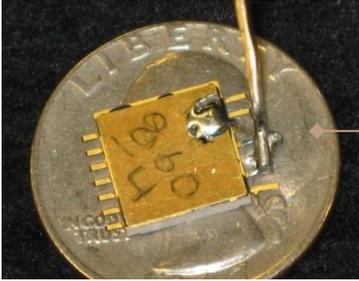
Sandia project lead Greg Nielson holds a solar cell test prototype with a microscale lens array fastened above it. Together, the cell and lens help create a concentrated photovoltaic unit. These tiny glitter-sized photovoltaic cells could revolutionize the way solar energy is collected and used. Read more about Sandia's Microsystems Enabled Photovoltaics (MEPV): Solar Glitter™ technology on page 7.

(Photo by Randy Montoya)

*Exceptional service
in the national interest*



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Energy & Natural Resource Management

Packed Particle Bed Reactor creates hydrogen fuel using a thermochemical process powered by the sun

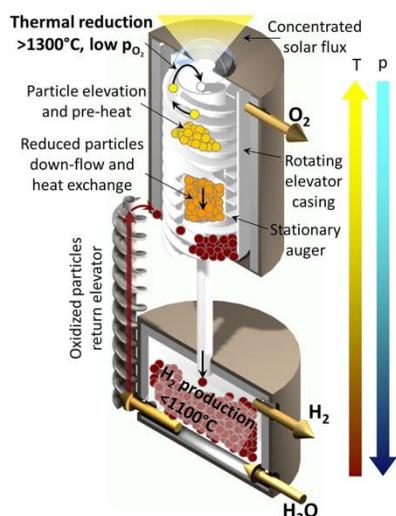
Sandia has developed a packed particle bed reactor for converting solar energy into a chemical fuel, such as hydrogen.



Hydrogen fuel may be an environmentally friendly alternative to gasoline, natural gas, and other carbon-based fossil fuels—especially if

the hydrogen can be generated without using fossil fuels in the process. The reactor creates hydrogen fuel using a two-step thermochemical process powered by the sun.

In the Sandia reactor, minuscule metal-oxide particles (a few tens of microns in diameter) acting as the working “fluid” are transported between two isolated reaction zones: an upper chamber heated by concentrated solar energy and a lower chamber exposed to steam. Particles are lifted from the lower



to the upper chamber using an elevator concept patented by the team. They are returned to the lower chamber by gravity. In the upper chamber, sunlight heats the particles to temperatures up to 1600 °C, providing sufficient energy to remove oxygen from the oxide particle. The oxygen is pumped away,

and the oxygen-deficient particles flow to the lower chamber. Here, oxygen in the steam breaks away from the water molecule to deposit back into the reduced particle, creating hydrogen in the process. The re-oxidized particles are then elevated to the upper chamber to repeat the cycle up to thousands of times before particle replacement.

Applications and Industries

- * Fuel cell technology
- * Transportation
- * Solar energy

Redox Non-Innocent Metal Complexes have the potential to revolutionize flow battery electrolyte development

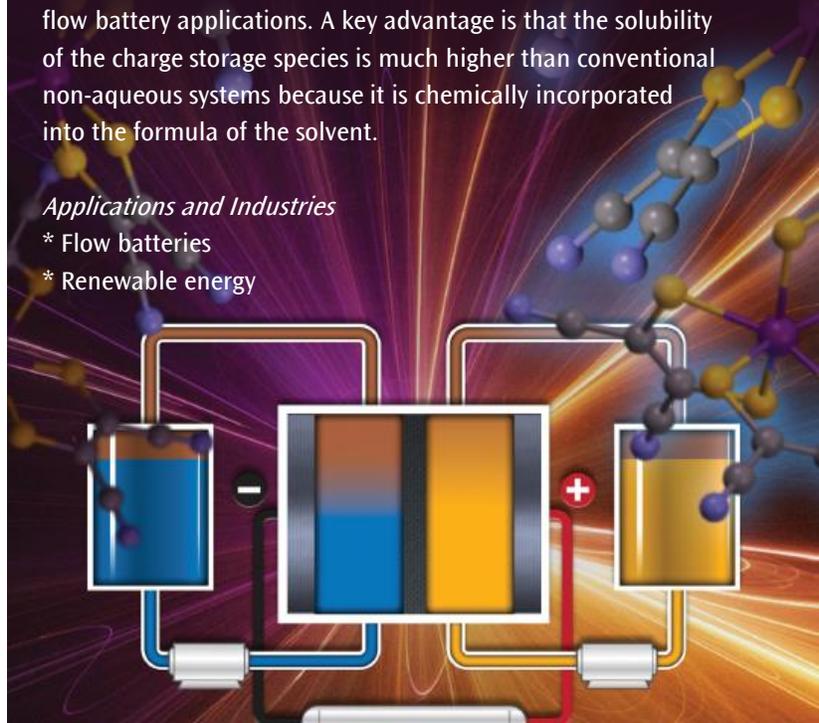
Numerous energy storage technologies have been proposed to meet the need of electrical grids with a high percentage of renewable energy sources. Among the many types of energy storage systems, reducing-oxidizing (redox) flow batteries have emerged as a promising approach. A growing area of research in redox flow batteries is directed toward developing non-aqueous electrolytes. Non-aqueous electrolytes offer wider voltage windows, higher charge cycle efficiency decreased temperature sensitivity, increased cycle life, and lower costs compared to current systems.

Transition metal-based systems have received the most attention, but limitations related to solubility, membrane permeability, and cell voltage have not resulted in rampant commercial success. Further advancements will have to come from the development of new redox chemistries, larger cell potentials, and fast redox kinetics. Sandia has improved on electrolyte development through the use of redox “non-innocent” metal-based compounds. This strategy makes use of the entire mass of the material. Non-innocent redox events also result in increased stability of the molecule by preventing redox-induced structural changes. Increasing stability over thousands of charge-discharge cycles will drastically reduce cost, putting this technology on par with current energy storage methods.

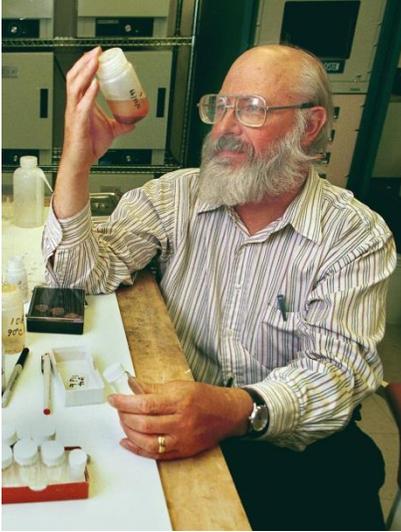
As an alternative to non-innocent metal complexes, Sandia has also developed a new family of redox-active ionic liquids for flow battery applications. A key advantage is that the solubility of the charge storage species is much higher than conventional non-aqueous systems because it is chemically incorporated into the formula of the solvent.

Applications and Industries

- * Flow batteries
- * Renewable energy



Environmentally friendly, low cost, and inherently safe
In-Situ Uranium Recovery provides more efficient
process for uranium removal and aquifer restoration



As uranium mining continues to grow in the United States, so does the concerns over its environmental impact. An approach that may alleviate some of these problems may be in situ recovery (ISR) of uranium which involves circulating reactive fluids through an underground uranium deposit. These

fluids contain chemical agents that dissolve the ore so uranium can be recovered once the fluid is pumped back to the surface. New and more stringent standards of uranium traces in drinking water are making mining operations more difficult and costly.

Sandia's technology package has four pieces that integrate a green "leaching" process that immobilizes uranium and other trace metals, a back up decontamination process, optimized well-field design that increases uranium recovery efficiency while reducing contaminated water, and finally a protocol for long-term monitoring. The process is environmentally friendly because the land surface is not degraded by mining or ore milling operations. The mobility of these pollutants can be tied to the artificial oxidizing condition imposed on the aquifer by the ISR activity. Our set of novel technologies will be used to re-impose reducing conditions on the aquifer once the mining process has been completed. This could potentially restore the aquifer to a suitable condition for regulatory bodies would be more inclined to sign off on final site closure plans.

Applications and Industries

- * Nuclear power & waste applications
- * Mining operations

Economical ***Fire-Resistant Activated Carbon***
reduces risk and environmental impact associated with
traditional activated carbon

Sandia has developed an economical and efficient activated carbon adsorbent for the trapping of noble gases including Argon, Krypton, Xenon and radioactive ⁸⁵Kr. Unlike currently used adsorbents, this superior material is fire-resistant with spontaneous ignition temperatures (SIT) of up to 860°C and favorable sorption capacity. This solution is simple, reliable, and affordable. The advanced forms of activated carbon are formulated by addition of certain amounts of hydrated stable solid phases, which can release crystalline water well below the ignition temperature of activated carbon if they are heated. Therefore, while the advanced forms of activated carbon have adsorption capacities comparable to activated carbon, the fire hazard of activated carbon is completely eliminated.

Activated carbon adsorbents have numerous industrial applications including chemical, petrochemical, environmental engineering, nuclear, military, and specialist extraction. In these industries, the activated carbon is used to control emissions of solvents, volatile organic compounds (VOCs) and other chemicals, with the reduced risk of spontaneous ignition and fire hazards.

Applications and Industries

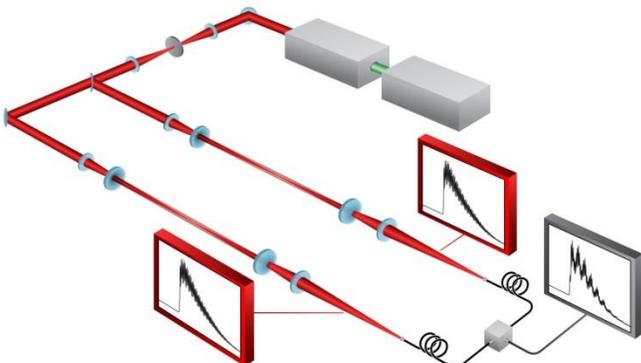
- * Mining
- * Nuclear power & fuel processing
- * Waste management
- * Water purification
- * Environmental cleanup
- * Medical
- * Chemical industry



Dual-Etalon Frequency-Comb Spectrometer provides compact, low-cost tool for identifying environmental contaminants

Absorption spectroscopy is the most quantitative and straightforward means of measuring the concentration and temperature of a species having a known spectrum. The primary criteria associated with using absorption spectroscopy, as an everyday tool for identifying environmental contaminants, are that large spectral bandwidths with good resolution are needed and high sensitivity is required. Sandia researchers have developed a compact, low-cost, simple spectrometer that will allow doing both high resolution and broad bandwidth spectroscopy simultaneously within only a few microseconds and requiring no special light source or electronics.

Sandia's new absorption-based spectrometer is capable of both high sensitivity and broad bandwidth coverage with high spectral resolution. The broadband light source (e.g., pulsed laser, LED, lamp) is split into two beam paths. One light travels through an etalon and a sample gas, while the other travels through the second arm of an etalon cavity, and the two beams are recombined onto a single detector. The resulting



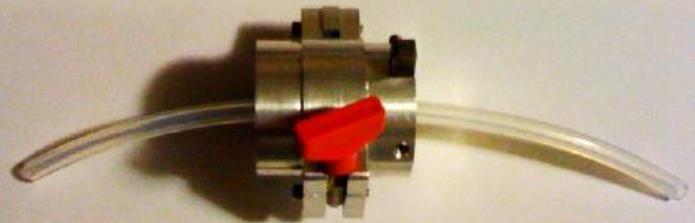
interference pattern is Fourier transformed to recover the spectrum of the sample. It has the high resolution over a broad bandwidth that is needed for chemical fingerprinting and the sensitivity of cavity ring-down spectroscopy.

Applications and Industries

- * Point sensor for monitoring combustion by-products, environmental pollutants, and warfare agents
- * Identification of unknown gases, liquids, and aerosols in either the laboratory or real-world applications
- * Monitoring of multiple species in reaction flow streams
- * Time-resolved multispectral imaging with nanosecond time resolution

Improved Grooving Tool can make a groove anywhere along tubing for a more secure connection

Sandia has developed an improved grooving tool for Teflon® or other plastic tubing. Grooving tools are used at the end of a tubing section to provide a better seal with compression fittings for connections to equipment. When used with a compression fitting, grooves can significantly increase the pressure rating of the tube to the fitting seal. Current tools can only be used to make grooves at the ends of tubing, while this new technology can make a groove anywhere along the tubing.



The new tool also allows for easy replacement of the tube grooving blades, an advancement from current grooving tools which do not allow for blade replacement once they become broken or have been exposed to corrosive chemicals.

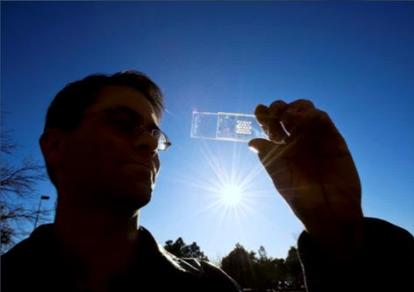
Applications and Industries

- * Industrial Equipment
- * Construction
- * Waste Management
- * Oil and Gas
- * Chemicals
- * Electric Utility

Microsystems Enabled Photovoltaics (MEPV): Solar Glitter™ Photovoltaic Technology

revolutionizes solar energy collection

2012 R&D 100 Award Winner



These tiny glitter-sized photovoltaic (PV) cells could revolutionize solar energy collection. Made from robust semiconductor materials, miniaturized PV generate clean

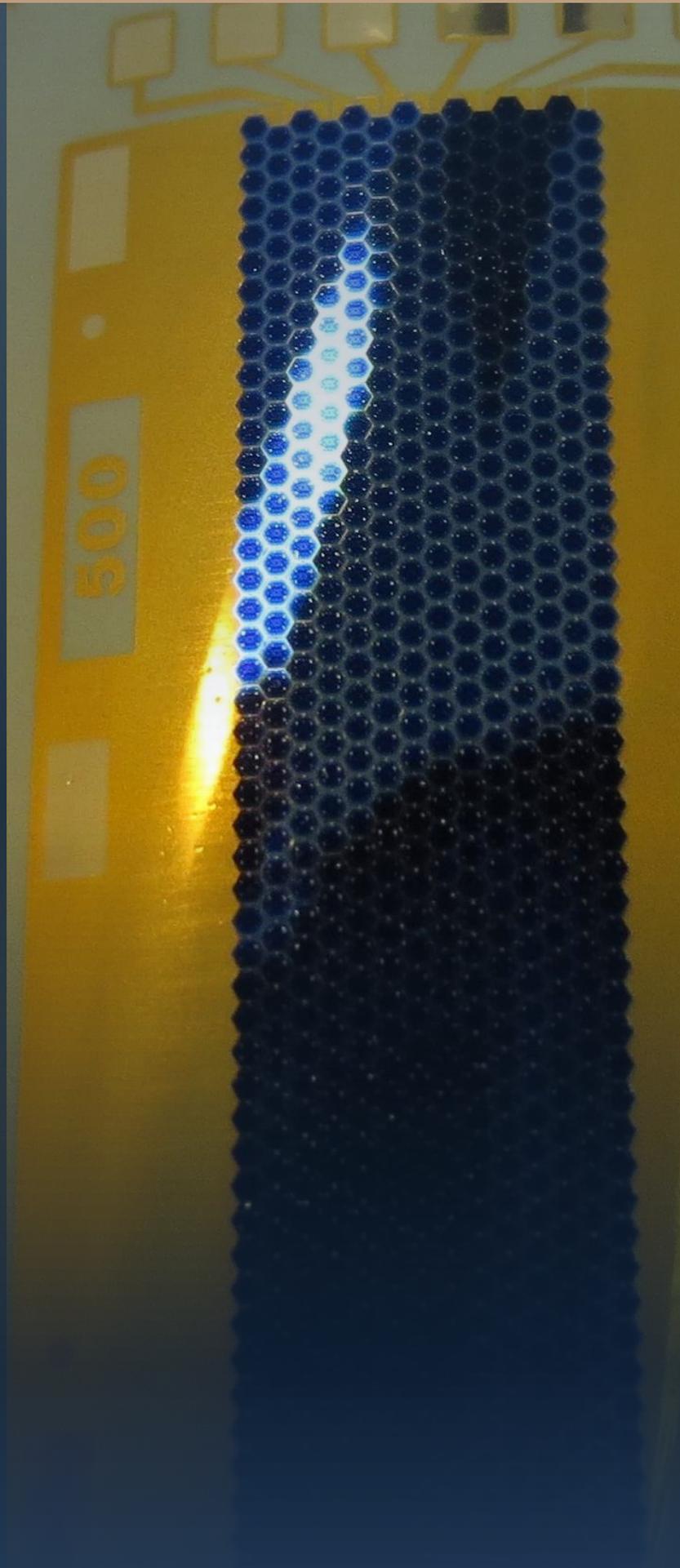
electricity that can work as safely, reliably, and durably as present day grid power, and can be cheaper than all other forms of energy.

Sandia's microsystems-enabled photovoltaics (MEPV) uses microdesign and microfabrication techniques to produce solar cells as small as 3-20 microns thick and 100-1000 microns wide. These PV cells are then placed or 'printed' onto a low-cost substrate with embedded contacts and microlenses for focusing sunlight onto the cells. Moving to micro-scale PV cell sizes results in distinct benefits at cell, module, and system levels, including reducing the amount of expensive semiconductors by 30 times while still achieving high efficiencies.

MEPV solar power systems can have impact in both mobile and stationary power applications. At the system level, the large number of individual micro-PV cells can be interconnected to tailor voltage and current output to meet system requirements. The flat panel profile with micro-optical focusing further simplifies sun tracking, reducing both the cost and complexity of the solar concentrating design.

MEPV units can be placed into flexible sheets that could wrap around unusual shapes for solar power integrated into buildings, tents, and maybe even clothing. Rooftop micro-PV modules could have intelligent controls, inverters, and even storage built into the chip—simplifying the grid-integration process.

Put together, glitter-sized photovoltaic cells become the building blocks for generating electricity in a new, efficient, versatile, and inexpensive way—the powering of anything could become as simple as exposing it to light.



*Small, robust **Wireless Passive Radiation Sensor** gives immediate real-time warning of radiation doses using a portable, inexpensive transceiver*

Existing small radiation detectors do not produce an immediate real-time warning of radiation doses because the detectors need to be sent to a lab for readout, which can require days or weeks to complete. Other detectors are fragile, need human interpretation of colors, cost hundreds of dollars each or are not easily mass produced. Therefore, a need remains for a wireless passive radiation sensor that can remotely detect radiation using a portable, inexpensive transceiver.

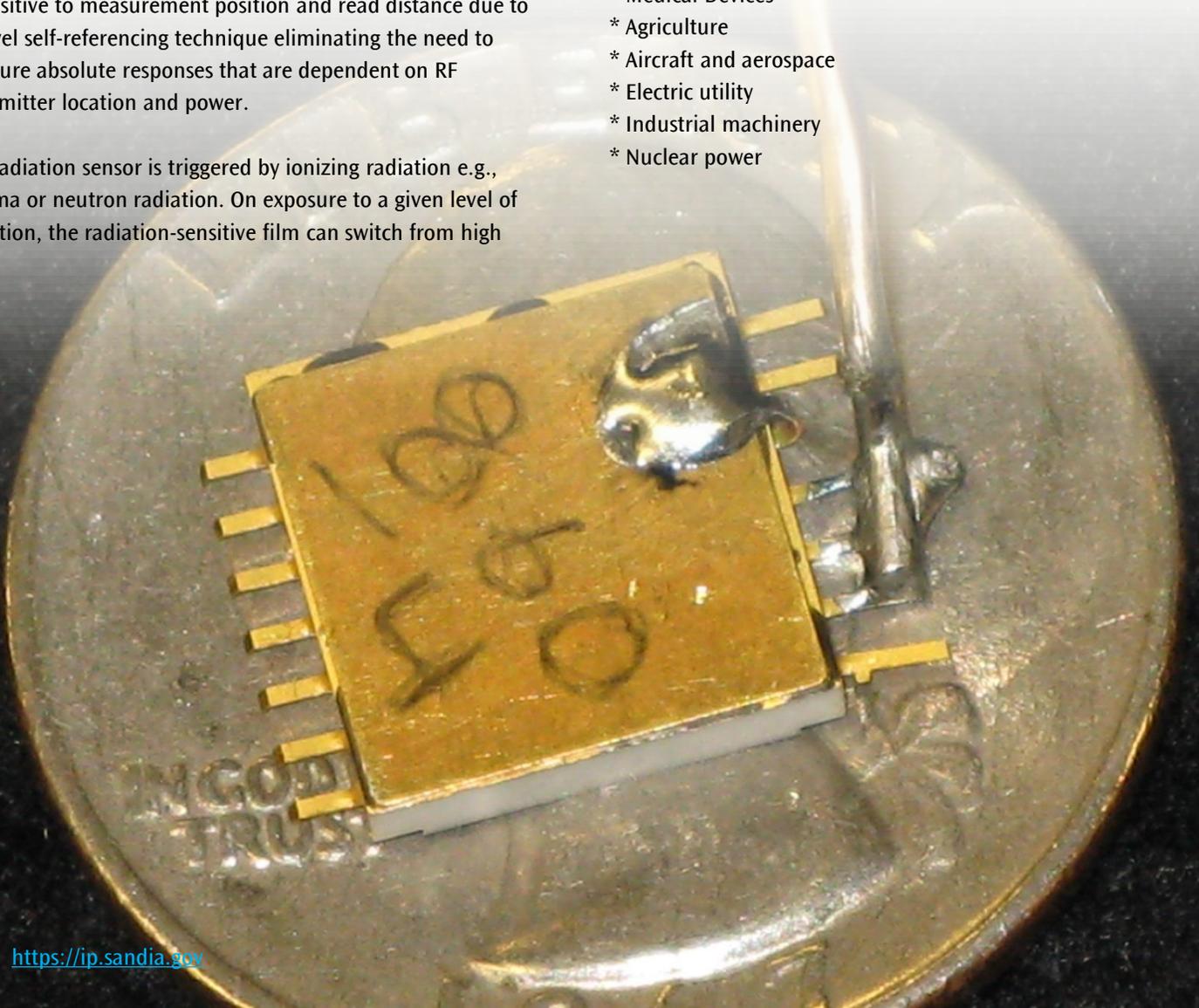
A novel measurement technique is employed using surface acoustic wave (SAW) devices, passive RF, and radiation-sensitive films to provide a wireless passive radiation sensor that requires no batteries, outside wiring, or regular maintenance. The sensor is small ($<1 \text{ cm}^2$), physically robust, and will operate unattended for decades. In addition, the sensor can be insensitive to measurement position and read distance due to a novel self-referencing technique eliminating the need to measure absolute responses that are dependent on RF transmitter location and power.

The radiation sensor is triggered by ionizing radiation e.g., gamma or neutron radiation. On exposure to a given level of radiation, the radiation-sensitive film can switch from high

resistance (e.g., $>10^5 \Omega$) to low resistance (e.g., $<10^2 \Omega$). The radiation-sensitive film forms catalytic sites when electrons are ionized from the molecules due to a radiation event and the resulting cascade reaction converts the initially dielectric film to a conductive metallic film. This response covers several orders-of-magnitude change in resistance after a minimum radiation threshold is reached. The sensor is analogous to a 'smoke detector' in that it detects either the presence or absence of radiation but also retains the exposure information after the radiation is gone like a radiation dosimeter. The sensor is comprised of non-moving parts, RF monitor, sensor film, and sensor chemistry, enclosed in a robust package. The advantage of this radiation sensor is its size, simplicity, and immediate response. The sensors do not require batteries that add unacceptable mass and maintenance to the structure or wires to retrieve the data, enabling remote sensing.

Applications and Industries

- * Health care
- * Medical Devices
- * Agriculture
- * Aircraft and aerospace
- * Electric utility
- * Industrial machinery
- * Nuclear power

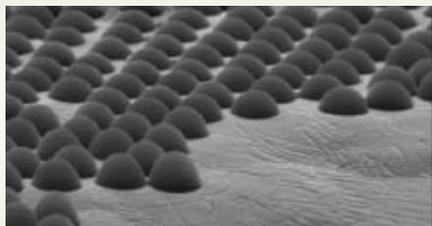


Low cost method for **Nitride Growth and Liftoff** uses microsphere layers to reduce crystal defects in LED displays by over 90%



Increase Building and Industrial Efficiency

The LED market is one of the fastest growing markets worldwide, driven by demand for clean solid state lighting, LED displays and mobile devices. GaN-based materials are essential components of these technologies. Due to the very high cost and lack of availability of bulk GaN substrates, current GaN production methods rely on silicon, sapphire or silicon carbide substrates. These low-cost substrates suffer from a large number of defects, which limit efficiency and lead to early device failure.



GaN partially grown through sphere



LED device made from templated films

Sandia has developed an elegant and inexpensive method for the growth and removal of low-defect density GaN using microsphere layers. In contrast to current methods for GaN dislocation reduction involving lithographically patterned masks, this new method does not require

lithography and produces uniform material over the entire wafer. This method can also lift-off GaN-on-GaN substrate devices. Benefits include low cost, reduced crystal defects by over 90%, and easy substrate removal.

Applications and Industries

- * LED displays
- * Laser diodes
- * Solid-state lighting
- * High power transistors
- * Mobile devices

Sandia Wave Reflector improves gain performance for wireless transmission

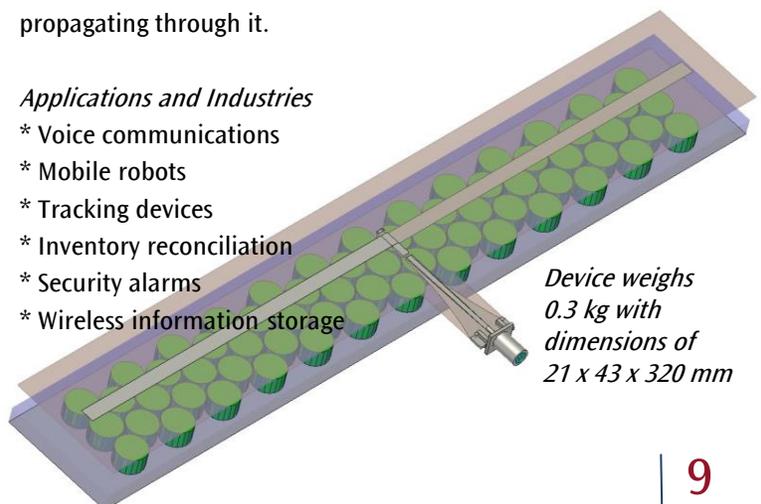
The Sandia Wave Reflector is a magnetic conductor for wireless transmissions near 433 MHz. The device reflects perpendicular electromagnetic waves in-phase and suppresses surface waves resulting in improved gain performance and effective operation regardless of physical placement.

The reflector achieves gain improvement through a quarter-wave short phenomenon. The height of the ceramic rods is electrically equivalent to a quarter-wavelength near 433 MHz. The rods are able to provide this electrical delay in a small form factor due to their high dielectric constant. As an electromagnetic wave travels through the rods along their axes it receives a 1/4 period of phase delay before it reaches the conductive short. The conductive backing reflects electromagnetic waves with a +180° phase, and then the waves travel back through the rods along their axes to receive another 1/4 period of phase delay. This causes the waves to arrive at the antenna surface with a +180° phase and a 1/2 period delay, creating positive interference that effectively doubles the gain of the antenna.

Placement-immunity is achieved in the reflector through surface wave suppression. By preventing surface waves from propagating out of the substrate (perpendicular to the main beam direction), they cannot interact with the surrounding environment and affect the antenna's performance. Surface wave suppression is achieved through the magnetic dipole resonance of the ceramic rods. When an electromagnetic wave near 433 MHz excites the dielectric rods in the substrate with a transverse electric field polarization, the permeability of the dielectric rods skyrockets at that frequency due to the rod's resonance. The large permeability of the rods in resonance creates a high impedance surface for the incident electric field, which causes the wave to reflect off of the rod instead of propagating through it.

Applications and Industries

- * Voice communications
- * Mobile robots
- * Tracking devices
- * Inventory reconciliation
- * Security alarms
- * Wireless information storage



Device weighs 0.3 kg with dimensions of 21 x 43 x 320 mm

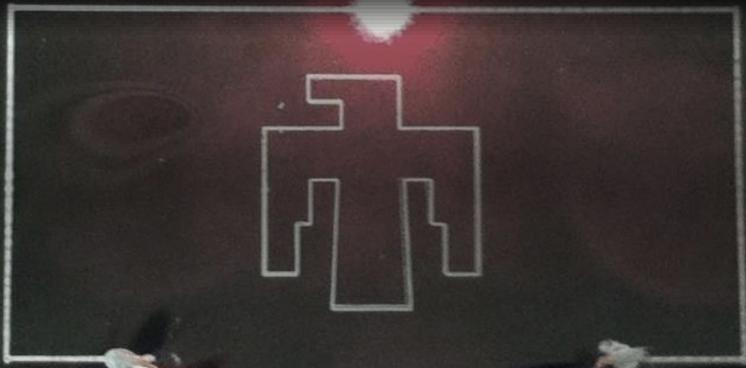
Ultra-Low Temperature Curing Silver Ink for conductor printing provides long-term stable ink without the use of silver flake, nanoparticles, and surfactants

Many applications require the ability to print conductors on devices that cannot tolerate high temperatures. Current methods for making printable conductors generally consist of silver nanoparticles or silver flake suspended in a suitable solvent amenable to printing. These silver metal suspension formulations require high processing temperatures to sinter the particles (180 °C). They leave behind unwanted by-products (usually surfactants) and demonstrate significantly reduced performance at high frequency due to voids remaining in the printed line after thermal processing. These nanoparticle and flake suspensions also tend to precipitate, resulting in shortened shelf life and clogging in certain printing operations.

Sandia has developed a superior process for creating ultra-low temperature curing silver inks. This technology is specifically designed to avoid the use of silver flake, nanoparticles, and surfactants. This system is a silver solution consisting of a silver complex with high silver content. The solvated silver complex exhibits good stability in relatively innocuous solvents and has a very low decomposition temperature (<140 °C). It produces pure silver with no residues after the curing process. The formulation provides for a long-term stable ink, volatile residues during processing, and a lower processing temperature.

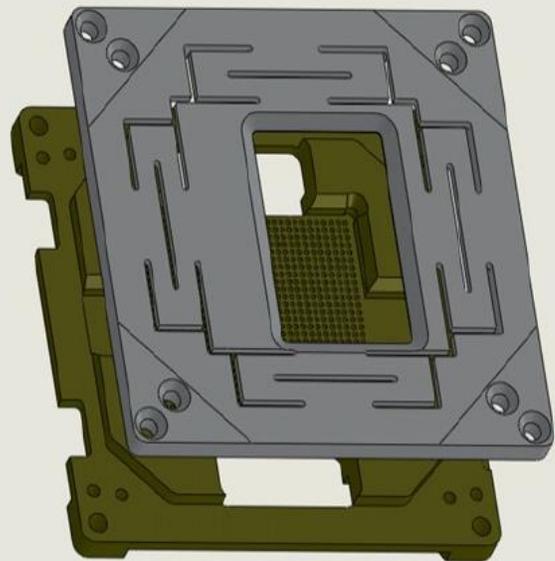
Applications and Industries

- * Printable/Thin film battery applications
- * Conductive polymer contacts for printable electronics
- * Thin photovoltaic systems
- * Conductors on flexible polymer substrates for antenna applications



Superior Push Plate addresses shortcomings of current ball grid array (BGA) socket clamping methods

Sandia has developed a low profile, controlled force, minimal torque push plate for ball grid array multi-chip module (MCM) test sockets. The ball grid array (BGA) is an enabling technology for multi-chip modules, a significant improvement over pin grid arrays. Traditional pin grid array technology suffers from physical limitations; as package pins get closer together, the risk of accidentally bridging adjacent pins with solder increases. In a BGA, the pins are replaced by balls of solder on the bottom of the multi-chip module. The solder balls are melted to a printed circuit board and surface tension maintains the necessary alignment while the solder cools and ultimately solidifies. Before melting the solder balls, test sockets are used to probe the MCM, allowing testing and troubleshooting, but current test sockets are not always reliable.



Sandia's superior push plate addresses shortcomings of current BGA socket clamping methods. Existing methods to clamp the MCM to these temporary sockets are unreliable and block access to the module. Sandia's superior push plate incorporates cantilevers to provide stiffness, allowing a uniform, calibrated downward force and minimizing torque while providing access to the MCM components. This is achieved both by minimizing thickness and moving the mechanism responsible for the down force (the cantilevers) to the perimeter area outside the area of the MCM.

Applications and Industries

- * Microelectronics
- * Semiconductor manufacturing



***Sandia Hand** addresses challenges that have prevented widespread adoption of other robotic hands, such as cost, durability, dexterity, and modularity*

Sandia has developed a cost-effective robotic hand that can be used in disarming improvised explosive devices, or IEDs. The Sandia Hand is low-cost, dexterous, and modular enabling it to support a variety of applications including:

- * Counter-IED
- * Countermine
- * Explosive ordnance disposal
- * Search and rescue
- * Casualty care
- * Extreme environments

The Sandia Hand consists of a hand frame that supports a set of identical finger modules that magnetically attach and detach from the hand frame. The finger modules consist of several sensor systems that enable the hand to perform complex manipulation tasks and is supported by several imaging systems to increase function and performance. Control of the hand is realized through autonomous software, semi-autonomous collaboration with high-level human input, and low-level human control via teleoperation.

The Sandia Hand has enabled significant cost reductions by employing 3D high-resolution rapid prototyping technologies for low volumes, ensuring each component is amenable to injection molding for high volumes, and designing around components found in large consumer markets. The low-cost robotic hand is designed with four 3 Degree of Freedom (DOF) fingers to enable dexterous tasks such as finger gating while still maintaining form closure. In addition, the Sandia Hand is modular. It's hand frame has identical finger modules that attach through magnetic attachment with electrical power and communications achieved through spring contacts. Power to each finger socket is actively controlled, permitting hot swapping of finger modules. The system design provides multiple benefits, including mechanical breakaway of fingers from palm in overload conditions, reduced down time for customizations and repair, pluggable tools (e.g., screw driver, forceps, sensors, etc.), and limitless variations in palm geometry.

Security & Asset Management

RAZAR provides an instantaneous, push-button zoom that exceeds traditional (moving lens) zoom rifle scopes
2014 R&D 100 Entry

Traditional zoom imaging requires the mechanical movement of two or more optical elements along the optical axis, as is done in 35mm cameras or conventional, variable-power riflescopes. Adaptive zoom is a revolutionary method whereby true optical zoom is accomplished by cooperatively varying the focal lengths of multiple active optical elements in the system. Sandia has demonstrated and patented this using various optical elements, including liquid crystal (LC) spatial light modulators, adaptive lenses, and deformable mirrors. This technology is ideal for any imaging system that requires extremely fast, variable magnification but is limited by size, weight, and power (SWaP) constraints.

The U.S. Military requested a compact zoom riflescope, capable of rapidly toggling between magnification at the push of a button without changing the grip on the weapon or losing sight picture. The Rapid Adaptive Zoom for Assault Rifles (RAZAR) filled this request. RAZAR can zoom in milliseconds and perform 10,000 actuations on two AA batteries. The weight, power, and speed requirements for mechanical zoom make them prohibitive. RAZAR allows target engagement at diverse ranges and provides several distinct advantages including speed and high resolution at varying distances.



RAZAR, and its component lenses, are market leaders from a performance standpoint. The variable-focal length lenses we developed, and which are at the heart of the Adaptive Zoom concept, have the following distinguishing characteristics, relative to similar lenses:

- * Mil-Spec Shock/Vibration/Temperature (per MIL-STD-810G)
- * Largest Dynamic Range (Diopters/Focal Length)
- * Largest Usable Clear Aperture (Actuated)
- * Largest Clear Aperture/Outer Diameter Ratio
- * Temperature Compensation (Focal Length vs. Radius of Curvature)
- * Best Image Quality (Wavefront Error—WFE)

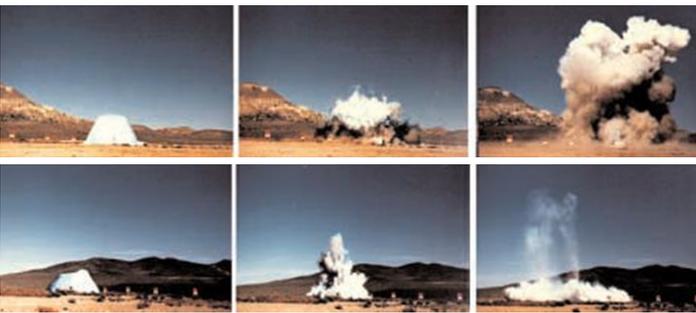
RAZAR provides instantaneous, push-button, zoom in a form factor that meets or exceeds traditional (moving lens) zoom rifle scopes.

Applications and Industries

- * Rifle scopes
- * Spotting scopes
- * Monoculars and binoculars

*2% concentrate of **Blast Mitigation Foam** achieves greater expansion ratio and foam stability than AFC-380*

The current emergency response to a terrorism attack involving a radiological dispersion device is a blast suppression and dispersion mitigation foam. The foam is deployed over the radiological dispersion device to fully cover it. If the device is activated, the foam will reduce the blast overpressures, which will reduce collateral damage caused by the blast. The foam currently requires fifty, five-gallon drums of a foam concentrate called AFC-380, which can be a logistical and weight burden to emergency responders. In order to reduce the burden on the user, Sandia has developed a highly concentrated foam formulation that can be used for blast suppression and dispersion mitigation in responding to a terrorism event that involves a radiological dispersion device.



Blast Tests

*Top: Without foam mitigation
Bottom: With the foam mitigation*

The new formulation has a 2% foam concentrate and has a greater expansion ratio and higher foam stability than AFC-380. In order to make 100 gallons of finished product, the new formulation only requires 2 gallons of foam concentrate, compared to the 6 gallons of the AFC-380 foam concentrate. This difference reduces the weight and logistical burden on the user by approximately 67%.

Applications and Industries

- * Homeland security
- * Public safety
- * Emergency first responders
- * Local and federal agencies
- * Military applications

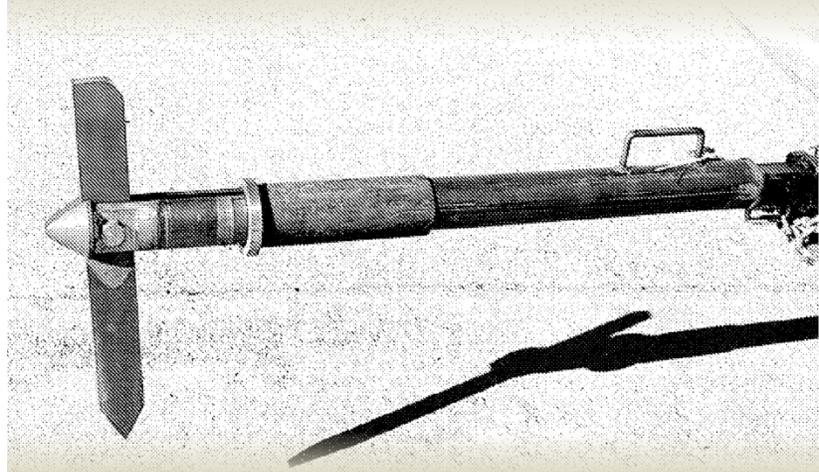
***Vehicle-Assisted Harpoon for Breaching** enables rapid, forced entry into structures*

There is a need for a way to ensure rapid, forced entry into a structure for police, firemen, SWAT teams, and security officers. Current commercially available methods, including cutting saws, spreading tools, explosive devices, and “burning” devices are often extremely noisy, have significant time-delay, present potential fire hazards, and require the close-proximity of personnel.

Sandia has developed a harpoon tool that allows law enforcement personnel to breach metal doors or walls within seconds. Because this tool can be mounted to a vehicle’s standard receiver hitch, danger to personnel can be mitigated. Also, because explosives are not used, the risk of a fire drops significantly. The harpoon works by first driving the vehicle toward the structure and penetrating the wall/door with the harpoon. Once the harpoon has entered the structure, the pivot blade can be released, essentially “hooking” the inside of the wall/door with the tip. The vehicle can then reverse direction, taking with it the door or a section of the wall thereby allowing law enforcement to enter the premises quickly (within seconds) of attempting to breach the structure.

Applications and Industries

- * Law enforcement agencies
- * Fire departments
- * Security personnel



Medical Applications & Bioscience

Automated Molecular Biology Platform enables the genomic sequencing revolution through automated sample preparation 2012 R&D 100 Award Winner

The advent of next generation DNA sequencing (NGS) technology represents a quantum leap in the field of genetic analysis: what once required a decade-long, multibillion dollar Human Genome Project can now be reproduced in 1-2 weeks time for less than \$5,000. Despite advances in sequencing technology, upstream library (sample) preparation protocols, which require numerous sample processing steps and hours of hands-on laboratory time, have not benefitted from comparable increases in speed or efficiency. While automation of the library preparation process can help overcome this



widely recognized bottleneck, current approaches rely on large and expensive pipetting robots designed for use in dedicated high-throughput sequencing facilities.

To fully realize the promise of next generation sequencing for more ubiquitous, individualized, decentralized applications such as personalized genomic medicine, point-of-care diagnostics, public health screening, and DNA forensics, technologies automating NGS sample preparation must also become more affordable and accessible. To address this need, our Sandia team has developed an Automated Molecular Biology (AMB) system enabling the cost-effective automation of complex protocols like NGS library preparation and other labor-intensive bioanalytical procedures and processes.

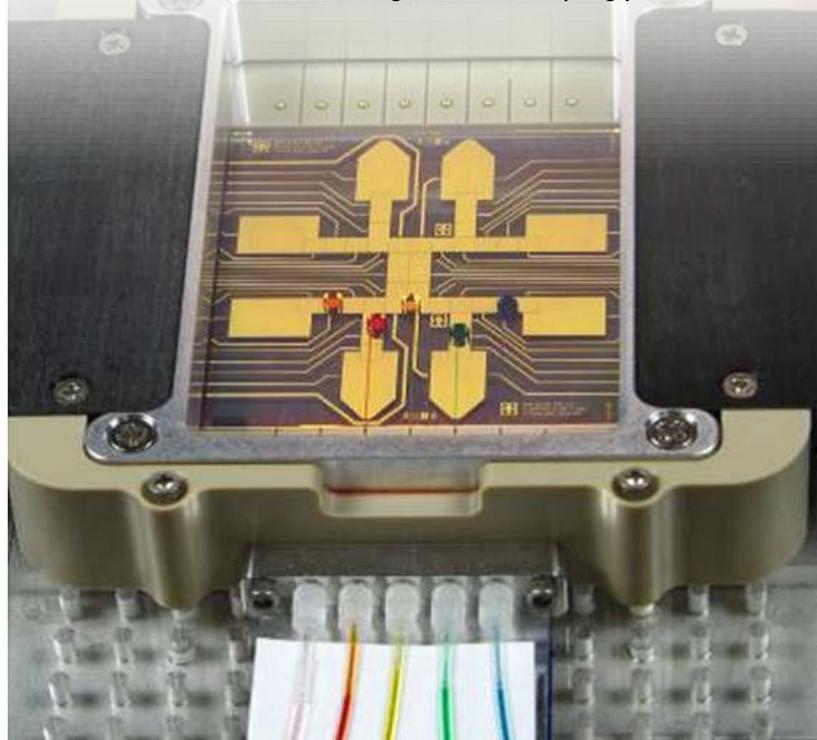
The heart of the AMB system is a unique droplet-based digital microfluidic (DMF) platform which functions as a central hub for the distribution and routing of samples and reagents. Digital microfluidic technology uses electrostatic and electrowetting forces to manipulate microliter-scale droplets sandwiched between closely spaced, hydrophobically coated substrates patterned with individually addressable electrodes. These devices enable discrete droplet movement and droplet operations such as merging, splitting, mixing, and aliquotting to be performed at scales much smaller than what can be conventionally achieved. Accordingly, our DMF platform functions instead as a sample distribution and reagent

interface hub and fills a role equivalent to that of a pipetting robot in a high-throughput laboratory automation workflow, but at a fraction of the size, cost, and complexity.

The central innovation of our digital microfluidic platform was the development of a custom manifold frame providing self-aligning registration of top and bottom DMF substrates to achieve the precise tolerances required for reliable DMF operation. The open architecture of the frame enables access to the interior of the DMF device by in-plane transfer capillaries. This capillary interface allows liquid to be transferred to and from the DMF device with nanoliter precision using external syringe pumps, providing not only a method for coupling the DMF platform to external modules, but also the means to execute a variety of advanced on-platform operations including serial dilution, droplet subsampling, chaotic mixing, fraction collection and sorting, magnetic bead manipulations, and sample archiving. The AMB system is completed by integrating this adaptable digital microfluidic platform, its high-voltage control electronics, supporting syringe pumps, and functional submodules with a PC-based user interface enabling coordinated control and script-based automation of all sample preparation operations. We estimate that the full AMB platform including all supporting hardware and software will cost less than \$3,000 per unit.

Applications and Industries

- * Public health – rapid threat organism recognition system
- * Forensics – automated DNA analysis and sampling system
- * Biosurveillance – advanced diagnostic and sampling platform



Software

ParaView can quickly build visualizations to analyze data using qualitative and quantitative techniques

ParaView is an open-source, multi-platform data analysis and visualization application. ParaView users can quickly build visualizations to analyze their data using qualitative and quantitative techniques. The data exploration can be done interactively in 3D or programmatically using ParaView's batch processing capabilities.

ParaView was developed to analyze extremely large datasets using distributed memory computing resources. It can be run on supercomputers to analyze datasets of terascale as well as on laptops for smaller data.

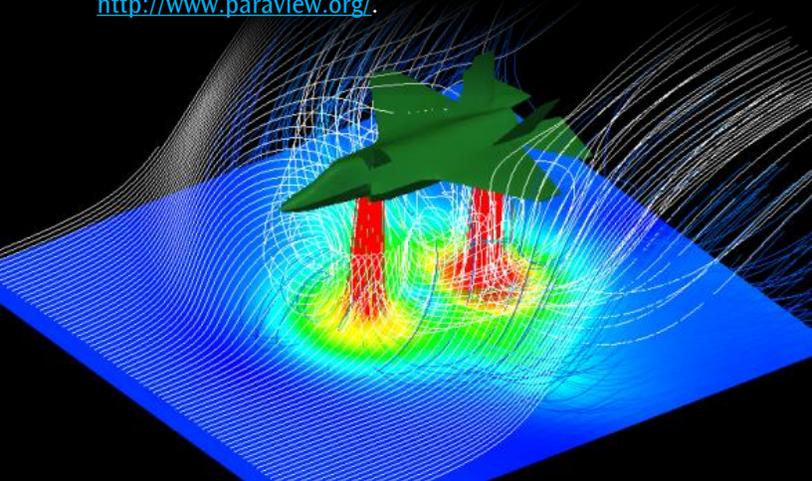
ParaView is an application framework as well as a turn-key application. The ParaView code base is designed in such a way that all of its components can be reused to quickly develop vertical applications. This flexibility allows ParaView developers to quickly develop applications that have specific functionality for a specific problem domain.

ParaView runs on distributed and shared memory parallel and single processor systems. It has been successfully tested on Windows, Mac OS X, Linux, IBM Blue Gene, Cray Xt3 and various Unix workstations, clusters and supercomputers. Under the hood, ParaView uses the Visualization Toolkit (VTK) as the data processing and rendering engine and has a user interface written using Qt®.

Applications

- * *Scientific and information visualization*
- * *3D computer graphics*
- * *Image processing*
- * *Modeling*
- * *Volume rendering*

ParaView is free and available to the public at <http://www.paraview.org/>.



Coopr supports a diverse set of optimization capabilities for formulating and analyzing optimization models



Coopr is a collection of Python software packages that supports a diverse set of optimization capabilities for formulating and analyzing optimization models.

A key driver for Coopr development is Pyomo, an open source tool for modeling optimization applications in Python. Pyomo can be used to define symbolic problems, create concrete problem instances, and solve these instances with standard solvers. Thus, Pyomo provides a capability that is commonly associated with algebraic modeling languages like AMPL and GAMS.

Coopr has also proven an effective framework for developing high-level optimization and analysis tools. For example, the PySP package provides generic solvers for stochastic programming. PySP leverages the fact that Pyomo's modeling objects are embedded within a full-featured high-level programming language, which allows for transparent parallelization of subproblems using Python parallel communication libraries.

Applications

- * *Formulate algebraic models within Python's modern programming language*
- * *Generic solvers for stochastic programming problems*
- * *Customize MIP solvers to expose model structure to the MIP solver engine*

Coopr is free and available to the public at <https://software.sandia.gov/trac/coopr>.

Trilinos delivers a wide array of capabilities ranging from basic linear algebra to time integrators
2004 R&D 100 Award Winner

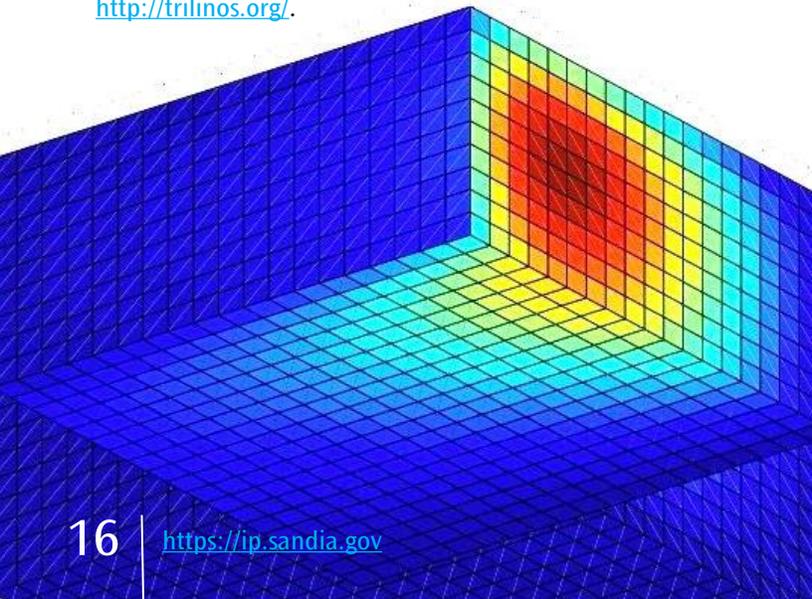
The Trilinos Project is an effort to develop and implement robust algorithms and enabling technologies using modern object-oriented software design, while still leveraging the value of established libraries such as PETSc, Metis/ParMetis, SuperLU, Aztec, the BLAS and LAPACK. It emphasizes abstract interfaces for maximum flexibility of component interchanging, and provides a full-featured set of concrete classes that implement all abstract interfaces.

Because of the tools and infrastructure that Trilinos provides, the degree of effort required to develop new algorithms and enabling technologies has been substantially reduced because our common base provides an excellent starting point. Furthermore, many applications are standardizing on the Trilinos APIs. As a result, these applications have access to all Trilinos solver components without any unnecessary interface modifications.

Algorithmic Areas

- * Automatic differentiation
- * Data partitioning for load balance and robustness
- * Multi-level preconditioners
- * Block iterative methods (linear and eigen solvers)
- * Incomplete factorizations
- * Solution of linear systems with successive and simultaneous right-hand-sides
- * Nonlinear methods including continuation
- * Large-scale optimization, e.g., SAND
- * Time integration methods

Trilinos 11.6 is free and available to the public at
<http://trilinos.org/>.



BIOGEOCHEM 2.1 environmental analysis software helps design and optimize laboratory experiments

BIOGEOCHEM Ver. 2.1 conducts environmental analysis, bioremediation, performance assessments of radioactive and non-radioactive waste disposal. The Fortran code numerically simulates the coupled process of solute transport, microbial population dynamics, microbial metabolism, and geochemical reactions. BIOGEOCHEM Ver. 2.1 utilizes a finite difference method and a Newton-Raphson technique to solve a set of coupled nonlinear partial differential equations and algebraic equations.

Applications

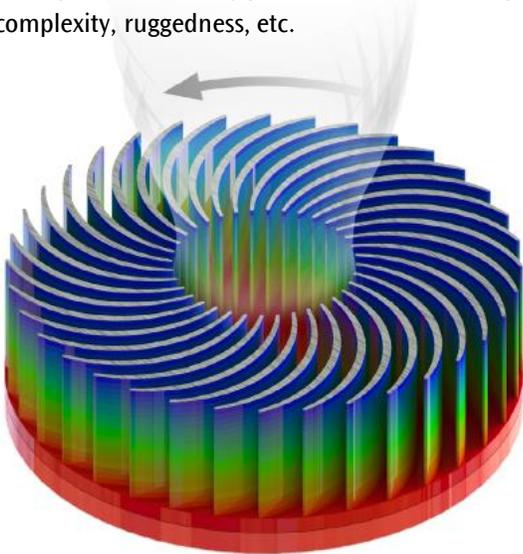
- * Sensitivity and uncertainty analyses for assessing impact of microbial activity on subsurface geochemical systems
- * Extraction of biogeochemical parameter values from field observations or laboratory measurements
- * Design and optimize laboratory biogeochemical experiments
- * Data integration



Highlights from Past Issues

Sandia Cooler provides dramatic increase in cooling performance with simple, cost-competitive design 2012 R&D 100 Award Winner

In a conventional CPU cooler, the heat transfer bottleneck is the boundary layer of "dead air" that clings to the cooling fins. This insulating layer is largely unaffected by the impinging airflow generated by the fan. The Sandia Cooler architecture simultaneously eliminates drawbacks of conventional air-cooled heat exchanger technology. The cooler provides a several-fold reduction in boundary layer thickness, intrinsic immunity to heat sink fouling, and drastic reductions in noise. It is also expected to be very practical from the standpoints of cost, complexity, ruggedness, etc.



In this new device architecture, heat is efficiently transferred from a stationary base plate to a rotating (counterclockwise) structure that combines the functionality of cooling fins with a centrifugal impeller. Dead air enveloping the cooling fins is subjected to a powerful centrifugal pumping effect, providing a 10x reduction in boundary layer thickness at a speed of a few thousand rpm. Additionally, high-speed rotation completely eliminates the problem of heat exchanger fouling. The "direct drive advantage", in which relative motion between the cooling fins and ambient air is created by rotating the heat exchanger, provides a drastic improvement in aerodynamic efficiency. This translates to an extremely quiet operation. The benefits have been quantified on a proof-of-concept prototype.

Applications and Industries

- * Laptops
- * High performance "gaming" PCs and video game boxes
- * Automotive
- * LED lighting
- * HVAC and large appliances

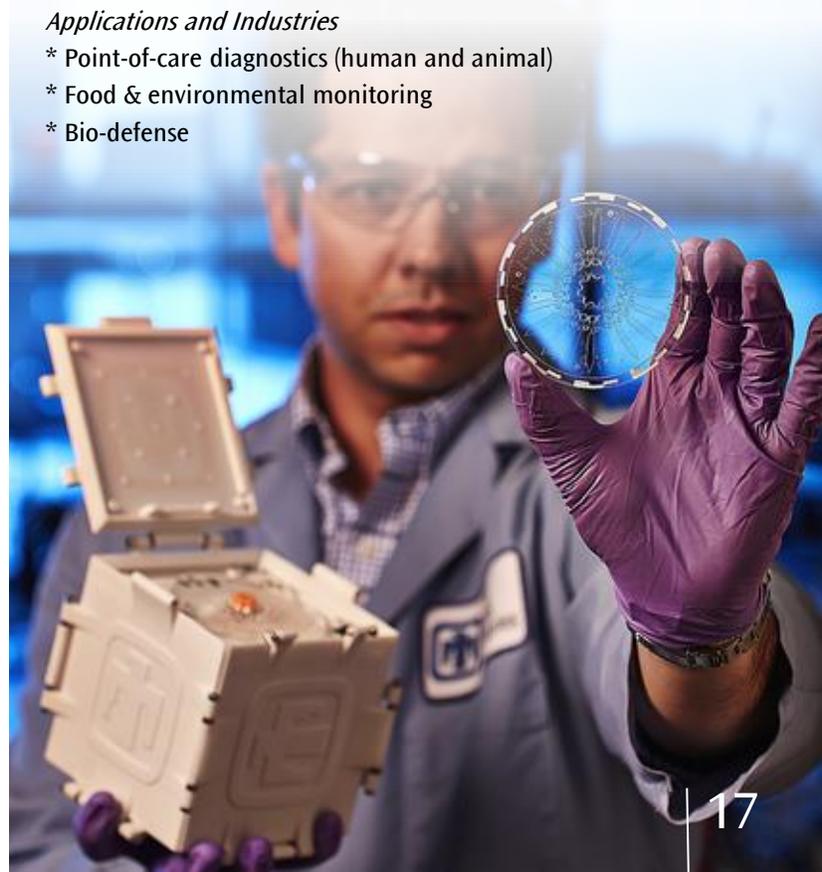
Faster, less expensive SpinDx™ point-of-care diagnostics prototype detects heart attacks, strokes, infections, certain cancers and other afflictions days or weeks sooner than previously possible

Currently, when a patient arrives at the hospital or doctor's office feeling ill, they are first examined by the doctor, sent to a blood lab where vials of blood are taken, and then sent home to wait for results. This approach often means patients must wait days or weeks, to get results. During that waiting period, they are not receiving treatment, which can be a critical factor for cancer, heart attack, or stroke patients. Sandia researchers have developed a break-through technology which can test and diagnose up to 64 assays on a single disc within 15 minutes of sample collection.

SpinDx™ can revolutionize the way we get test results from doctors' offices and hospitals alike. It requires significantly less blood (less than a pin-prick) than the current laboratory blood draw. Besides the inherent portability of the testing device, the assay discs can be manufactured for pennies, making this an affordable option for both small and large practices with the potential to drive down the cost of testing, visits, and to shorten time-to-treatment. This technology has broad application beyond medical diagnostics. It can be broadly applied across food safety, over bio-terrorism detection, and commercial drug testing markets.

Applications and Industries

- * Point-of-care diagnostics (human and animal)
- * Food & environmental monitoring
- * Bio-defense



Silicon Micromachined Dimensional Calibration Artifact for Mesoscale Measurement Machines improves measurement accuracy while reducing manufacturing costs
2008 R&D 100 Award Winner

With increasing miniaturization in manufacturing (such as nozzles in fuel injectors, watch parts, inkjet printer parts, or other small-scale parts), it is necessary to improve inspection accuracy while maintaining the ability for high-volume manufacturers to inspect at high speeds. The accuracy of vision metrology systems used to inspect these small-scale parts is limited by the accuracy of the calibration artifact.

The Micromachined Dimensional Calibration Artifact for Mesoscale Measurement Machines has both lower cost and up to ten times better accuracy than other vision calibration artifacts. Purchasing, installing, and qualifying new equipment is expensive. With Sandia's artifact, a user can improve their accuracy by simply recalibrating their equipment, using the Silicon Micromachined Dimensional Calibration Artifact as the calibration standard. The user would operate and calibrate their equipment in the same fashion as before, and potentially improve inspection accuracy by a factor of ten. Its three-dimensional nature provides a new capability for multi-sensor system calibration.

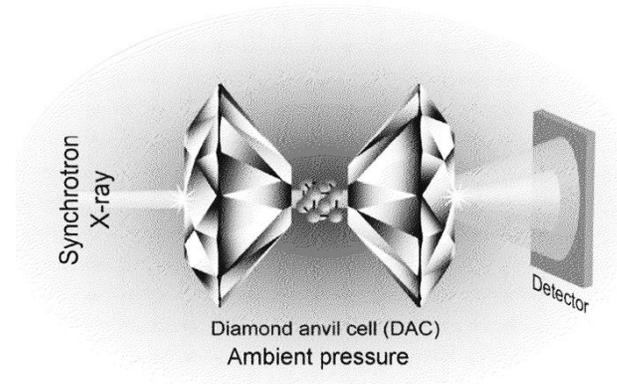
Applications and Industries

- * Calibration of vision-based inspection equipment
- * Calibration of hybrid/multi-sensor inspection systems
- * Calibration of micro-coordinate measuring machines



Stress-Induced Nanofabrication technique synthesizes uniform semiconductor nanostructures
2014 R&D 100 Entry

Stress-Induced Nanofabrication is a mechanical compression method for the synthesis of uniform semiconductor nanostructures including nanorods, nanowires, and nanosheets. Due to the size- and shape-dependent properties, nanoparticles have been successfully used as functional building blocks to fabricate multi-dimensional ordered assemblies for the development of 'artificial solids' (e.g., metamaterials) with potential applications in nanoelectronic and optic devices. To date, fabrications of ordered nanoparticle assemblies have relied on specific interparticle chemical or physical interactions such as Van der Waals interactions, dipole-dipole interaction, chemical reactions, and DNA-templating. The consequent self-assembly scenario is the formation of higher dimensional nanoparticle architectures from single nanoparticles.



Stress-Induced Nanofabrication is a technique used to make nanostructures by preparing a face centered cubic-ordered metal nanoparticle film from metal nanoparticles, such as gold and silver nanoparticles, and exerting a hydrostatic pressure upon the film at pressures of several gigapascals. The initial exertion is followed by a non-hydrostatic stress that is applied perpendicularly at a pressure greater than approximately 10 GPa. This forms an array of nanowires with individual nanowires having a relatively uniform length, average diameter and density.

Applications and Industries

- * Nanostructure fabrication
- * Semiconductor nanostructures
- * Optic devices
- * Nanoelectronics

Mantevo pioneers miniapp concept
2013 R&D 100 Award Winner

The Mantevo project is an effort to provide open-source software packages for the analysis, prediction and improvement of high performance computing applications.

Mantevo is an integrated collection of small software programs (miniapps) that model the performance of full-scale applications, yet require code only a fraction of the size of the full application. The Mantevo project pioneered the miniapp concept, and Mantevo is the first integrated collection of full-featured miniapps. Miniapps have emerged as central components of computer system co-design in an era of rapid architectural changes. Major companies like Intel, IBM, NVIDIA, AMD, and Cray, along with universities and national laboratories, use miniapps for rapid design-space exploration in the development of the next generation of high-performance computers.

Application Domains

- * Implicit and Explicit unstructured partial differential equations
- * Implicit and Explicit structured partial differential equations
- * Molecular Dynamics
- * Hydrodynamics
- * Circuit Simulation

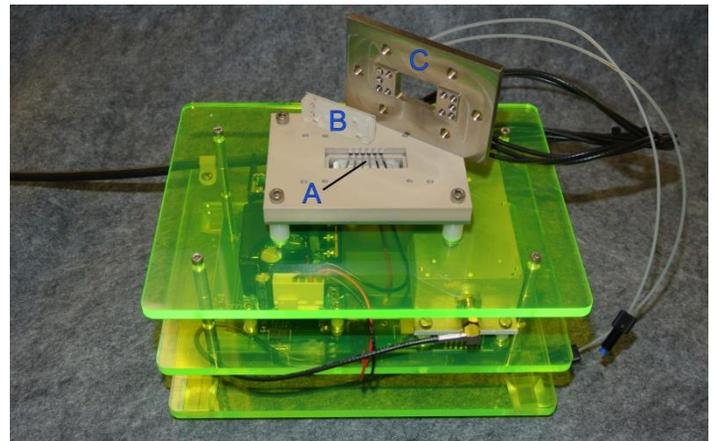
Mantevo is free and available to the public at <http://mantevo.org/>.

CleanBurst biosensor overcomes limitations of current extraction methods to enable high-speed sample preparation techniques for clinical point-of-care medical diagnostics

2013 R&D 100 Entry

Most biosensors in today's market require a critical sample preparation procedure prior to analysis of cellular contents such as nucleic acids and proteins. Technology is needed to release the cellular contents in a format compatible with nano/microfluidic and point-of-care devices.

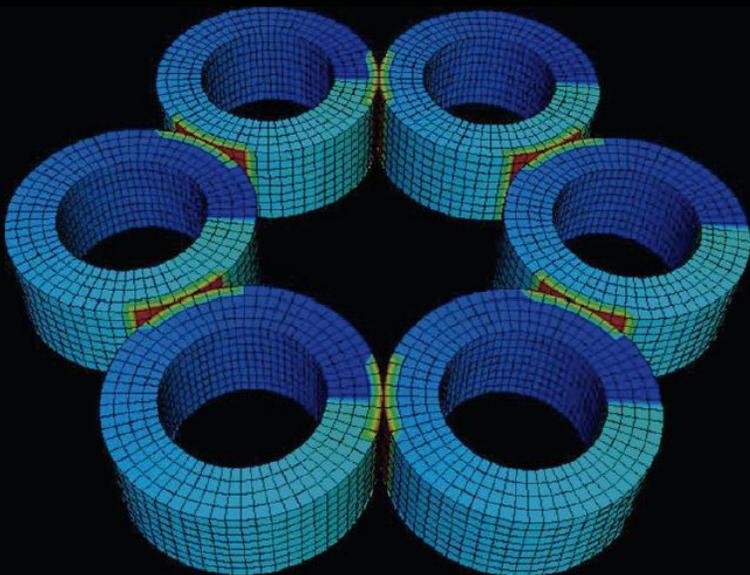
Sandia has developed CleanBurst Rapid Acoustic Lysis For Point-Of-Care Diagnostics, a miniature cell lysis system, to overcome the limitations of current extraction methods. This system utilizes high-frequency compression waves with a wavelength similar to the size of cells, resulting in more efficient energy transfer. Unlike commercial acoustic transducers, the technology does not generate significant amounts of heat, making it compatible with protein assays. This technology releases viable DNA, RNA, and proteins from human or bacterial cells, without chemicals or additional processing, to enable high-speed sample preparation for clinical point-of-care medical diagnostics and use with nano/microfluidic devices.



(A) Five channel acoustic array that couples reversibly to user-specified nano/microfluidic devices (B). The nano/microfluidic device (B) reversibly couples to (A). A plate (C) holds the nano/microfluidic device in contact with the acoustic array while also making microfluidic connections.

Applications and Industries

- * Same-day pathogen diagnosis
- * Lysing of resilient cells
- * Rapid DNA testing
- * Species-specific drug prescriptions
- * Bio-agent identification



Licensing Overview

Intellectual Property Creation at Sandia

Sandia's intellectual property results primarily from R & D conducted for the government in the national security sector. We collaborate with industry, leveraging each other's strengths to develop innovative technology. We perform internal R & D directed at the most challenging issues in national security, for which breakthroughs would provide exceptional value to government and industry. All totaled, Sandia has more than 1200 patents and 500 commercial copyrights, the bulk of which are available for licensing.

Licensing Sandia's Intellectual Property

Sandia's intellectual property may be licensed for commercial use (internal or commercial sale), test and evaluation, or execution of a government contract. One may also secure an option on a future license. Example licenses include:

- Commercial Patent License
- Commercial Copyright License (software or design plans)
- Commercial Hybrid License (copyright and patent)
- Test and Evaluation License
- License Option
- Government Use Notice

Sandia is mandated by the Department of Energy to move its technology to the marketplace for the benefit of the U.S. economy. Given our national security focus, government is the primary customer for many Sandia licensees, but our technologies also find use in the industrial and consumer markets. Sandia issues licenses to companies ranging in size from start-ups to multinationals. Our qualification procedure considers a company's ability to bring a product to market as conveyed by their business plan, among other factors. The possibility to create a new company that can leverage our technology and achieve substantial growth is also important, given our interest in entrepreneurship.



Licensing Practices

- License term usually runs the length of the patent or copyright. Terms for Test and Evaluation licenses and License Options are limited in time.
- Financial consideration may include an upfront license fee, annual license fee, milestone fee, or running royalty, as appropriate. We seek an equitable return to the laboratory without impeding the licensee's ability to successfully commercialize the technology.
- Performance requirements may be established to insure the licensee is diligent in their commercialization plan.
- Licenses may be limited by field of use, region, or period of restraint. Non-exclusive licenses are preferred, but we consider exclusive licenses when the business case is justified. Exclusive licensing requires a competitive assessment of potential licensees to select the one having the highest probability of success. Performance requirements are also more stringent.
- Commercial licensees must substantially manufacture their product in the U.S., given the Department of Energy's intent to provide benefit to the U.S. economy.
- The U.S. government retains a right to use the technology for government purposes.



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