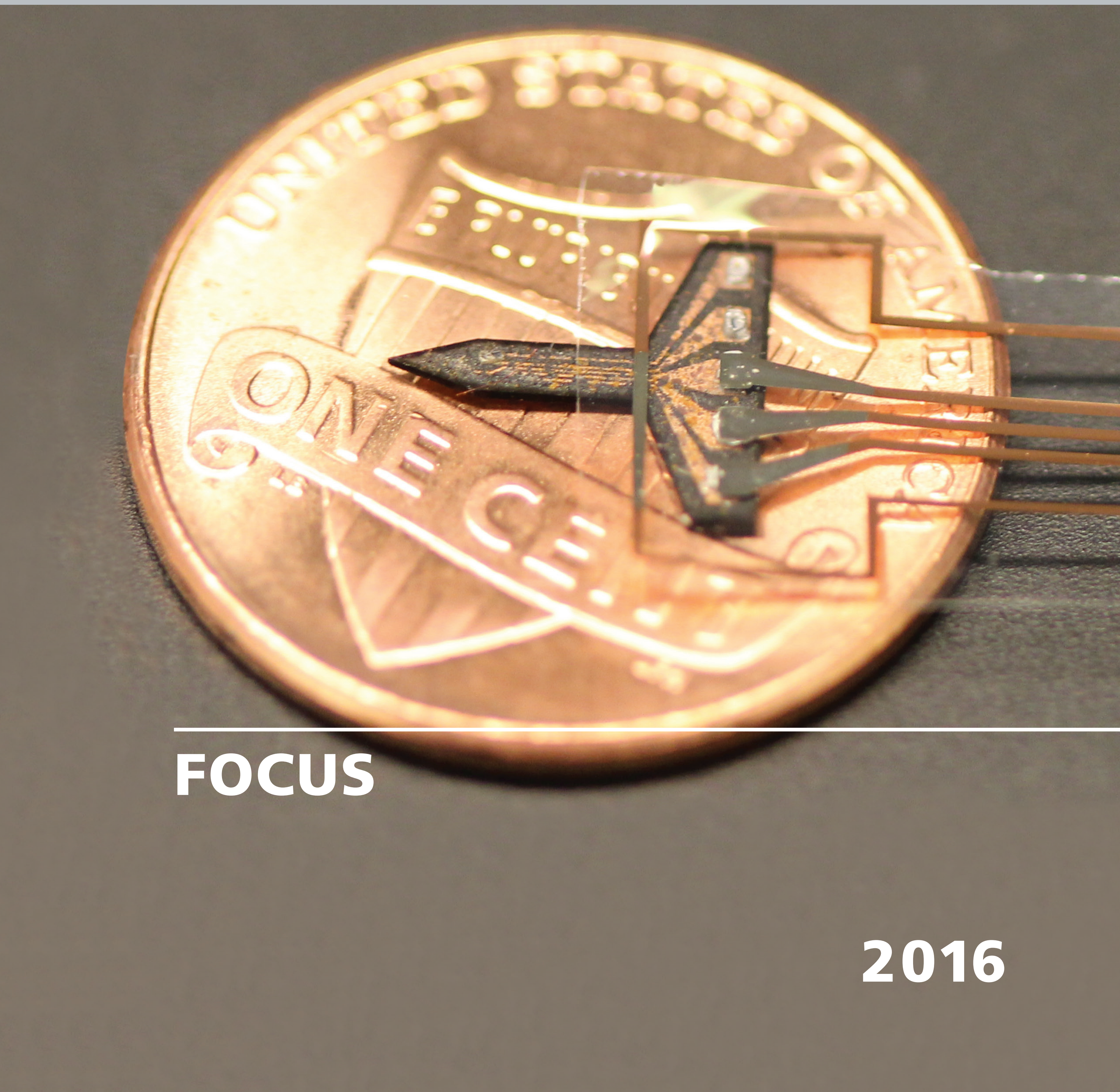
Fraunhofer

USA




# FOCUS

2016

**FRAUNHOFER FOCUS**

Welcome to the first edition of Fraunhofer USA Focus. Focus highlights our business – world-class industrial services and research activities, and presents some of our highly trained and innovative staff members.

Fraunhofer USA celebrated its 20th anniversary in 2014. Two years later we are both proud and humbled to have continued our journey to become the organization we are today. Our customers rely on us. They trust the knowledge and experience that Fraunhofer USA and the global Fraunhofer network offers for vanguard research and development. Fraunhofer finds the technology solutions that our industrial customers and partners need. Our diverse and multi-disciplinary centers can work independently, together with our Fraunhofer network of centers and institutes, or with any of our partners to leverage our comprehensive know-how, project experience and state-of-the-art equipment.

In this edition you will find selected projects of 2015 and 2016. Together with selected staff portraits these activities exemplify the broad range of science and engineering capabilities we provide. Our mission is to transform vision into innovation, built on technology. We can help you realize your vision too!

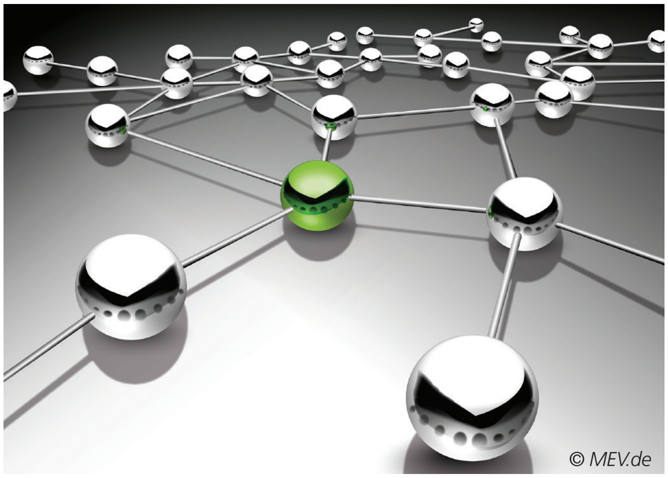
Dr. Patrick Bressler,
*Executive Vice President*

# MANAGEMENT REPORT

## Strategic Development

Beginning in late 2014, Fraunhofer USA initiated strategy audits of each of its centers. The Center for Experimental Software Engineering (CESE) in College Park, Maryland was the first center in the initiative. In 2015, the Center for Coatings and Diamond Technologies (CCD) in East Lansing, Michigan and the Center for Laser Applications (CLA) in Plymouth, Michigan, underwent their strategy audits. In the spring of 2016, the Center for Sustainable Energy Systems (CSE) was similarly reviewed. In each case, a group of carefully selected experts and stakeholders was chosen and charged with analyzing and evaluating strengths and weaknesses, opportunities and threats to each center, assessing the R & D portfolio and making recommendations for the future strategic path for the center.

The process involved preparation of detailed capability reports and on-site visits by the auditors to each of the locations. The auditors were asked to provide a report to each of the centers complete with actionable items. The strategy audits have proven to provide extremely valuable insight and guidance, and Fraunhofer USA plans to continue the practice on a regular rotating schedule.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## Operating Objectives

Like its parent organization in Germany, Fraunhofer USA provides contract research and development to customers from industry and state and federal governments.

Fraunhofer USA has an important role in the U.S. R & D environment. This is to act as a bridge between industry and university, and for transatlantic research and development opportunities with our parent organization in Germany. The United States has a world class research and development climate. This country has the well-deserved reputation for creation, innovation, entrepreneurship and a "can do" attitude that marries well with the R & D universe. Fraunhofer USA is continually evaluating how it, together with the Fraunhofer Society, can enhance and support the global science progress to benefit life in socially responsible ways.

Since its founding in 1994, Fraunhofer USA has matured into an organization fully integrated into the environment. The organization must now focus its strategy on finding new and innovative approaches for sustainability with funding models and partner outreach.

Foundations were laid in 2015 for an upcoming initiative to prepare a study to examine the sustainable funding models of similar organizations in the United States. Mid- 2017 is the target for the completion of data collection and analysis.

Fraunhofer USA centers endeavor to look beyond the R & D horizon to future targets and to have the vision to offer customers look ahead solutions. The recruiting and hiring of innovative and highly qualified employees helps Fraunhofer USA stay advanced and original in its vanguard approach to science and engineering solutions.

- 2015 FhUSA Budget exceeds $41M
- Government and University Revenue 58%
- Industry Revenue 27%
- Fraunhofer Institute Revenue 14%
- Miscellaneous Revenue 1%

*The seven Fraunhofer USA research centers attract a diverse group of scientists and engineers at all levels of their careers due to Fraunhofer's exciting and rewarding research and development environment. Each center has a specialization area; however, in some cases research fields may overlap or complement those of other centers.*

Flexibility is the outstanding feature of the Fraunhofer USA **Center for Manufacturing Innovation (CMI)**. The scientists and engineers offer product development ranging from electro-mechanical design to the associated software development. Customers come to the center for solutions such as custom automated systems, including conceptual design, feasibility experiments, detailed design software and controls development, procurement, fabrication, assembly and testing. The center works in the aerospace, bio-tech / bio-medical, consumer products, energy and fiber-optics/photonics industries.

The Fraunhofer USA **Center for Coatings and Diamond Technologies (CCD)** has expertise in diamond materials, thin film coatings, micro-fabrication and materials analysis. The center's world class technology development has been utilized by customers for applications in medical and bio-medical devices, in the energy and automotive fields, for industry products requiring specific wear or friction parameters, and for scientific devices.

The Fraunhofer USA **Center for Laser Applications (CLA)** has one of the premier laser applications research facilities in North America. The center has highly trained employees specializing in a broad spectrum of laser applications from micro to macro scale processes including laser cutting, drilling, ablation, cladding, additive manufacturing welding, and heat treatment. The state-of-the -art facility includes lasers ranging from 1 watt to 16 kW output power and 10 CNC and robotic work stations which are utilized by customers in automotive, aerospace, medical, oil and gas, power generation and alternative energy sectors.

The Fraunhofer USA **Center for Sustainable Energy Systems (CSE)** accelerates the adoption of sustainable energy technologies. The center's expertise in solar photovoltaics, smart energy-efficient buildings and grid technologies provides a platform for deeply integrating distributed energy resources through collaborative R & D with private companies, government entities and academic institutions. With its work, the center explores ways to integrate distributed energy resources and match energy supply and demand in the 21st century electric grid.

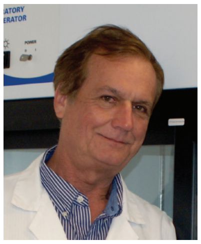
The Fraunhofer USA **Center for Experimental Software Engineering (CESE)** performs analysis and application of empirical research methods to transfer practical and novel solutions to its customers. In addition to verification and validation, the center has expertise in process and product measurement, offers empirically-based risk and safety management programs, process improvement and best practices, analysis of the business impact on adoption or purchasing of a new software technology and program, and project and risk management.

With its state-of-the-art infrastructure and custom built pilot plant, the Fraunhofer USA **Center for Molecular Biotechnology (CMB)** is the destination of choice for proof of concept, process development, formulation development, analytical services and pre-clinical evaluation. The center offers GMP manufacturing, yielding gram quantities of target proteins. Key processing areas in the pilot plant include plant growth, fermentation, infiltration and protein accumulation, harvesting, protein purification, and fill and finish. The center maintains its own quality group with trained personnel in cGMP compliance.

Energy Innovation is a hot topic for all the right reasons. The Fraunhofer USA **Center for Energy Innovation (CEI)** is focusing on batteries and energy storage, fuel cells and electrolyzers, microgrid engineering and environmental technology.

Fraunhofer USA also has a **Digital Media Technologies Office (DMT)** promoting state-of-the-art audio coding and multimedia real-time system technologies.

**Dr. Jerzy Karczewski**
***Scientist***



Dr. Jerzy Karczewski received his Master's Degree in Electronic Engineering from the Technical University of Warsaw, Poland and Ph.D. in Biochemistry from the Medical University of Lodz, Poland. During his Ph.D. thesis he studied molecular mechanisms underlying interactions of cancer cells and platelets with thrombospondin. After coming to the United States, he joined the Department of Biochemistry at Merck Research Laboratories (MRL), West Point, PA, where he made numerous contributions to drug discovery efforts, including the discovery of novel inhibitors of intergrins, cardiac ion channels, G-protein linked receptors and other pharmaceutically relevant targets. He developed high throughput methods allowing rapid assessment of potential drug side effects such as ventricular arrhythmias and studied molecular interactions between small molecule compounds and the cardiac potassium channels. Dr. Karczewski discovered and isolated several potent, naturally occurring inhibitors from the African tick Ornithodoros Moubata (antithrombotics), from the leech Hirudo medicinalis (anti-coagulants) and from the sea anemone Anthopleura elegantissima (analgesics). These unique proteins served as important leads for the development of novel drugs to treat coagulation disorders (Aggrastat®), arrhythmias and inflammatory pain. Dr. Karczewski then moved to the Department of Vaccines Basic Research (also at MRL) where his research was aimed at discovering novel recombinant vaccines and biologics against bacterial and viral pathogens, including Clostridium Difficile, Chlamydia, Respiratory syncytial virus (RSV), Cytomegalovirus (CMV) and Neisseria meningitis. He developed the recombinant vaccine based on fragments of the clostridial toxins (TcdB, CROP domains) and demonstrated in vivo efficacy of such recombinant vaccine. In collaboration with the Department of Infectious Diseases (MRL), Dr. Karczewski participated in studies leading to solving the X-ray structure of the TcdB CROP domain and identification of structural basis for neutralization of TcdB by the clinically important antibody Bezlotoxumab. Dr. Karczewski also authored several peer-reviewed publications and co-authored two U.S. patents.

In 2014 Dr. Karczewski joined the Fraunhofer USA Center for Molecular Biotechnology (CMB) where he supports several projects focusing on plant-expressed vaccines and monoclonal anti-bodies. Dr. Karczewski's personal interest is to apply plant-based technology for development of an ultra-low cost vaccine or monoclonal antibody against nosocomial infections with Clostridium difficile.

**Dr. Madeline Diep**
***Research Scientist***

Dr. Madeline Diep has been a Research Scientist at the Fraunhofer USA Center for Experimental Software Engineering (CESE) in Maryland since 2009. She has also taught Software Requirements courses at the University of Maryland - College Park from 2009 through 2012. She holds a Ph.D. in Computer Science from the University of Nebraska - Lincoln. At Fraunhofer, Dr. Diep has participated in research on software and system assurance practices funded under NASA's Office of Safety and Mission Assurance. She is also involved in a major software-intensive systems development effort, especially with assisting in the analysis of system/software development metrics for monitoring and managing the development effort and risk. She has hands-on experience in building prediction models and has provided measurement expertise to organizations implementing CMMI high maturity practice. Her past projects include research and empirical studies in software instrumentation and monitoring for improving software testing and analysis. Her research interests are in the area of software quality assurance, testing, and analytics.

**Linda Esker, M.Sc.**
***Senior Applied Technology Engineer***

Ms. Linda Esker is a Senior Applied Technology Engineer at the Fraunhofer USA Center for Experimental Software Engineering (CESE) in Maryland. She is experienced in software management, process and metrics development and analysis, and software engineering in air traffic control, real-time space systems, defense systems, and commercial business areas. Prior to her position at Fraunhofer USA, she was a statistical analyst for clinical trials at the National Institutes of Health, a software developer and analyst of longitudinal student data for Fairfax County Virginia Public Schools, and a software development manager and software engineering research manager for CSC. She holds a M.Sc. in Computer Science from Johns Hopkins University and a BA in Mathematics from Trinity University (Washington, D.C.).

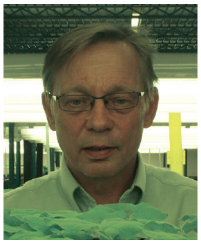
At Fraunhofer USA, she is currently providing expertise to the software project management offices for NASA and DoD programs and assisting them with project estimation, software development assessments, metrics programs and analyses, software safety, and software maturity metrics definition and analysis. Her interests and recent publications and conference presentations have addressed making software metrics programs more relevant and helpful in decision making, and the challenges of developing COTS-intensive software systems.

**Dr. Alexis Sauer-Budge**
***Senior Research Scientist***

Dr. Alexis Sauer-Budge received her B.S./M.S. in Chemistry from Stanford University and her Ph.D. in Biophysics from Harvard University. While at Harvard, she worked on developing methods for studying and controlling the passage of DNA through biological nanopores in the laboratory of Professor Daniel Branton. After completing her Ph.D., she joined a start-up company, BioScale, Inc., developing infectious disease and protein diagnostics on bioMEMS resonating membrane platform technology.

In 2007, Dr. Sauer-Budge joined the Fraunhofer USA Center for Manufacturing Innovation (CMI) to lead the biotechnology group. Her research portfolio includes rapid diagnostics, tissue engineering, medical devices, and bench-top instrumentation. Some of her recent projects include design and development of integrated lab-on-a-chip molecular diagnostics for pathogen detection from physiological samples, isolation of pathogens from blood for integration with surface enhanced Raman spectroscopy that enables strain specificity, methods for rapid antibiotic susceptibility detection within minutes, surgical tools and coatings for implantable devices, wearable chemotherapy monitors, and handheld drug detection systems. Dr. Sauer-Budge also manages the BU-Fraunhofer Alliance for Medical Devices, Instrumentation, and Diagnostics and the beta-prototyping core for the NIH Center for Future for Technologies in Cancer Care - both translational research and engineering programs.

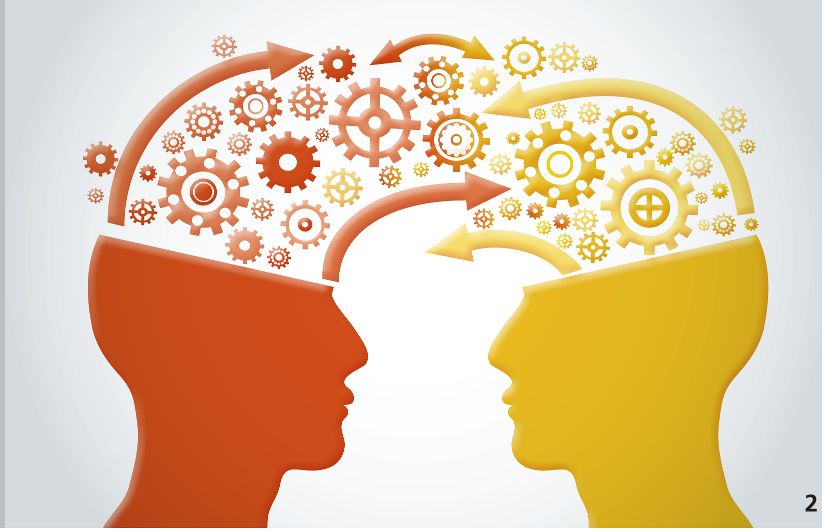
**Dr. Jukka Kervinen**
***Scientist***



The Fraunhofer USA Center for Molecular Biotechnology (CMB) specializes in the use of plant-based biotechnology for the production of pharmaceutically important proteins (biologics). Dr. Kervinen's interest in plant biology started early in his scientific career. As an undergraduate student and intern in the Department of Biochemistry at the University of Jyvaskyla, Finland, he assisted in the field collection and analysis of crop seed and leaf samples. After receiving his M.Sc. in 1988, he performed graduate research on the occurrence, enzymatic characterization and intracellular localization of barley aspartic protease in the Plant Molecular Biology Laboratory at the Institute of Biotechnology, University of Helsinki, Finland. Dr. Kervinen received his Ph.D. in Cell and Molecular Biology from the University of Jyvaskyla in 1994. As a post-doctoral fellow under Dr. Alexander Wlodawer at the National Cancer Institute in Frederick, MD from 1995-1998, he studied the structure and catalytic mechanism of plant and retroviral aspartic proteases using X-ray crystallography. Many plant aspartic proteinases, pepsin-like enzymes and collectively named as Phytepsins (phyto (Lat.) = plant "pepsin"), contain a unique domain (plant-specific region) and Dr. Kervinen was the first to describe the domain folding in X-ray structural terms. In 1998, he moved to the laboratory of Dr. Eileen Jaffe at the Fox Chase Cancer Center in Philadelphia, PA. His research focused on the purification, biochemical characterization and crystallization of porphobilinogen synthases which are involved in tetrapyrrole (heme, chlorophyll, vitamin B12) biosynthesis. In 2001, he began studying multiple proteases, protease inhibitors and other enzymes involved in inflammatory and metabolic diseases as a research scientist in the pharmaceutical industry.

Since joining Fraunhofer CMB in Newark, Delaware in 2012, Dr. Kervinen's main responsibilities have been to develop efficient protein purification processes for novel biologics that can be feasibly and cost-efficiently scaled-up to pilot plant production in the GMP environment. He evaluates and implements new technologies for process development and actively looks for novel therapeutic opportunities. In addition to laboratory activities with his team, he works as part of a larger cross-functional group including Process Development, GMP manufacturing and Quality. Fraunhofer CMB has been a very rewarding environment for Dr. Kervinen because he is able to use his protein biochemistry and pharmaceutical industrial experience to work on a team with excellent colleagues utilizing plant biotechnology. Above all, he is grateful for the opportunity to use his expertise to advance Fraunhofer's cutting-edge research and innovative technology with potential to improve people's lives against some of the world's most devastating maladies such as malaria, yellow fever, HIV, anthrax and Ebola.

Dr. Kervinen is also an adjunct faculty member in the Department of Biochemistry, University of Helsinki, Finland.






## University Partnerships

Fraunhofer USA has enjoyed excellent and mutually beneficial partnerships with universities in the United States. These universities conduct much of the federally funded research in vanguard technologies such as nanotechnology, clean energy and of course biotechnology. These institutions have considerably expanded their research labs and subsequent resulting patent portfolios in the last several years.

Like the Fraunhofer Society in Germany, Fraunhofer USA understands the benefits of partnering with academic institutions of excellence and fostering integrated and enduring relationships. The research and development universe is enriched as each entity adds value.

**Boston University:** The Fraunhofer USA Center for Manufacturing Innovation (CMI) has collaborated closely with Boston University since the center's inception in 1995, located on the university's Charles River campus.

CMI collaborates directly with a number of its schools and colleges, including the College of Engineering, the Medical School, the Business School, and the College of Arts & Sciences. Faculty and students participate in a number of joint research programs funded by both government and industry.

**University of Maryland:** The Fraunhofer USA Center for Experimental Software Engineering (CESE) has collaborated with the University of Maryland since 1997, specifically within the College of Computer, Mathematical and Natural Sciences. The University of Maryland has become one of the nation's leading public research and innovation universities. The proximity to the nation's capital has resulted in research partnerships with the federal government.

**Michigan State University:** Since 2003, the Fraunhofer USA Center for Coatings and Diamond Technologies (CCD) and Michigan State University have closely collaborated on applied research and development projects in the areas of diamond and coatings technologies. Michigan State University frequently ranks among the top 30 public universities in the United States, and the top 100 research universities in the world.

**University of Delaware:** The Fraunhofer USA Center for Molecular Biotechnology (CMB) partners with the University of Delaware to expand the innovation pipeline by enhancing technology and product development activities. The University of Delaware is classified as a research university with very high research activity by the Carnegie Classification of Institutions of Higher Education.

**University of Connecticut:** The Fraunhofer USA Center for Energy Innovation (CEI) is located on the campus of the University of Connecticut (UConn). UConn has a rich history of excellence in energy innovation.

## Other University Joint Projects:

The Fraunhofer USA Center for Sustainable Energy Systems (CSE) has collaborations with the MIT Energy Initiative (MITEI), the University of Massachusetts, Amherst, and the University of New Mexico, Albuquerque.

Fraunhofer CSE and MIT have performed several projects together and submitted several joint proposals to government entities. Based on CSE's presence in Albuquerque, a collaboration with the University of New Mexico (UNM) and its Center for Emerging Energy Technologies was initiated. CSE's Building Energy Management Group developed several major proposals with UNM's Mechanical Engineering Group, two of which are currently funded by the Department of Defense and the National Science Foundation.

PARTNERSHIPS AND COLLABORATIONS


## State Support and Collaborations

Several Fraunhofer USA centers receive financial support from the states in which they operate directly or through state agencies.

- Delaware-Fraunhofer USA Center for Molecular Biotechnology
- Maryland-Fraunhofer USA Center for Experimental Software Engineering
- Massachusetts-Fraunhofer USA Center for Sustainable Energy Systems
- Connecticut-Fraunhofer USA Center for Energy Innovation

## Fraunhofer Partnerships and Cooperation

Fraunhofer Centers in the US and their parent Fraunhofer Institutes in Germany

| *Fraunhofer Center for:* | | *Fraunhofer Institute for:* |
|---|---|---|
| Coatings and Diamond Technologies CCD | ⇔ | Material and Beam Technology IWS |
| Experimental Software Engineering CESE | ⇔ | Experimental Software Engineering IESE |
| Laser Applications CLA | ⇔ | Material and Beam Technology IWS |
| Manufacturing Innovation CMI | ⇔ | Production Technology IPT |
| Molecular Biotechnology CMB | ⇔ | Molecular Biology and Applied Ecology IME |
| Sustainable Energy Systems CSE | ⇔ | Solar Energy Systems ISE |
| Energy Innovation CEI | ⇔ | Ceramic Technologies and Systems IKTS |



Fraunhofer USA centers also work and collaborate with other institutes in the 67 institute network of the Fraunhofer Society in Germany.

The United States has recognized that the key to economic competitiveness and growth depends on continuing investments in research and development, and in education that fuels innovation – in particular in STEM (science, technology, engineering and mathematics) fields.

The 2016 U.S. Federal Budget provides for a 6% increase in spending, for a total of $146 billion for R&D overall. The budget also provides $67 billion for basic and applied research, a 3% increase from 2015 enacted levels (source: Office of Science and Technology Policy Fact Sheet).

This increase in spending reflects the continuing support of the R & D environment to enhance the development of technology which benefits not only the people of the United States, but also the global community.

Fraunhofer USA intends to continue its role as an innovative problem solver to the benefit of our customers, and through them contribute to the greater goal of improving the human condition with the next generation of technology innovations.

## Fraunhofer USA, Inc.

Balance Sheet
As of December 31, 2015

| | |
|---|---|
| **Assets** | |
| **Current Assets** | |
| Cash and Cash Equivalents | $ 1,553,576 |
| Accounts Receivable | 8,069,011 |
| Investments | 664,864 |
| Prepaid Expenses and Other Current Assets | 1,107,461 |
| Total Current Assets | 11,394,912 |
| Property and Equipment - Net | 47,054,522 |
| Intangible Assets | 334,704 |
| Long-Term Receivable | 1,338,484 |
| Total Assets | $ 60,122,622 |
| **Liabilities and Net Assets** | |
| **Current Liabilities** | |
| Accounts Payable | $ 997,208 |
| Deferred Revenue | 1,729,754 |
| Accrued Liabilities and Other | 6,517,616 |
| Total Current Liabilities | 9,244,578 |
| Long-Term Obligation | 15,886,320 |
| Total Liabilities | 25,130,898 |
| **Net Assets** | |
| Unrestricted | |
| Undesignated | 2,697,987 |
| Decrease in Undesignated Assets | (219,218) |
| Designated | 31,308,969 |
| Decrease in Designated Assets | (1,437,773) |
| Temporarily Restricted | |
| Temporarily Restricted | 3,761,686 |
| Decrease in Temporarily Restricted Assets | (1,119,927) |
| Total Net Assets | 34,991,724 |
| Total Liabilities and Net Assets | $ 60,122,622 |

## Fraunhofer USA, Inc.

### Statement of Activities and Changes in Net Assets
### Year Ending December 31, 2015

| | |
|---|---|
| **Contract Revenue** | |
| Industry | $ 6,725,719 |
| Government & Universities | 14,381,869 |
| Fraunhofer Institutes | 3,404,255 |
| Miscellaneous | 109,687 |
| **Total Contract Revenue** | 24,621,530 |
| **Support** | |
| Base Funding | 10,421,459 |
| In-Kind Contributions | 3,628,671 |
| Other | 778,108 |
| **Total Support** | 14,828,238 |
| **Funds Released from Restrictions** | 1,356,664 |
| **Total Undesignated Revenue, Support and Released Funds** | 40,806,432 |
| **Labor Costs** | 23,286,805 |
| **Undesignated Other Expenses** | |
| Administrative Expenses | 12,350,924 |
| Cost of Goods Sold - Excluding Labor | 5,048,277 |
| Depreciation and Amortization | 339,644 |
| **Total Undesignated Other Expenses** | 17,738,845 |
| **Total Labor Costs and Undesignated Other Expenses** | 41,025,650 |
| **Decrease in Undesignated Assets** | (219,218) |
| **Undesignated Net Assets** | 2,697,987 |
| **Designated Revenue** | 1,554,677 |
| **Designated Expenses** | (2,992,450) |
| **Decrease in Designated Assets** | (1,437,773) |
| **Designated Net Assets** | 31,308,969 |
| **Temporarily Restricted Revenue** | 236,737 |
| **Funds Released from Temporary Restriction** | (1,356,664) |
| **Decrease in Temporarily Restricted Assets** | (1,119,927) |
| **Temporarily Restricted Net Assets** | $ 3,761,686 |

*The seven Fraunhofer USA centers conduct research and development for state, federal and industry customers in fields that have been identified as directly impacting current and future societal needs. Below is a selection of some of the recent projects at the centers.*

# HEALTH AND ENVIRONMENT

### Racing Against Heart Disease

Nothing kills more people than heart disease. In fact, 17 million people die from heart disease each year, all while scientists work feverishly to understand its causes and to create new therapies and new devices to prevent and manage it. Unfortunately, the number of victims is climbing quickly, while research remains slow and painstaking.

To speed up and improve the research and development of cardiac devices, the Fraunhofer USA Center for Experimental Software Engineering (CESE) and 6 U.S. Universities are involved in the "Cyber Heart" project. Supported by the U.S. National Science Foundation, this project is developing rigorous, closed-loop approaches for designing, simulating, and verifying medical devices. The work will enable new approaches that greatly accelerate the pace of medical device innovation, especially in the sphere of cardiac-device design. Specific attention is being paid to developing advanced approaches for analyzing the safety and effectiveness of controller designs and for expediting regulatory and other third-party reviews of device designs.

### Health Care's 800-Pound Gorilla

1 out of every 3 dollars disbursed by the U.S. Medicare program is spent on diabetes. One contributing factor is that doctors are forced to treat the 'average' patient, not the individual in front of them. This is due to the fact that they lack long term, accurate and reliable data about that specific individual. Having access to such data would allow for better, personalized, more effective care, and ultimately, less expensive health care.

Right now, however, there's no way to collect this data and present it to doctors. That is where the Fraunhofer USA Center for Experimental Software Engineering (CESE) comes in. In particular, CESE is working with a research team from the Robert H. Smith School of Business at the University of Maryland to develop a mobile data collection application called Diasocial. Not only does it collect long term data, but it is also a simple and effective way for patients and doctors to communicate, preventing the need for frequent and costly office visits. For example, a doctor using our software can be alerted to fluctuations in a patient's glucose levels, pull up data on the patient, and then send a message to their phone, encouraging some specific behavioral adjustment. This application is targeted towards older adults suffering from diabetes, and is currently undergoing user studies at the Veterans Affairs Hospital in Baltimore, Maryland.

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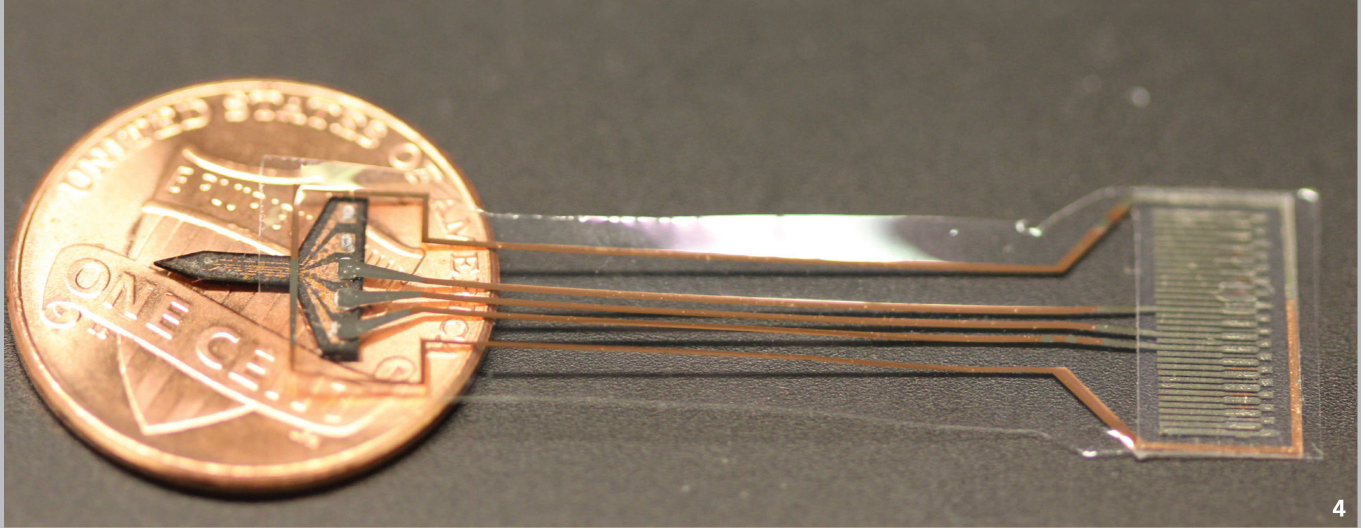
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## Optogenetics with Polycrystalline Diamond

Since its discovery in 2005, optogenetic technology has contributed to much progress in understanding the correlation between brain function and brain circuitries. The method uses light to modulate electrophysiological responses of genetically target-specific neurons with millisecond-scale precision. Compared to traditional neural modulation through electrical and pharmacological stimulation, which affects the targeted cells during stimulation, the cell type specificity of optogenetics can identify the primary contributor to the corresponding brain function more precisely, fast and with good reversibility. This will help researchers treat, cure and prevent a variety of brain disorders such as depression, social dysfunction, and Parkinson's disease. The Fraunhofer USA Center for Coatings and Diamond Technologies (CCD) and partner Michigan State University are working on the development of "optrodes" that combine light-emitting diodes and microelectrodes on a polycrystalline diamond substrate to optogenetically stimulate and electrically record neural activity. The diamond material is critical to the process as it dissipates the electrically generated heat and thus reduces the risk of thermal damage to the nerve tissue.

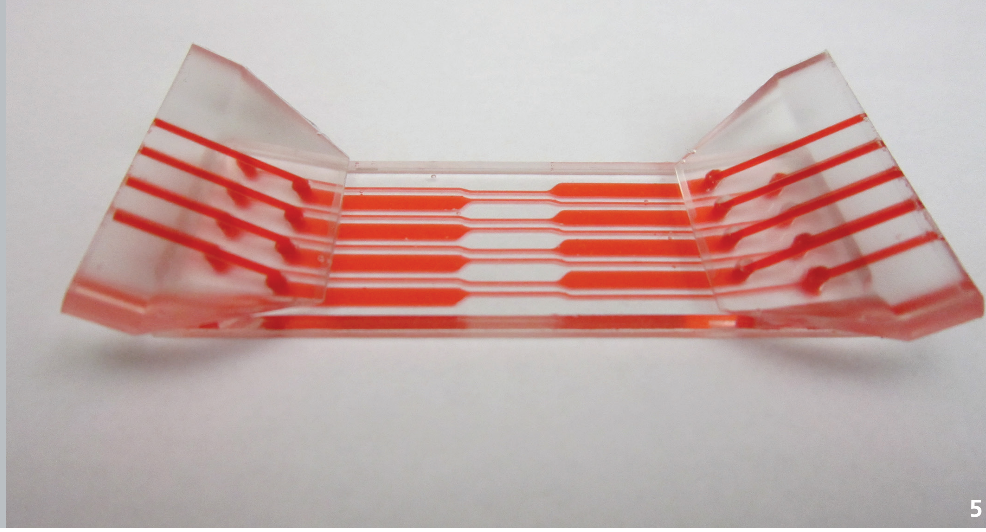
## Diamond Sensors to Detect Human Carcinogens

The demand for simple, rapid-sensing methods is as rampant as ever due to the increasing applicability to daily life. Field-deployable sensors for both the environmental and medical fields must be able to handle the rigor and harsh environments used for such measurements. As a result, many materials will not suffice. However, diamond has proven to be a material capable of withstanding these conditions while still delivering solid results. Amongst the Fraunhofer USA Center for Coatings and Diamond Technologies (CCD) efforts to create sensors for a variety of applications such as the measurement of heavy metals and neurotransmitters, there has been significant interest for detection of organic contaminants such as polycyclic aromatic hydrocarbons (PAHs). PAHs, a class of over 100 organic compounds, are ubiquitous contaminants found worldwide. With this, many of these compounds belong to the International Agency for Research on Cancer's (IARC) classification as Group 1 (human carcinogens), Group 2A (probable human carcinogens), and Group 2B (possible human carcinogens). In collaboration with a research group in the department of chemistry at the University of Cincinnati, CCD has begun the development of diamond optically transparent electrodes for indirect spectro-electrochemical sensing of 1-hydroxypyrene, a urinary metabolite, commonly used as a biomarker for human exposure to PAHs. Spectroelectrochemistry provides additional selectivity compared to stand-alone spectroscopic and electrochemical methods, lowering the analyte detection limit. The application of this sensing ranges from drinking water analyses to urinary measurements, capable of quick monitoring of PAH exposure.

## Detecting Superbugs

Disease-causing microbes that have become resistant to drug therapy are an increasing public health problem. Factors contributing to the rise in antibiotic resistance include widespread and inappropriate prescription of broad-spectrum antibiotics and patient non-compliance to antibiotic regimens. Bloodstream infections, which can lead to sepsis, are of particular concern as they represent a serious and growing health burden (9% of all deaths in the US). The ability of hospitals to optimally treat patients is severely hampered by the lack of rapid diagnostics that can accurately inform the medical staff if: 1) the patient is infected with bacteria and 2) which of the frontline antibiotics should be deployed to fight the infection. Despite exhaustive research and development into such rapid diagnostics, the leading technologies still involve media, agar plates, and approximately 43 hours from the first blood draw.

The major challenge of diagnosing blood-borne pathogens and prescribing the appropriate antibiotic is that the microbes are present in low concentrations in blood (often 10 CFU/mL). Hence, amplification and isolation of the pathogens prior to drug susceptibility testing is required. A standard clinical workflow includes inoculating blood culture medium with several 10 mL samples of



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blood and waiting 12-48 hours for microbial replication and a positive blood culture. These cultures are then Gram stained and plated onto selective agar for colony isolation (~18 additional hours) which provide the starting material for antibiotic susceptibility tests (a final 8-18 hours). Waiting for the bacteria to grow can have serious consequences for the patient. For septic patients, each hour of delay in administering appropriate antimicrobial therapy increases morbidity and mortality by 8%.

The Fraunhofer USA Center for Manufacturing Innovation (CMI) has developed a novel and rapid sample preparation methodology that efficiently isolates microorganisms directly from whole blood and entirely circumvents the need for blood culture. The process takes less than one hour and maintains the viability of the pathogens for downstream live processing while reducing the 10 mL blood sample into a 30 µL pellet. Using a microfluidic platform, we have shown that shear stress in combination with low levels of chemical stress can cause irreparable damage to susceptible, but not resistant strains. Thus, we are able to accurately assign antibiotic susceptibility profiles without waiting for bacterial growth (entire assay <1 h). We are now working to combine these two technologies to enable rapid diagnostics of drug resistant bacteria – also known as superbugs.

# SECURITY AND SAFETY


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### Insecure Devices Are Unsafe Devices

Modern cars, medical devices and other cyberphysical systems rely on vast amounts of software. As a result, computer security is becoming a critical concern. For instance, recent news reports show how easy it is for hackers to take control of automobiles, medical devices, industrial control systems and more. In short, insecure devices are unsafe devices. The Fraunhofer USA Center for Experimental Software Engineering (CESE) is working to stop hackers in their tracks.

CESE brings a wide variety of skills and tools to this work. Specifically, CESE conducts tool-based analyses to model existing and proposed systems, to model potential security threats, to identify concrete attack vectors, and to ultimately redesign those systems to proactively cut off those threats. For existing systems CESE also performs tool-based penetration testing, playing the role of attacker and finding ways to break into a system – before the hackers do. Finally, CESE uses its detailed security knowledge and experience to train other companies' software developers on how best to avoid security problems from the beginning.

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# MOBILITY AND TRANSPORTATION

### Validating Autonomous Systems

Autonomous systems must undergo extensive validation before being put into operation. These systems are designed to operate in unstructured, even unknown environments and they are designed to make their own decisions. It is extremely difficult and expensive however, to design and conduct cost-effective validation for these systems. The Fraunhofer USA Center for Experimental Software Engineering (CESE) is working on a project sponsored by the US Naval Air Warfare Center aimed at creating powerful and cost-effective model-based approaches for validating autonomous systems.

The long-term goal of this project is to develop comprehensive support for building and certifying next generation autonomous systems. One focus of the project is to integrate simulation environments with model-based testing techniques, allowing rapid, in-depth exploration of large numbers of test scenarios within the simulation environment.

### Coating Solutions for Better Fuel Economy

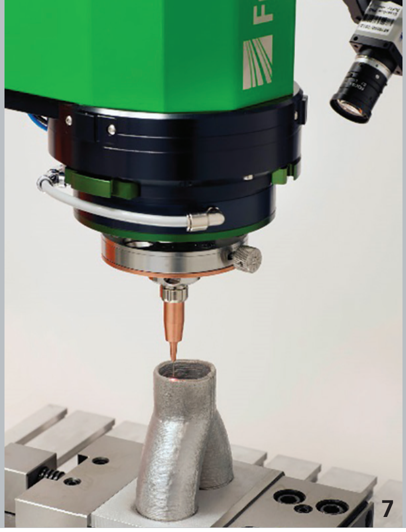
In vehicles powered by combustion engines, approximately 50 percent of frictional losses occur in the powertrain. The Fraunhofer Center for Coatings and Diamond Technologies (CCD) developed low-friction wear-resistant coatings for powertrain components that perform very well over a wide temperature range. Engine tests showed a 25% friction reduction at temperatures below freezing, which is particularly important for cold starts of vehicle engines and stand-by power generators. The coatings were also evaluated in terms of the friction and wear behavior against aluminum alloys for engine applications. They performed very well in terms of friction and wear reduction while maintaining the properties at temperatures up to 400°C.

### Lasers for Lightweight Vehicle Manufacture

The U.S. EPA (Environmental Protection Agency) regulations for CAFE (Corporate Average Fuel Economy) boosted the auto industry's mandatory overall fleet mpg from 25.3 in 2010 to 34.1 by 2016. This was, by far, the biggest CAFE increase in decades. Now the administration is pushing the standards even higher with a target of 54.5 miles per gallon by 2025.

In order to achieve these ever increasing requirements for improved fuel economy, automakers are left with no alternative but to look to the increased use of advanced technology in order to achieve vehicle mass reduction.

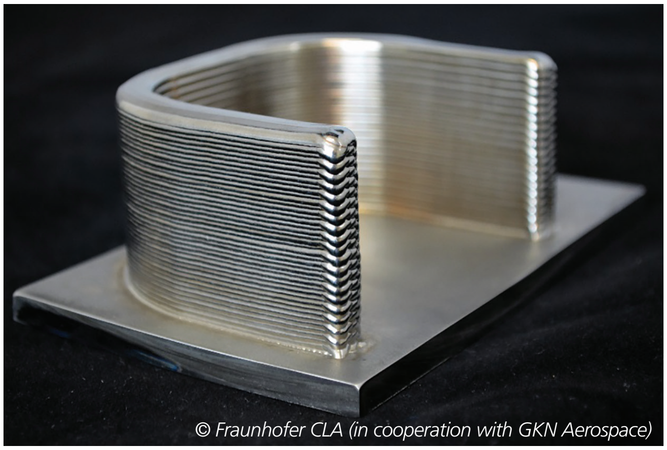
The Fraunhofer USA Center for Laser Applications (CLA) is actively engaged in a wide range of research programs where lasers can be used as an innovative tool for vehicle component mass reduction. These range from cutting, joining and laser-assisted forming of advanced materials such as aluminum, magnesium and carbon fiber composite materials to simple techniques like reducing flange sizes on door assemblies by replacing resistance spot welding with smaller laser weld joint designs. Such techniques are not only limited to Body-In-White and closures, but current projects are also focused on producing light-weight powertrain components where laser welding enables the use of lighter and thinner materials and novel multi-material design techniques which enable significant weight savings compared to conventional manufacturing techniques.



# PRODUCTION AND SERVICES

### Advanced Industrial Surfaces for Energy Efficiency

There are a variety of ways in which process surfaces can be treated to increase energy efficiency, including new approaches that are emerging in cutting-edge research. In the petroleum and chemical processing industry, the process scale is so large that even marginal improvements to industrial energy efficiency can have profound economic and sustainability impacts. In 2015, the ExxonMobil Research and Engineering Company partnered with Fraunhofer USA Center for Sustainable Energy System's (CSE) TechBridge program to invite proposals for innovative technologies in an Advanced Industrial Surfaces Challenge. The challenge sought to identify approaches to enable the scalable, cost-effective deployment of advanced surfaces that are durable and that will improve energy efficiency in the petroleum and chemical processing industries. The recently announced winner of this challenge, DropWise Technologies Corp., is developing and commercializing ultra-thin, durable and hydrophobic coatings with anti-fouling and condensation heat transfer applications. DropWise will be awarded up to $100,000 in testing services by Fraunhofer, which will help to accelerate their product to market.




### Building Parts from the Ground Up – Additive Manufacturing

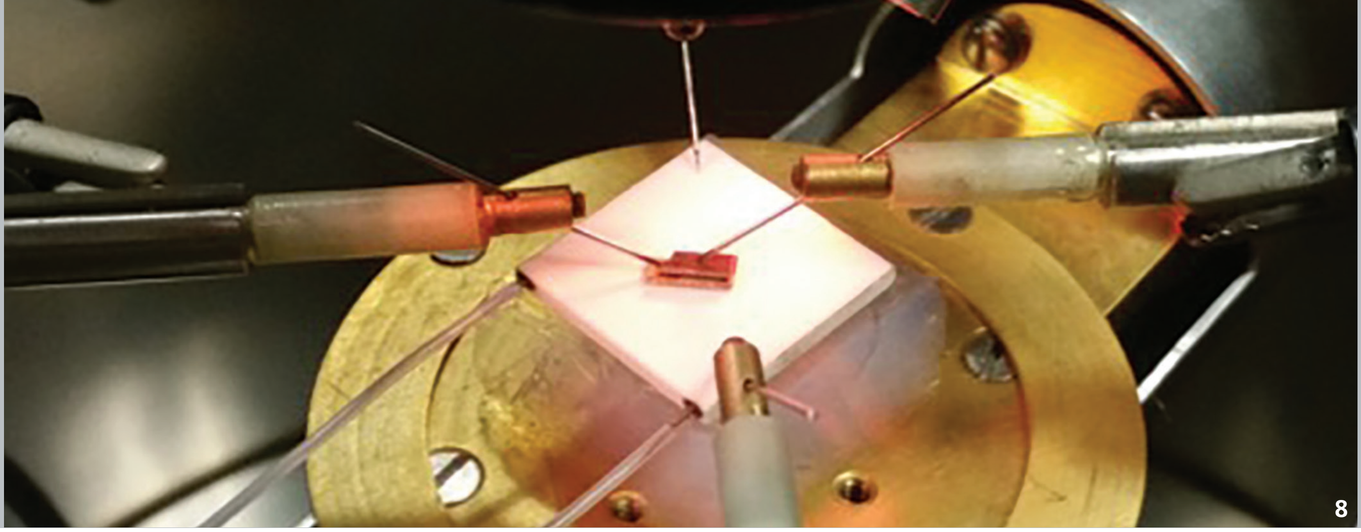
Additive manufacturing represents a radical new departure from traditional manufacturing methods.

The technique involves building parts layer by layer, typically using materials in powder or wire form.

The Fraunhofer USA Center for Laser Applications (CLA) is working together with its parent institute, Fraunhofer IWS, to develop and apply new technology for both direct powder and wire metal deposition which enables the construction of large scale structures.

Powder materials offer the advantage of being able to produce functionally graded materials where the materials deposited can be varied during the build sequence in order to produce the optimal part material properties and performance.

Wire materials can be deposited using the newly developed Fraunhofer IWS Coaxial wire deposition head. Now, for the first time, the deposition of wire materials can be accomplished with build movement in any direction using special processing optics which splits and then refocuses the laser beams into a concentric focus spot at the wire tip. Wire processing offers the advantage of deposition with 100% material utilization. We are working with several customers in the power generation and aerospace fields to produce test parts using this exciting new technology where unique part geometries can be built which result in significant reduction in the required material and machining time.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# ENERGY AND MATERIALS

### How to Turn Sun Power On (and Off)

Two of the greatest challenges to widespread use of solar electric energy are the variability and uncertainty of the solar resource. Large quantities of solar photovoltaic (PV) production need to be integrated with the electric grid without compromising power reliability and quality. In 2015, the U.S. Department of Energy announced that a Fraunhofer USA Center for Sustainable Energy Systems (CSE)-led team was awarded a three-year $3.5M research project that addresses these challenges. The project team will design, develop, and deploy a sustainable and holistic system for integration of solar PV, energy storage, and facility load management at the utility distribution scale in Massachusetts.

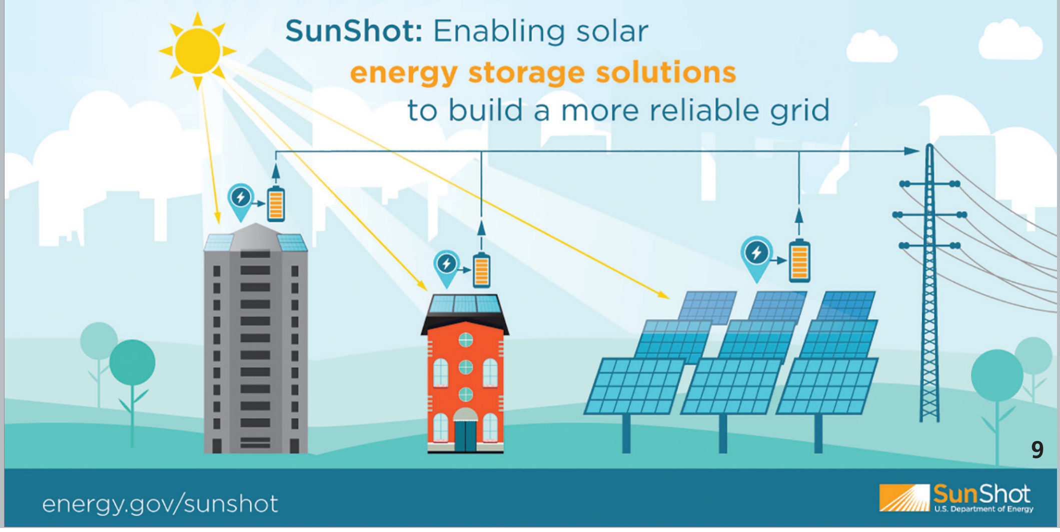
At the heart of the developed system is a Global Scheduler, "SunDial", that will tightly integrate control of PV, energy storage, and aggregated facility loads. SunDial will actively manage net system power flows to and from the feeder, regardless of whether these individual components are co-located at the same site or distributed at different sites. System design, development and implementation will culminate in a year-long field demonstration in Massachusetts. The project partners, CSE, National Grid, the Massachusetts Clean Energy Center (MassCEC), and EnerNOC, will match the award and put $3.5M towards the project.

### Enabling High-Efficiency Energy Systems with Ultra-Wide Bandgap Diamond Power Electronics

Power switching devices are at the heart of America's energy infrastructure enabling high voltage power distribution and conversion systems, connecting renewable energy sources to the grid, powering cloud-based computing infrastructures, driving industrial motors in manufacturing and enabling high power density traction inverters for propulsion systems in transportation. Most of today's high voltage semiconductor switches are still based on silicon and face serious material performance limitations in terms of power handling capabilities. However, the commercial availability of new power devices based on wide bandgap semiconductors such as silicon carbide and gallium nitride are beginning to transform the field. That is why in 2014 the U.S. Department of Energy's Advanced Research Programs Agency (ARPA-E) launched the SWITCHES program, short for "Strategies for Wide-Bandgap, Inexpensive Transistors for Controlling High-Efficiency Systems". Within this program, the Fraunhofer USA Center for Coatings and Diamond Technologies (CCD) and partner Michigan State University work on even further advanced switching technologies based on the ultra-wide bandgap semiconductor material diamond. If diamond devices prove feasible, the electrical resistance, and thereby the power loss, of devices would be reduced by a factor of thousand. In combination with its high temperature capability and the reduced need for cooling, diamond devices would enable substantial energy, space and weight savings compared to all existing solutions. The project is funded by the Department of Energy, Advanced Research Programs Agency – Energy (ARPA-E), project number DE-AR0000455.

### Increasing the Resiliency of the Electric Grid

With the goal of increasing the resiliency of local communities to phenomena that can disrupt the electrical grid and strongly affect urban community systems for undetermined periods of time, the Fraunhofer USA Center for Sustainable Energy Systems (CSE), the University of New Mexico (UNM), the University of Tennessee (UTK), the University of Texas, and Michigan Technological University were awarded with a grant under the National Science Foundation (NSF) CRISP Program. The project focuses on the transformation of power distribution feeders from relatively passive channels for delivering electricity to




customers, to distribution microgrids, or entities that actively manage local production, storage, and use of electricity.

The Key objective of the 3 year-project Revolution through Evolution: A Controls Approach to Improve How Society Interacts with Electricity is to produce a unified model that incorporates aspects of power generation and delivery, information flow, market design, and human behavior. Collaborating with the UNM and UTK researchers, a Fraunhofer USA CSE Energy and Behavior Scientist leads the project's human factors research. The research will focus on learning the boundaries of what should be expected from local populations in terms of changing the type or duration of everyday routines for diverse grid constraints and will analyze the response to several types of social, normative, and economic incentives.

### Reducing Energy Waste through Windows

In the U.S., buildings consume nearly 40 percent of the entire energy consumption, and of this, about 10 percent is caused by thermal losses through windows. The energy waste through windows amounts to 4 quads or approximately the energy content of 32 billion gallons of gasoline. The Fraunhofer USA Center for Coatings and Diamond Technologies (CCD) goal is to minimize these losses to well below 1 quad by developing a high performance window insert product having thermal resistance of R>12 at cost points that result in ROI's of less than 9 years. CCD partners with Mackinac Technology Company of Grand Rapids, Michigan, and the Fraunhofer USA Center for Laser Applications (CLA) in Plymouth, Michigan, on developing low-emissive (low-e) coatings that are compatible with polymer materials, apply these to all sides of the thin polymer panels, and utilize multiple panels according to the thermal need. The project is funded by the Department of Energy, Advanced Research Programs Agency – Energy (ARPA-E), project number DE-AR0000682.

### Modeling the Energy Efficiency of Residential Attics

The U.S. Department of Energy Buildings Energy Data Book shows that for about 120 million houses (2016) in the residential sector, space heating and cooling are accountable for the consumption of about 9.5 quads of prime energy, with heating and cooling representing 27.8% and 15.1% of primary energy end-use respectively. The same source shows that residential roofs are responsible for about 12% of heating loads (0.65 quad) and about 14% of cooling loads (0.16 quad).

To help predict (and ultimately avoid) losses in building construction, the U.S. Department of Energy asked ORNL and the Fraunhofer USA Center for Sustainable Energy Systems (CSE) to enhance CSE's Attic Thermal Model (FATM) and compute radiation, convection, and thermal losses during both on and off cycles of the comfort conditioning system. In 2015, Fraunhofer USA CSE completed new components of the framework, which now includes the attic air duct algorithm. The computer generated data was validated with experimental data generated by ORNL during a series of laboratory scale attic tests and by comparisons with results of field experiments performed by Fraunhofer USA CSE using test huts in Albuquerque, New Mexico, and Boston, Massachusetts.

Throughout this multi-year project, CSE is responsible for the development and validation of several new components of the FATM framework. After completion of development and validation tasks, the final product will be integrated with EnergyPlus – a widely used whole building energy model – and will become public domain.

### Glass Seals for Batteries

The Fraunhofer USA Center for Energy Innovation (CEI) in Storrs, Connecticut is developing new glass formulations for hermetic sealing of high temperature batteries for increased life and durability under exposure to harsh environments. Designing a seal suited for this exposed aggressive environment (redox atmosphere, molten salt/metal) is a persistent challenge for commercialization of these systems for safe operation and environmental sustainability. Self-healing glass/glass-ceramic materials have been developed for hermetic sealing in batteries. These sealing techniques provide


for long-term durability and thermo-mechano-chemical stability in these aggressive environments.

The use of glass-ceramic composite seals will enhance sealant life and the reliability of the system. Glass is considered to be a very good sealing material for high temperature advanced energy conversion and storage systems such as fuel cells, NaS/ZEBRA batteries and liquid metal batteries. The major advantages of the glass seals are formulation flexibility, good wetting and bonding with adjacent ceramic and/or metallic components, and hermeticity. The electrically insulating property of the glass seal is crucial to protect the system from electrical short circuit and related accident. These glasses can be used for similar application in various energy sectors such as fuel cells, thermal storage systems, and thermal power plants.

### Adsorbents for Gas Phase Contaminants Removal

The Fraunhofer USA Center for Energy Innovation (CEI) is investigating a new class of adsorbents for Si- and S- containing compounds. The center's activity is focused on the utilization of high surface area, crystalline walls and monomodal pore size distributions. Such materials have been used in $H_2S$ adsorption experiments and demonstrated high adsorption capacity. Siloxanes and organic sulfur compounds are present in in a number of feeds and fuels. These adsorbents have been optimized (w.r.t. synthesis temperature, calcining ramp and calcining temperature.) Absorbents have been generated with surface areas of up to 790 $m^2/g$ and adsorption capacities in the 500-600 mg/g range. They have demonstrated effective siloxane capture in the liquid phase and will be investigated for the gas phase.

A similar adsorbent for sulfur is also being developed. Removal of Sulfur-containing compounds from feed stocks will result in more efficient combustion with reduced $SO_2/SO_3$ by-products. As seen below, the so-called Meso $Mn_2O_3$ material and the OMS-2 materials under investigation show significant promise as an adsorbent over activated carbon.

Adsorbent regeneration is also in the process of being studied with preliminary results indicating that these adsorbents are reusable.

### Ceramic Filtration and Liquid Separation

A major project that the Fraunhofer USA Center for Energy Innovation (CEI) is currently working on in cooperation with Rauschert and Inopor of Germany is liquid water filtration utilizing ceramic membrane technology. A pilot filtration system provided by Rauschert/Inopor is in operation and located within CEI's laboratories for conducting research and development on current processing methods for organic material separation utilizing ceramic membrane technology. Connecticut has expressed particular interest in water filtration and waste clean-up which CEI is exploring with the State.

Ceramic membrane technology offers an array of benefits for the separation of organic and inorganic fluid feed streams under harsh operating conditions. The technology is based on a pressure driven filter separating a given feed stream into permeate and retentate. The separation process can be performed at varying temperatures for energy efficiency and is less harmful to streams than the utilization of classic separation techniques like distillation and organic membranes. These ceramic membranes can be operated using feed streams with high or low pH, abrasive properties and high temperatures. Bacterial resistance, high flux rates and high durability are unique properties of ceramic membranes that separate it from polymeric type membranes. The water filtration system was designed for a wide range of applications from micro-filtration to nano-filtration.

Potential customers who are interested in exploring this technology for their waste streams can bring their samples to be tested in the unit at CEI's facilities.

CEI has also built a bubble point apparatus and a gas permeation bench top unit which is used in the evaluation and qualification of membranes for testing on the large scale pilot liquid filtration system for demonstration and application work with industry sponsors.

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