Sandia’s **INNOVATION MARKETPLACE**

A QUARTERLY UPDATE OF AVAILABLE TECHNOLOGIES FOR INDUSTRY

Green Technology Issue

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Welcome to Sandia National Laboratories’ Intellectual Property Magazine

_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. This publication is intended for indications of interest only.

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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.

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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.

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Microgrids are localized energy grids that provide flexibility through their ability to operate independently from the bulk power grid. Well-designed microgrids support resiliency, security, efficiency, local control, and increased access to renewable resources. Sandia’s Microgrid Design Toolkit (MDT) is a decision support software toolkit that aids designers in creating optimal microgrids.

Employing powerful algorithms and simulation capabilities, MDT searches the trade space of alternative microgrid designs based on user-defined objectives (e.g., cost, performance, and reliability) and produces a set of efficient microgrid solutions. MDT allows designers to investigate the simultaneous impacts of several design decisions and gain a quantitative understanding of the relationships between design objectives and trade-offs associated with alternative technological design decisions. MDT can account for grid-connected and islanded performance, power and component reliability in islanded mode, and dozens of parameters as part of the trade space search, and presents designers with an entire trade space of information from which to base final design decisions.

Without MDT, designers rely on engineering judgment and perhaps a quantitative analysis of relatively few candidate designs. MDT allows designers to explore a larger field of options and provides defensible, quantitative evidence for design decisions.

Technological Benefits:
- Provides ability to perform topology optimization
- Illuminates large trade space of design alternatives
- Provides a variety of performance, reliability, and cost-related insights for candidate microgrid designs
- Provides microgrid designers a full understanding of trade-offs associated with certain design decisions
- Provides many result views and graphs to help interpret results

Design optimal microgrids with Sandia’s Microgrid Design Toolkit to support resiliency, security, and increased access to renewable resources.
Inter-area oscillations may develop on power grids with large generation and load complexes separated by long transmission lines. Poorly damped inter-area oscillations can have devastating effects, such as extensive blackouts like those experienced on the West Coast in August 1996. The current approach to prevent these effects is to operate the grid well below transmission capacity on these long lines—which is not economical.

Sandia Labs has developed a control system for damping these inter-area oscillations in order to improve power grid reliability and enable higher power flows.

The Department of Energy has made significant investments in the installation and application of over 1000 Phasor Measurement Units (PMUs) across North America to provide high speed, accurate insight into grid dynamics and stress. Sandia’s Control System leverages these PMUs by using their real-time measurements as feedback information to modulate real power flow over a High Voltage DC (HVDC) transmission line. The Control System has an integrated supervisory system that determines damping performance, maintains failsafe operation of the controller, and ensures the controller does no harm to the grid.

Extensive testing of Sandia’s Control System on the Pacific DC Intertie (PDCI), an HVDC transmission line, has proven its effectiveness at damping critical inter-area oscillations without reducing the damping of peripheral oscillations. The Control System also demonstrated fast response times (~100 ms) from the acquisition of PMU measurement data to the time it takes for the PDCI commanded power to reach the grid.

Sandia’s Control System can be easily integrated into current grid systems and would improve damping of worrisome inter-area oscillations. It would also reduce and/or postpone the need for new transmission capacity, increase revenue by enabling higher power flows, and facilitate higher penetration of renewable energy on the grid.

**Technological Benefits:**

- Improves grid reliability and efficiency
- Enables higher power flows on stability-limited transmission lines
- Utilizes existing PMUs and HVDC transmission lines
- Incorporates a supervisory system to ensure robust, reliable, and safe performance
Power Electronics

Sandia’s Ultra-Wide Bandgap Power Electronics miniaturize & improve efficiency of power systems for power grids & electric vehicles (SD#14049)

Power electronics used for routing, control, and conversion of electrical power traditionally utilize silicon semiconductors. These systems tend to be bulky, require active cooling, and are inadequate for applications demanding portable power conversion requirements (e.g., distributed power generation, vehicles, and satellites). Researchers at Sandia have grown ultra-wide bandgap (UWBG) AlGaN materials and from them fabricated an Al$_{0.3}$Ga$_{0.7}$N PiN diode with a breakdown voltage > 1600 V and an AlN/Al$_{0.85}$Ga$_{0.15}$N high electron mobility transistor (HEMT) with a breakdown voltage > 800 V. These are seminal, world-record devices that can be used as building blocks to make next-generation power electronics for transferring electrical power from a source to a load and converting voltages, currents, and frequencies.

The UWBG power semiconductor devices developed by our team will eventually miniaturize and vastly improve the performance and efficiency of power systems for electrical power grids, electric vehicles, computer power supplies, and motors. The device performance, defined by breakdown voltage and electrical conductivity, is ultimately determined by the bandgap of the material utilized. Compared with Si and even with commercial state-of-the-art wide-bandgap (WBG) materials, UWBG AlGaN materials (with bandgaps larger than SiC and GaN) have the potential to dramatically improve device performance and operate at even higher voltages, frequencies, and temperatures.

Different materials for power semiconductor devices are compared through a Figure of Merit (FOM) which quantifies the trade-off between electrical conductivity and breakdown voltage. The FOM scales with the seventh power of the bandgap. Thus, realizing devices in wide bandgap GaN rather than Si, improves FOM by 870X. Another factor of 37X is gained in FOM, by moving to ultra-wide bandgap AlN from wide bandgap GaN.

Because these power electronic devices could enable 10 times faster switching speeds than the current state-of-the-art, passive components in the power circuits can be smaller, and thus virtually every electrical power conversion system can be miniaturized commensurately. At the same time, the devices can function at higher operating temperatures without active cooling and in high radiation environments such as outer space. Just as silicon integrated circuits put supercomputer capabilities into everyone’s hands, UWBG devices can enable order-of-magnitude improvements in size, weight, and power for portable electrical power on demand.

**Technological Benefits:**
- Improved size, weight, and power
- 10 times faster switching speeds
- Improved efficiency
- Suitable for use in harsh environments (high radiation, high temperature)
Increase in bioethanol production throughout the US has led to an increase in the process coproduct—distillers grains with solubles (DGS). DGS can be used to feed livestock, however, product inconsistency and contamination issues have greatly reduced demand, resulting in significant surplus. In order to commoditize this DGS surplus, a team at Sandia developed a “one-pot” bioconversion process that converts both the major biochemical pools (carbohydrates and sugar) into valuable biofuels, industrial chemicals, and high value acids for fertilization.

While other competing bioconversion processes focus on conversion of the sugar fraction of DGS to fuel, our process simultaneously converts both carbohydrates and sugar—significantly increasing yields and minimizing separation costs. The process involves dilute acid hydrolysis and genetically modified *E.coli* strains optimized for conversion of hydrolyzed carbohydrates and proteins. The primary bioconversion products are isobutanol and isopentanol—ASTM certified biofuels with higher energy density and lower corrosivity than ethanol, with industrial applications beyond transportation fuels. The process also remineralizes the nitrogen and phosphorus pools present in DGS to struvite, a field-tested fertilizer with low run-off potential.

Sandia’s “one-pot” bioconversion process provides the means to produce ~10 tons of fusel alcohols in addition to the ~30 tons of ethanol per 100 tons of corn, while simultaneously remineralizing the major nitrogen/phosphorus nutrients for use as fertilizer.

Conversion of DGS to alternative fuels will potentially decrease the cost of the established bioethanol process.

**Technological Benefits:**

- Converts DGS into multiple commodities: isobutanol, isopentanol, and struvite
- Easily incorporated into established bioethanol infrastructure
- Can be used with other biomass sources and organic waste streams, including algae from wastewater treatment and mixed solid wastes
Polymer membrane separators play a crucial function in many energy and water technologies including: energy storage, hydrogen generation through water electrolysis, and fuel cell based stationary and transportation power systems. The cost and performance of current polymer membranes have hindered the widespread adoption of these clean energy technologies. Sandia’s inexpensive poly(phenylene)-based hydrocarbon polymer membrane separator was developed to encourage increased implementation of these next-generation energy-water systems.

Sandia’s membrane technology starts with a poly(phenylene) backbone that is chemically functionalized based on the intended application, which greatly reduces manufacturing costs. For instance, the membrane can be optimized for transportation of protons (H+) or hydroxyl ions (OH-) depending on the acidic or alkaline environment of the energy-water system. To further reduce costs, the membrane is designed to eliminate the need for precious metal catalysts. This technology can reduce costs associated with stationary energy storage and promote growth of renewable energy sources while providing grid stability. It also provides a more efficient, cheaper alternative to membranes currently used in fuel cell vehicles which are becoming strong competitors to electric vehicles due to their shorter refueling times and longer driving ranges.

This is the first membrane technology of its kind to demonstrate superior performance and cost savings over current state-of-the-art. Sandia’s innovative membrane has the potential to change the landscape in fuel cell and water electrolysis systems and can usher in a new era of clean technologies.

**Technological Benefits:**
- Reduced manufacturing cost
- High ion conductivities
- Reduced cross-over
- Operates over a wide range of temperatures
- Chemical and thermal stability in acidic and alkaline environments

Sandia’s Poly(phenylene)-based hydrocarbon polymer membrane separator promises to usher in the next generation of energy-water systems (SD#10987)
EMISSIONS & GASES
REAL-TIME MONITORING

Sandia’s SolidSense is the only sensor platform that measures all EPA regulated gas emissions (SD#14182)

In partnership with the University of New Mexico, Sandia Labs has developed the only sensor platform that measures all EPA regulated gas emissions (nitrogen oxides, carbon monoxide, and hydrocarbons) in addition to ammonia with high accuracy and sensitivity. The SolidSense chip-scale gas analyzer provides real-time diagnostics and is suitable for monitoring emissions from diesel and gasoline engines, turbines, steam power plants, and other combustion technologies. This novel device replaces a complex and expensive rack of chemical analysis equipment currently used today.

Designed to operate in hostile high temperature combustion environments, SolidSense operates without the need for cooling or filtration. The ceramic-based mixed-potential sensor comprises three electrodes connected to an artificial neural network. The differences between the catalytic activities of the electrodes for the electrochemical oxidation/reduction of the target gases provides the signals for concentration determination. The artificial neural network provides signal processing to determine compound concentration from sensor electrode output voltages. The device enables real-time diagnostics with response times less than 1/100 of a second.

The sensor’s ceramic platform enables easy manufacturing through thick film, high temperature co-fired ceramic technology.

SolidSense provides valuable exhaust chemistry feedback that can assist in improving combustion efficiency for engines, turbines, and power plants. It also has potential applications in explosive detection and can be integrated into a hand-held device to provide a molecular fingerprint of explosive compounds.

Technological Benefits:

• Provides quantitative data to monitor and control the emissions of hydrocarbon, carbon monoxide, nitrogen oxides and ammonia
• No cross interference from CO₂ or H₂O
• Real-time diagnostics—no sampling lag time
• Direct operation in exhaust gas streams
• Does not need frequent recalibration
• High throughput manufacturing using high temperature co-fired ceramics technology

Sandia’s SolidSense chip-scale gas analyzer
Pure molecular oxygen is important to many industrial processes such as oxy-fuel combustion, steel production, on-board oxygen generation in military aircraft and medical oxygen concentrators. Industrial-scale oxygen separation is conventionally carried out by cryogenic air separation. Cryogenic air separation produces high quality O$_2$ (99% oxygen purity), however, it is energy intensive, expensive and requires large housing facilities. A competing technology, pressure swing adsorption (PSA), can carry out O$_2$ separation on a smaller scale, but its application is limited to processes that require lower purity O$_2$. PSA processes rely on adsorbents such as zeolites, to capture N$_2$ from air, however, zeolites are costly, inefficient, and unable to produce high oxygen purity.

Seeking a more effective alternative to zeolites, Sandia researchers looked to Metal-Organic Frameworks (MOFs). MOFs are crystalline, porous materials in which a metal center is bound to organic molecules by mild self-assembly chemical synthesis. During synthesis, MOFs can be modified to be highly selective for a certain molecule. The MOFs created by Sandia researchers are designed to be highly selective for O$_2$ over N$_2$, resulting in the simultaneous separation of nitrogen and other air components from oxygen. When incorporated into the PSA process, MOFs have the ability to produce a purer form of oxygen, rivaling the purity from cryogenic air separation. MOFs offer better sorbent purity, fewer structural defects, and can store greater amounts of adsorbates compared to zeolites. Additionally, MOFs provide the ability to perform O$_2$ separation under mild conditions (ambient pressure and temperature), potentially revolutionizing the swing adsorption process and increasing the potential application fields.

**Technological Benefits:**
- Increased efficiency
- Reduced cost
- Can be implemented on a smaller scale
- O$_2$ separation at ambient temperature & pressure
- Produces high purity O$_2$
Carbon dioxide (CO$_2$) makes up 80% of all human-caused greenhouse gases and is a long-lived molecule that traps heat and warms the Earth for centuries. Despite investments in renewable and low-carbon fuels for electricity, domestic and global CO$_2$ emissions are expected to increase over the next quarter century. Conventional liquid absorption technology can achieve 90% CO$_2$ reduction target set by the Department of Energy (DOE), but the cost is staggering. To address the challenge of efficient CO$_2$ capture, a team from Sandia and the University of New Mexico developed a potentially transformational technology called the CO$_2$ Memzyme.

Current commercial technologies use vats of expensive, amine-based liquids to absorb CO$_2$. This method consumes about one third of the energy produced by the plant and requires large, high-pressure facilities. As an alternative method, the team developed a thin, enzyme-loaded, liquid membrane with the highest combined CO$_2$ flux and selectivity yet reported. The CO$_2$ Memzyme is one of the first technologies to exceed DOE’s standards for CO$_2$ capture. It was designed to achieve the high efficiency of natural biological separations that typically take place in liquids for faster molecular diffusion than solids, through ultra-thin membranes for short diffusion pathways, and assisted by enzymes (carbonic anhydrase) that speed uptake and release of CO$_2$ specifically.

The CO$_2$ Memzyme is 100 times faster in passing flue gas and is significantly more selective for CO$_2$ over nitrogen than any membrane currently on the market.

If the CO$_2$ Memzyme is applied to a single coal-fired power plant, then over one year we could avoid CO$_2$ emissions equivalent to planting 63 million trees and letting them grow for 10 years.

The CO$_2$ Memzyme has the added benefit of producing 99% pure CO$_2$, which can be used in many industries such as: advanced oil recovery, feed for algae in biofuel production, or to carbonate beverages.

**Technological Benefits:**
- Low cost
- Increased efficiency
- Easy to implement
- High selectivity and fast flux for CO$_2$
- Scalable manufacturing
A n Albuquerque company founded by a Sandia National Laboratories scientist-turned-entrepreneur has received a license for a “home-grown” technology that could revolutionize the way solar energy is collected and used. The licensing agreement was signed Jan. 23 between mPower Technology Inc. and Sandia for microsystems enabled photovoltaics (MEPV).

“This is an important milestone,” said Murat Okandan, founder and chief executive officer of mPower. “It is an extremely exciting time in the solar industry with the upcoming critical, rapid change in the worldwide energy infrastructure. A lot of things are coming together and we’re excited to be part of it.”

Andy McIlroy, Sandia’s director of Research Strategy and Partnerships and deputy chief technology officer, said at the Jan. 23 signing that the license is special to Sandia because the technology is home grown. “To have it blossom in Albuquerque is something we can be proud of,” he said. “We’d love to see it grow and become part of the country’s solar-energy infrastructure.”

Sandia’s Solar Glitter Technology Moves Closer to Market with New Licensing Agreement
Flexible, miniature solar cells

MEPV uses microdesign and microfabrication techniques to make miniature solar cells, also known as “solar glitter.” mPower is commercializing MEPV as Dragon SCALEs, small, lightweight, flexible solar cells that fit into and power devices or sensors of any shape or size, including wearable ones. The high-efficiency cells can be integrated into satellites and drones, biomedical and consumer electronics, and can be folded like paper for easy transport.

Dragon SCALEs also make possible new shapes and materials and faster, cheaper installation of solar energy systems on buildings, Okandan said. The product offers higher voltage, greater reliability and lower energy costs than standard silicon photovoltaic (PV) cells, he said.

“The key limitation to silicon is that if you bend and flex it, it will crack and shatter,” he said. “Our technology makes it virtually unbreakable while keeping all the benefits of high efficiency, high reliability silicon PV. It allows us to integrate PV in ways that weren’t possible before, such as in flexible materials, and deploy it faster in lighter-weight, larger-area modules.”

Okandan said standard silicon PV operates with low voltage and high current at the cell and module level, which requires more silver or copper and adds cost. MEPV allows high-voltage and low-current configurations with less metal in the system and meshes well with integrated power electronics. “These are basic benefits that apply fundamentally to large-scale solar deployment,” Okandan said. “And the same technology provides key advantages in satellites, drones and portable power applications.”

Left the labs to start a company

Okandan, who worked at Sandia 16 years and helped develop MEPV through funding from the Laboratory Directed Research and Development program, founded mPower after leaving the labs in May 2015 through Entrepreneurial Separation to Transfer Technology, which lets Sandia employees go, with their jobs guaranteed for up to three years, to start or expand technology companies. Another former Sandia employee, Pete Atherton, joined mPower as chief operating officer after retiring last year.

Okandan said the cost of PV systems has dropped 70 percent in the past seven years and the number of installations has increased more than tenfold. “You can see that the momentum is there to deploy solar faster and more cost effectively,” he said. “Our technology makes that even faster and lower cost by leveraging the massive silicon PV and microelectronics infrastructure and supply chain already in place.”

The Sandia license will allow mPower to ramp up commercialization and attract more investment, Okandan said. The company has manufactured product prototypes that customers are evaluating. “We’ve been defining markets and partnerships,” he said. “The license gives us the exclusivity to proceed with further business, product and partnership development.”

Sandia licensing specialist Bob Westervelt said mPower used an exclusive license option on the MEPV technology in its initial product development and decided in October to convert it to a full commercial license that lets the company move to the next stage of its commercialization plan. He emphasized that the mPower license applies to a portion of Sandia’s MEPV intellectual property portfolio associated with silicon solar cells. “There is other MEPV intellectual property useful for other applications and using other materials,” Westervelt said. “That is still available for licensing.”

Mary Monson, Sandia’s senior manager of Industry Partnerships, said companies like mPower take the labs’ technology and further develop it so it can be manufactured for widespread use in the energy and defense sectors. “Sandia’s partnerships with industry play an integral role in our mission success,” she said.

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INTELLECTUAL PROPERTY CREATION
Sandia’s intellectual property results primarily from R&D conducted for the government in the national security sector. Our laboratory collaborates with industry, leveraging different 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 1600 patents and 550 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 remains an area of significant interest for Sandia.
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