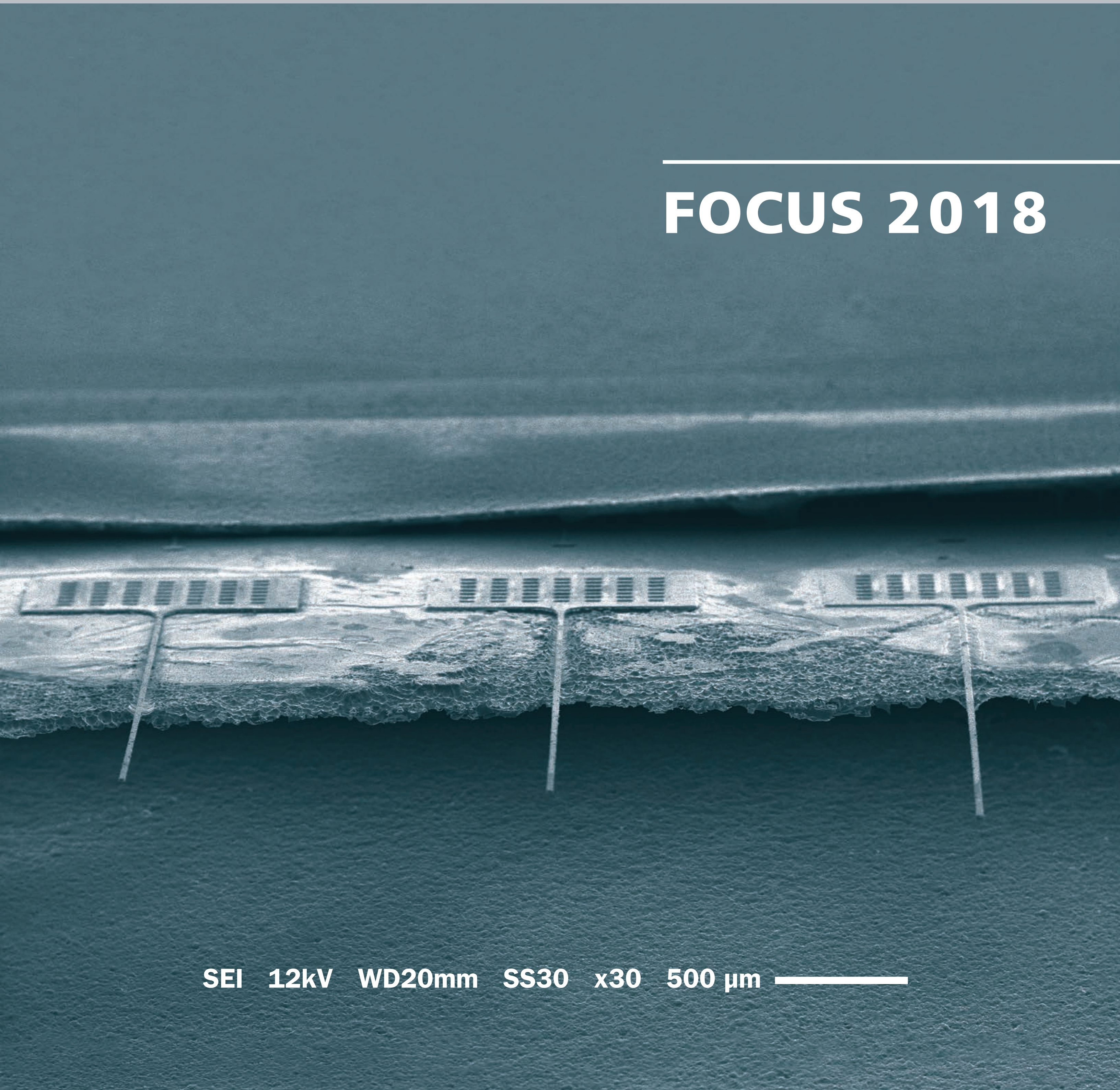
Fraunhofer

USA

FOCUS 2018



Welcome to the Fraunhofer USA Focus.
The Human Factor

As an applied research and development organization, we focus on taking today's technologies from original ideas toward future innovations. But technology in and of itself is lifeless, inanimate and ultimately useless without the human factor. As we boldly move into the future where we expect autonomous driving cars, computer networked manufacturing and 3D printers in every home, we need to be vigilant to keep technology the servant of man and not the master.

At Fraunhofer USA, we are committed to conducting applied research and development that serves the wider benefit of society. Our employees believe in this responsibility. In this edition of *Fraunhofer Focus*, we have highlighted several projects that reflect this commitment, such as the development of an intelligent chatbot to promote self-care for type 2 Diabetes patients, The Prometheus Program which tracks influenza transmission, a novel point-of-care blood dispenser and diamond microfiber electrodes for neurochemical sensing.

It is our employees and colleagues who make these technology breakthroughs possible. It takes hard work, creativity, perseverance and care. Here I take the opportunity to thank all the staff at Fraunhofer USA for their wonderful contributions to the organization, to the science and engineering body of knowledge and to society.

Sincerely,

Thomas Schuelke

Prof. Dr. Thomas Schuelke
Executive Vice President

Cover *Fraunhofer CCD – Diamond Micro Needles for Brain Research.*
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MANAGEMENT REPORT

Strategic Development

"There are not more than five primary colors (blue, yellow, red, white, and black), yet in combination they produce more hues than can ever been seen."
– Sun Tzu, *The Art of War*

The philosophy expressed in the above sentiment by Sun Tzu is also applicable to the marvelous capabilities of applied research and development. At Fraunhofer USA, we have core science and technology competences that when combined with new challenges and customer needs, lead to an unlimited innovation potential. It is for this reason that our customers come to us. It is the know-how, combined with innovation potential and flexibility that provides the desired solutions.

At Fraunhofer USA, we know that the science and technology world is changing at a rapid pace. We see evidence today of changes brought about by the transformative mindsets of younger generations reaching their majority. A clear example of this is the reluctance of younger citizens to buy into the idea of individual car ownership and the subsequent advent of ride sharing concepts. Suddenly the idea is growing that perhaps we don't really need circa 255 million cars on America's roads, if we can come up with an appropriate technology where the benefits outweigh the inconvenience of not having a personal car. We see all around us a general shifting of interests into the health fields, with new frontiers explored on how many emerging technologies can be utilized to secure a healthier and longer life. Of course, there is the ever-increasing usage of computer hardware and software in devices and products, making some of the everyday items we used even five years ago seem hopelessly antiquated.

As a society and as an organization, we need to be selective of the areas where we apply our resources and efforts. Our goal is to work with companies and agencies that are focusing on technologies that are beneficial to protecting and enhancing the quality of life. Our work priority is to provide results that do not cause additional strain on the environment and that provide sustainable solutions with tailored efficiencies.

Our strategy has two goals; stay fluid and diverse in key areas of science and technology and, together with our customers, keep positive technologies moving forward for the benefit of society. As a 501 (c) (3) membership organization, we have the ability to work with almost anyone, but we prefer to select customers who agree that those who create science and technology must act responsibly and with integrity.

In order to contribute to the scientific and engineering communities, our employees both attend and present at international conferences such as:

- Materials Research Society (MRS)
- Society of Vacuum Coaters Techcon (SVC)
- International Conference on Diamond and Carbon Materials (ICDCM)
- ARPA-e Energy Innovation Summit
- Pittcon
- International Conference on New Diamond and Nano Carbons (NDNC)
- European Materials Research Society (E-MRS)
- Electrochemical Society Conference (ECS)
- International Conference and Expo on Advanced Ceramics and Composites (ICACC)
- International Manufacturing Technology Show (IMTS)
- World Conference on Photovoltaic Energy Conversion (WCPEC)
- Intersolar North America
- Advanced Laser Applications Workshop (ALAW)

As a service organization, we recognize the value of sharing and learning from expertise, which is a strategic collaboration approach based on mutual trust that leads to better, faster and more efficient project results.

The Fraunhofer USA Centers recognize strategic planning as a key component to successful operations. Each Center ensures that its technological competences are applied across several business fields so that the risk of a particular technology becoming obsolete, unfunded or "disrupted" by competing or alternative solutions, is mitigated. The addition of business fields is carefully vetted to ensure that there is clear forward potential for the Center and interest in the larger community for these new efforts. Recent examples of this are the addition of a 3D printing group at the Fraunhofer USA Center for Coatings and Diamond Technologies CCD and a gear technology group at the Fraunhofer USA Center for Manufacturing Innovation CMI.

Customer acquisition and retention is of highest priority to the Centers. This requires not only assurance of high quality work and satisfied customers, but also the investment of time and attention by the staff at the Centers. Fraunhofer USA provides its customers with direct personal contact to the scientists and engineers who are performing the work. Our customers' feedback on their appreciation of this person-to-person contact is very positive.

Each year the Centers prepare an annual budget plan for next year's operations. This forward-looking exercise considers strategic hiring and acquisition needs, internal research plans and customer project execution and acquisition. Center directors conduct a careful assessment of planned operations over the next year in specific terms and broader strategic goals in three- to five-year outlooks. As science and technology move forward at very unpredictable rates, (think of electric vehicles already on the road in the 1800's) strategic mapping must rely on experience and market awareness. The risk is always the percentage of uncertainty that comes from operating in the open market environment.

Through our partnerships with US universities, Fraunhofer-Gesellschaft and others, we are able to gain information and share non-proprietary information on the latest and upcoming technology and technological needs of the future. This shared insight provides mutual benefit to all parties.

© Fraunhofer CESE, CESE research assistant conducting embedded system research.

Operating Objectives

As an applied research and development organization, we are committed to moving the science and technology forward by filling the gap between basic research and market deployment by providing industry and government customers with the support that they need. We act as an external R&D lab for companies or agencies that do not have specific labs or know-how.

The unique asset of Fraunhofer USA has always been its flexibility combined with its broad expertise and its innovative mix of scientist and engineering staff. This leads to strong responsiveness to technology challenges. This responsiveness is supported and expanded through the cooperative relationships formed with our partners, Boston University, Michigan State University, University of Maryland, University of Connecticut among others. Our closest partner, Fraunhofer-Gesellschaft, is Europe's largest applied research and development organization. We are proud to work together with such a renowned organization and are grateful for our potential to tap into the excellent science and engineering capabilities of our partner. Throughout the years, multiple joint projects have been completed allowing maximum benefit for the customer.

In 2019, Fraunhofer USA will reach its 25th year of operation in the United States. As we move forward into the next quarter century, we will apply the lessons learned over the years and continue the sustainable growth and scientific and engineering excellence that we provide to our customers.

Contract Research

Fraunhofer USA's research portfolio is very fluid and dynamic. In 2017, Fraunhofer USA earned research and development contract revenues of $9.7 million from industry, and $10.7 million from government and universities. The revenue split between the two types of customers demonstrates a healthy mix that offers protection in a sometimes volatile R&D spending environment. Customers range from well-known big-name and large companies, to small unknown startups. This customer range demonstrates the need for services that are offered by Fraunhofer USA. Across size and type of business, public or private companies or agencies, there is benefit in engaging the science and engineering experts at Fraunhofer USA. Our customers trust us to help them find solutions.

Our staff are able to adjust to the level of R&D development and support that the customer requires. Some customers have already identified a specific potential solution, such as adding a friction reducing coating to a device, decreasing wear on that device. Other customers come to Fraunhofer USA for help with a problem for which the solution is wholly unknown. Fraunhofer USA has the capability and expertise to solve complex and challenging problems. The contract research capabilities of the organization are further supported and expanded by the cooperation and partnerships with Universities and the access to its partner, Fraunhofer-Gesellschaft, based in Germany.

The seven Fraunhofer USA research Centers employ a diverse group of scientists and engineers with a broad range of expertise. Fraunhofer USA staff work closely with our customers to enable them to realize their goals.

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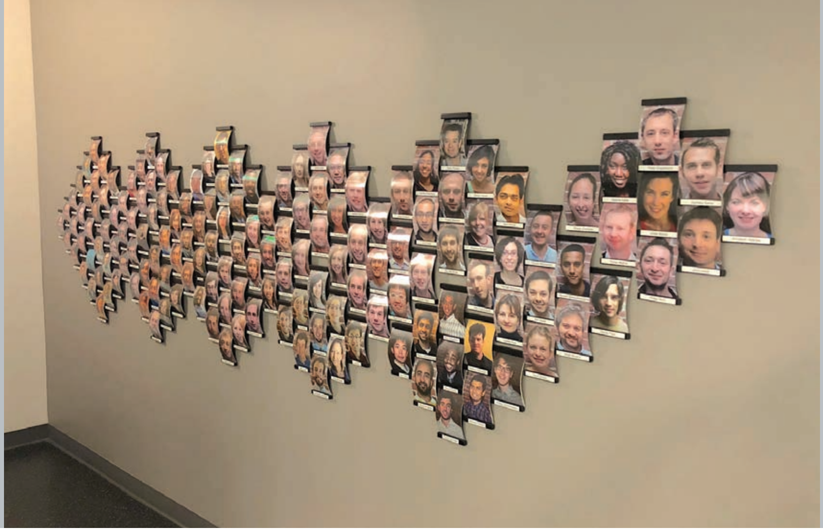


© Fraunhofer CSE, Fellow Wall of Fame.

Human Resources

Changes in personnel in an organization can occur for many reasons. Some evidence positive changes, such as fast-paced hiring due to expanding business and new customer acquisition, some reflect negative changes such as mergers and acquisitions resulting in involuntary downsizing. Some changes are simply a reflection of external factors such as the continued retiring of members of the baby boomer generation, or millennials becoming a much larger percentage of the work force.

Fraunhofer USA, like other organizations, bases its workforce composition on market factors. The research and development market can change rapidly however. Should a breakthrough technology be introduced into the world, R&D on that topic may no longer be supported.

As a provider of applied scientific and engineering research, the question always comes up whether reported shortages of scientists and engineers really exists. Several notable scholarly works have been published in recent years that argue for and against the shortage, with equal fervor. In recent years, we have empirical evidence that it is a tight hiring market and competition is tough for specialized skills. This is where retention becomes key. We recognize that excellent employees are key to an organization's success. Our organization works hard to preserve value of their employment to the employees of the organization. Our family-friendly benefits and competitive compensation packages are designed to keep employees satisfied.

In this era of changing mindset, benefit and compensation packages alone do not retain and attract employees. Survey after survey is showing that employees are opting to work for companies where they can feel they are making a difference, where they can have meaningful collaboration with others to solve problems, and where they have a voice in the business, no matter how high or low in the organization's hierarchy they currently are.

We value our employees and the talent and intelligence that they bring to their jobs. In the section "Faces at Fraunhofer" (beginning on page 21), you will read about some of our fine employees.

In addition to our regular full-time employees, we are currently hosting more than 50 interns. These interns are the next generation of scientists and engineers who are seeking the kind of hands-on practical training that will put them a step ahead of their peers competing in the job market.

Equipment and Infrastructure

Fraunhofer USA facilities have a total combined working space of over 173,000 square feet and more than $47 million in equipment and infrastructure assets. The Centers also have access to additional equipment and resources through the partnerships with universities and the network of the 72 institutes and research units at our partner organization, Fraunhofer-Gesellschaft, in Germany.

Fraunhofer USA has been able to expand its machine portfolio due to generous equipment donations from current and former customers. Several current customers of Fraunhofer USA have located their equipment on-site at the Centers to showcase the machines being used in the development of specific technologies.

University Partnerships

Fraunhofer USA has excellent and mutually beneficial partnerships with several US universities. Like the Fraunhofer-Gesellschaft 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. The university partnerships provide mutually beneficial synergies in many ways that increase the value and usefulness of both organizations.

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

Boston University has a student body of approximately 34,000 students of which circa 15,000 are graduate students. Boston University ranked #37 in national universities in *US News and World Report* for 2018. As a leading global research institution, BU has been awarded over $400 million in grants and contract awards in 2017.

Fraunhofer 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.

Founded in 1856, the University of Maryland has an enrollment of approximately 40,000 students, of which circa 10,000 are graduate students. The University of Maryland has become one of the nation's leading public research and innovation universities, receiving over $500 million in research awards in 2017.

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 has a total of approximately 50,000 students, of which circa 11,000 are graduate students. External researching funding for MSU totaled approximately $600 million in 2016-2017.

Michigan State University ranked number 33 in top public schools in the 2018 Best Colleges report released by *US News and World Report*. Fraunhofer CCD, in collaboration with Michigan State University and its College of Engineering, provides innovative research and development services based on its expertise in

© Fraunhofer CCD, Mr. Frank-Peter Bach from H-O-T, Prof. Dr. Thomas Schuelke, EVP of FhUSA and Prof. Dr. Leo Kemple, Dean of Engineering from Michigan State University open new MSU-Fraunhofer CCD Lab July, 2018

coatings and diamond technology. This collaboration has recently been expanded to support advanced scientific research in coatings, diamond electronics, and 3D printing technology.

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 was founded in 1743. Currently the enrollment is made up of circa 18,000 undergraduate students, and 3,800 graduate students. UDEL received over $140 million in sponsored research projects in 2017.

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 University of New Mexico, Albuquerque and Virginia Commonwealth University, Richmond, VA among others.

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 CMB
- Maryland – Fraunhofer USA Center for Experimental Software Engineering CESE
- Massachusetts – Fraunhofer USA Center for Sustainable Energy Systems CSE
- Connecticut – Fraunhofer USA Center for Energy Innovation CEI

Fraunhofer Partnerships and Cooperation

Fraunhofer USA Partner Institutes

Fraunhofer USA Center for		Fraunhofer Institute for
Coatings and Diamond Technologies CCD	«»	Material and Beam Technology IWS
Laser Applications CLA	«»	Material and Beam Technology IWS
Experimental Software Engineering CESE	«»	Experimental Software Engineering IESE
Manufacturing Innovation CMI	«»	Production Technology IPT
Sustainable Energy Systems CSE	«»	Solar Energy Systems ISE
Molecular Biotechnology CMB	«»	Molecular Biology and Applied Ecology IME
Energy Innovation CEI	«»	Ceramics Technologies and Systems IKTS
Digital Media Technologies Office DMT	«»	Integrated Circuits IIS

Fraunhofer USA Centers also work and collaborate with colleagues of the other 72 institutes and research units within the network of the Fraunhofer-Gesellschaft in Germany.

Outlook

President Trump signed a federal funding law, the Consolidated Appropriations Act, 2018, that delivers average funding increases of over 10% for science across the US government, the largest increase in a decade. This will provide increased opportunity to obtain government contracts from the various agencies. The Tax Cuts and Jobs act of 2017 passed on December 22nd 2017, reducing the corporate tax rate from 35% to 21%. How effective the changes to the corporate tax structure will be in freeing up spending for R&D for industry is unknown at this point, however the expectation is that this will increase spending.

Fraunhofer USA, Inc.

Balance Sheet
As of December 31, 2017

Assets	
Current Assets	
Cash and Cash Equivalents	$ 16,788,304
Accounts Receivable	8,381,315
Investments	636,651
Prepaid Expenses and Other Current Assets	576,009
Total Current Assets	26,382,279
Property and Equipment - Net	43,569,790
Intangible Assets	212,993
Long-Term Receivable	2,245,186
Total Assets	$ 72,410,248
Liabilities and Net Assets	
Current Liabilities	
Accounts Payable	$ 1,503,810
Deferred Revenue	1,478,767
Accrued Liabilities and Other	17,501,660
Total Current Liabilities	20,484,237
Long-Term Obligation	15,404,984
Total Liabilities	35,889,221
Net Assets	
Unrestricted	
Undesignated	3,742,245
Increase (Decrease) in Undesignated Assets	108,000
Designated	29,072,485
Increase (Decrease) in Designated Assets	(228,356)
Temporarily Restricted	
Temporarily Restricted	1,279,583
Increase (Decrease) in Temporarily Restricted Assets	2,547,070
Total Net Assets	36,521,027
Total Liabilities and Net Assets	$ 72,410,248

Fraunhofer USA, Inc.

Statement of Activities and Changes in Net Assets
Year Ending December 31, 2017

Contract Revenue	
Industry	$ 9,685,930
Government & Universities	10,711,558
Fraunhofer Institutes	2,006,454
Miscellaneous	197,903
Total Contract Revenue	22,601,845
Support	
Base Funding	10,716,080
In-Kind Contributions	3,909,885
Other	928,226
Total Support	15,554,191
Funds Released from Restrictions	1,025,575
Total Undesignated Revenue, Support and Released Funds	39,181,611
Labor Costs	19,589,457
Undesignated Other Expenses	
Administrative Expenses	12,325,679
Cost of Goods Sold - Excluding Labor	6,906,915
Depreciation and Amortization	251,560
Total Undesignated Other Expenses	19,484,154
Total Labor Costs and Undesignated Other Expenses	39,073,611
Increase (Decrease) in Undesignated Assets	108,000
Undesignated Net Assets	3,742,245
Designated Revenue	2,242,198
Designated Expenses	(2,470,554)
Increase (Decrease) in Designated Assets	(228,356)
Designated Net Assets	29,072,485
Temporarily Restricted Revenue	3,572,645
Funds Released from Temporary Restriction	(1,025,575)
Increase (Decrease) in Temporarily Restricted Assets	2,547,070
Temporarily Restricted Net Assets	1,279,583

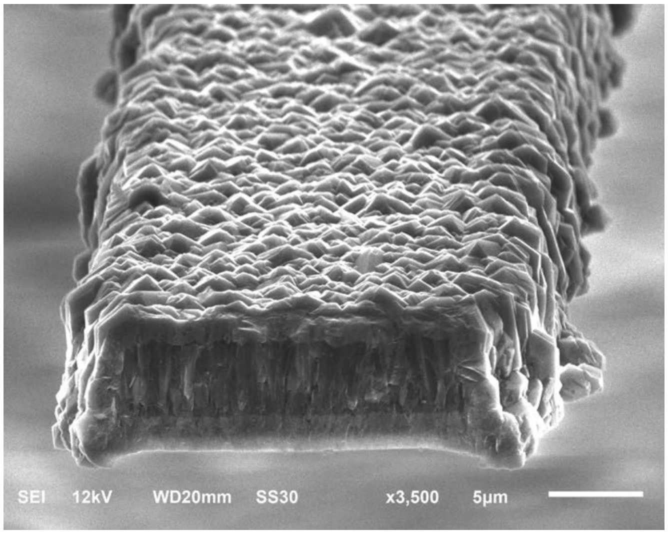
The seven Fraunhofer USA Centers conduct research and development for state, federal and industry customers in fields that have been identified as directly impacting current and future societal needs. Below is a selection of some of the recent projects at the Centers.

HEALTH AND ENVIRONMENT

All-Diamond Microfiber Electrodes for Neurochemical Sensing

Implantable microelectrodes have permitted vast expansion in neurochemical research in recent years. The ability to measure neurotransmitters with high sensitivity and selectivity has enabled a better understanding of brain and nervous system function. These measurements have traditionally been completed using carbon fiber microelectrodes and while they have shown promise, the need for a more stable electrode material remains. Diamond has many advantages as an electrode material: good biocompatibility, resistance to fouling, wide working potential window, and long-term stability, among others. All of these properties are beneficial for in vivo neurochemical sensing. As such, in conjunction with Michigan State University, researchers at the Fraunhofer USA Center for Coatings and Diamond Technologies CCD have developed all-diamond microfiber electrodes capable of reliable and precise neurochemical measurements. The all-diamond microfiber consists of a conductive, boron-doped diamond (BDD) core encapsulated by layers of insulating polycrystalline (PCD) diamond. These novel microelectrodes are fabricated using batch processes, thereby allowing for the construction of hundreds of electrodes in one fabrication procedure.

The all-diamond microfibers have proven capable of executing measurements at speeds similar to that of the neuron firing rate using fast-scan cyclic voltammetry (FSCV) of neurotransmitters such as dopamine and serotonin. With expertise spanning diamond deposition, microfabrication processes, electrochemical analysis, and in vivo testing, the MSU-CCD team has all the necessary tools to drive this novel device to market.



© Fraunhofer CCD, Electron Microscope Image Diamond Micro Needle.

Flexible Boron-doped Diamond Sensors for Neurotransmitter Measurements

Neurotransmitters (NTs) such as dopamine (DA) play a major role in the brain and regulate many fundamental processes in human physiology, specifically the renal, hormonal, and cardiovascular systems. Irregularities in DA levels can cause a number of neurological disorders such as Parkinson's disease and schizophrenia. For these reasons among others, real-time monitoring of dynamic changes in DA concentration is crucial to the understanding of the functionality of the brain.

Electrochemical measurements of NTs have proven to be an effective way to monitor brain function. Though carbon fiber microelectrodes (CFMEs) have been capable of executing sensitive measurements of NTs, this material has been known to bio-foul and in some cases, generate erratic results. As such, a more robust, reliable electrode material is desired to further development of in vivo measurements of DA and other NTs.

Boron-doped diamond (BDD) is a biocompatible material with an array of advantageous properties for in vivo measurements. It exhibits the widest electrochemical potential window of all solid electrode materials, is notoriously resistant to fouling, and is sensitive to many different NTs. Furthermore, BDD can behave as an excellent heat spreader, significantly reducing the risk of thermal damage to surrounding tissue. Though BDD growth is not possible on polymer substrates, the development of a wafer transfer process to yield flexible, yet sensitive BDD sensors for NT measurements is of importance to the neuroscience field.

Researchers at the Fraunhofer Center for Coatings and Diamond Technologies CCD and Michigan State University (MSU) have developed a wafer transfer process for the fabrication of flexible BDD sensors at high yield. Thin BDD films are deposited on silicon (Si) substrates, structured and transferred to Parylene C. Parylene C is a micromachinable, transparent, flexible, FDA-approved and USP Class VI biocompatible polymer, which has been widely used as an excellent structural and packaging material in neural implants. The first and second generation flexible BDD on Parylene C sensors are shown in Fig. 1A and B *(above)*. The first-generation sensors have the BDD nucleation-side exposed, while the second-generation sensors have the BDD grown-side exposed.

Concurrent to the BDD sensor development, Fraunhofer CCD and MSU researchers have also developed a diamond-based µLED probe for neural stimulation. The µLED probe consists of an anode and cathode each 60 µm in radius and is shown in Fig. 2. Prior studies completed by the CCD/MSU team suggests that a diamond heat spreader is able to keep the temperature variation of the µLED probe within 1.3 °C when driven by 3.4 V, 100 ms pulses. The developed stimulation and sensing package creates a powerful tool capable of a multitude of brain diagnostics.

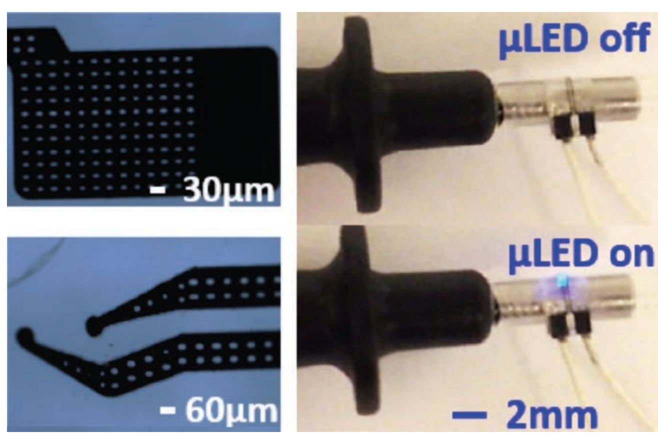


Fig. 2: BDD-based µLED for neural stimulation

1A and 1B © *Fraunhofer USA, Nucleation (left) and grown (right) side flexible BDD sensors on Parylene C*

Both generations of flexible BDD sensors have undergone extensive ex vivo testing to comprehensively characterize both the surface and electrochemical properties. This has included the investigation into such parameters as electron transfer rate, double layer capacitance (Cdl), iR drop, and charge transfer resistance (Rct) using the ferri/ferrocyanide ($Fe(CN)_6^{3-/4-}$) and ruthenium hexamine ($Ru(NH_3)^{2+3+}$) redox couples. The grown-side BDD sensors exhibited improved electrochemical results and cyclic voltammograms of each redox couple are shown in Fig. 3.

It should also be noted that the flexible sensors use BDD as the materials for all three electrodes: working, reference, and counter. Because reference electrode stability is crucial to repeatable electrochemical measurements, the BDD quasi-reference electrode potential was studied against a traditional silver/silver chloride (Ag/AgCl) reference electrode and results are shown in Fig 4. Minimal shift was observed from sensor to sensor over 12 h time periods, indicating that the BDD quasi-reference electrode can provide the stability needed.

The grown-side sensors have also returned promising results for the detection of DA, both individually and in the presence of ascorbic acid (AA), the primary interference for DA detection. This was completed using square-wave voltammetry (SWV), a method used to minimize background current and lower detection limits. Fig. 5 shows voltammograms of DA detection in the presence of AA. A calculated limit of detection of 0.8 µM was obtained with excellent spatial resolution of the DA and AA peaks.

Further developments include BDD surface pre-treatments and electrochemical measurements using fast-scan cyclic voltammetry (FSCV) to generate a third-generation flexible BDD sensor. FSCV is the traditional method used for in vivo measurements as data can be acquired as neuron-firing occurs. Biocompatibility studies are under current investigation as well to complete the comprehensive studies needed prior to executing measurements in vivo.

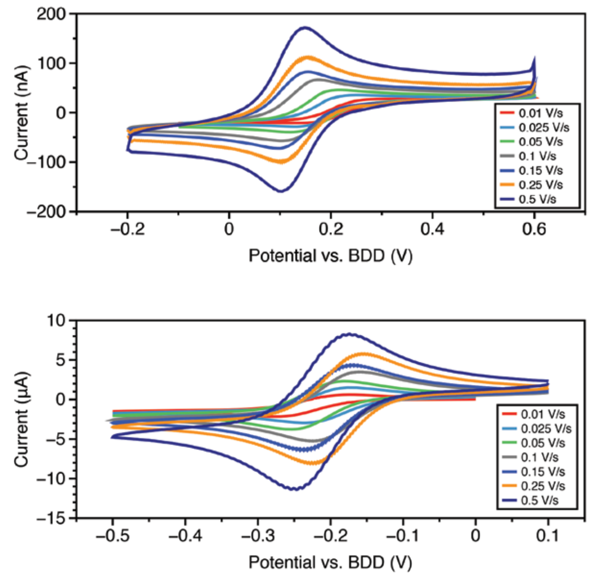


Fig. 3: Grown-side BDD cyclic voltammetric response to (top) 1 mM $Fe(CN)_6^{3-/4-}$ and (bottom) 5 mM $Ru(NH_3)_6^{2+/3+}$ at varied scan-rate. Semi-infinite linear diffusion observed for both redox couples.

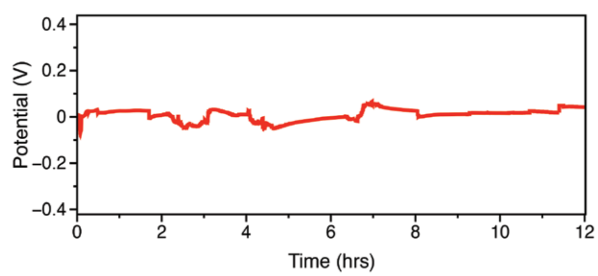


Fig. 4: Grown-side BDD sensor reference electrode stability vs. a traditional Ag/AgCl reference electrode in 0.1 M PBS, pH 7.4

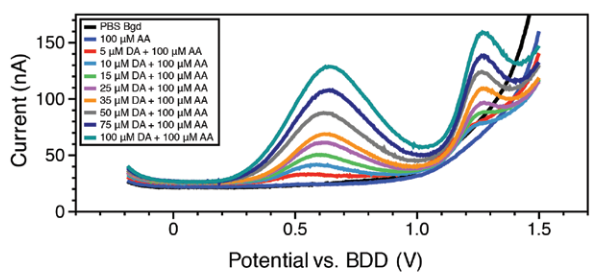
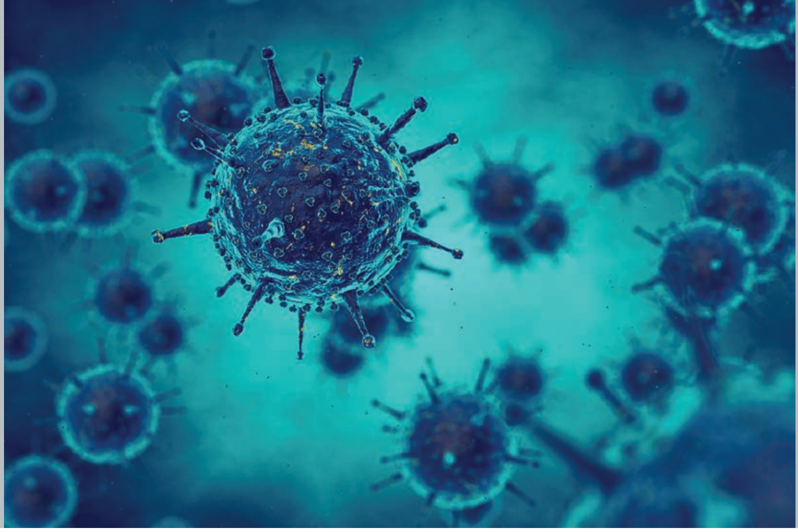


Fig. 5: Square-wave voltammetric response of dopamine in the presence of ascorbic acid on flexible BDD grown-side sensors



Using an Intelligent Chatbot to Promote Self-Care for Type 2 Diabetes Patients

With one in three Americans at risk of contracting Type 2 diabetes, there is a great and rapidly growing need for less costly ways to manage this chronic disease. The Fraunhofer Center for Experimental Software Engineering CESE has partnered with the MedStar Health Research Institute, the University of Maryland and the University of Tennessee to develop a chatbot-supported system that allows health-care providers to more effectively monitor and treat patients, without requiring them to visit a clinic.

With initial funding from the Latham Foundation, Fraunhofer CESE is building a context-sensitive chatbot that collects data about the patient's daily routines and behaviors and uses it to more intelligently support the patient/doctor interaction. Specifically, the system collects information from IoT devices, such as smart pill bottles, and it also queries patients (initially via SMS messaging, voice interactions will be added later) as to their health status, adherence to dietary guidelines, medication regimen, and uses this information to deliver patient-specific recommendations designed to supplement the patient's in-clinic care visits. To minimize patient burden while maximizing information value, our system leverages the AI capabilities found in the Lex platform which powers the Amazon Alexa to add context.

CESE has developed and tested the initial prototype. The next step is to recruit MedStar patients with Type 2 Diabetes to participate in focus groups, to further develop the chatbot's vocabulary and understanding of how patients view their disease, challenges and successes. This data will be used to build the library of terms with which patients interact with Alexa and then train the chatbot to respond accordingly with the customized advice.

As well as generating pilot data, this proof of concept project is designed to demonstrate the consortium-led approach to chronic disease management and can result in both better health outcomes for patients and reduced healthcare costs for providers. This will position the team to apply for funding from federal and third-party sources to build out a large-scale system in the near future and deliver in-home wellness and disease management advice to at-risk patients.

The Prometheus Program: Tracking Influenza Transmission

What if it were possible to know, within 24 hours after exposure to the flu or some other pathogen, whether a person would become contagious? Fraunhofer CESE is collaborating with the University of Maryland's Institute for Applied Environmental Health and others to look for the molecular biomarkers that would make that possible. The Defense Advanced Research Projects Agency's (DARPA) "Prometheus Program" aims to create an early detection system for contagious people in order to prevent epidemics and pandemics of influenza and other emerging infectious diseases.

The study will define the contagious phenotype, that is, what makes someone contagious. The Prometheus Program is the only study of its kind examining natural infections with the goal of increasing the predictive power of the biomarkers by leveraging a holistic (public) health perspective.

The experiment's real-world setting is a university residential dormitory, home to College Park freshmen. Student movements are captured by tracking their cell phones and environmental data is captured from their living quarters. When one of these students gets sick, they provide blood, nose and throat swabs, hair and nail samples for detailed analysis. Then, the mode of transmission is observed among those individuals who get sick with the flu, and their close contacts.

One outcome of this study may be a better understanding of how flu is transmitted in enclosed spaces or buildings, such as, offices, schools, prisons, and hospitals. This information can then be used to control the transmission of flu among military personnel in barracks or aboard aircrafts and ships.

© Fraunhofer CMI, POC Blood Dispenser.

Fraunhofer CESE is ensuring that the multiple information technology (IT) systems that the research relies on will work together to provide all necessary functional, data management, and data security capabilities. Specifically, Fraunhofer CESE is leading efforts in (1) Data Management – Developing standards for (meta) data format and content as well as policies for the acquisition, storage, archiving, preservation, and sharing or dissemination of data, as appropriate, (2) Process Monitoring – Developing a process and application program interface (API) for dynamic monitoring of the health and functionality of key Prometheus@UMD IT subsystems with a specific focus on system reliability and scalability planning, (3) System Architecture – Developing a comprehensive and integrated system architecture to increase the reliability of the Prometheus@ UMD subsystems through the use of redundant or high-availability design principles, (4) Configuration Management – Implementing reliable and controlled policies and processes for the establishment, modification, preservation, and archiving of the configuration data for IT subsystems, (5) Data Security – Defining policies and processes to establish and maintain standards for confidentiality, integrity, and availability of data collected as part of the project.

Eliminating Multiple Fingersticks Improves Patient Care

A global revolution in demand for lab-free diagnostics has generated a large market for point-of-care (POC) testing. Many of these tests rely on a fingerstick as the patient blood source. The blood is often fed directly into the POC cartridge with the device metering out the sample. When multiple tests are performed, blood delivery to multiple devices would generate a scenario in which coagulation and cross-contamination are significantly increased. Therefore, in the case of multiple POCs, the patient must endure multiple fingersticks. Some medical protocols require each patient to endure up to 4 fingersticks per visit. This is understandably a negative outcome for these patients who are often ill.

The Fraunhofer USA Center for Manufacturing Innovation CMI addressed this pressing need in the market by designing a novel POC blood dispenser. Modeled after a standard pipettor, the user simply attaches a standard capillary and aspirates up to 100 µL of blood directly from the fingerstick. Blood volumes from 5-50 µL in 5 µL increments can be accurately delivered to a broad array of downstream POC products. In this formulation, contamination and infection risk are reduced as only the disposable capillary tube comes in contact with patient blood.

In terms of design, the device contains a three-position shuttle valve which allows the user to fill, dispense, or hold the blood in the capillary. This third position is of particular utility if the user needs to bandage the patient or dispense to an additional device. Volumes are controlled through an internal mechanism. Each step corresponds to a 5 µL change in capillary volume and is easily controlled by a rotating dial on the handle of the device. The format is immediately familiar to lab technicians and allows for rapid adoption of the technology.

During in-house testing, the POC Blood Dispenser performance was directly compared to a standard calibrated P20 pipettor. Our device had lower systematic errors than the P20 and favorably compared to the P20 at all dispensing volumes. In collaboration with PATH, a global non-profit, we simulated a point-of-care low-resource clinic in order to test potential field performance. The volunteer team consisted of five novice users and 21 blood donors. Clinical testing demonstrated the accuracy and utility of Fraunhofer CMI's approach. This work was recently published and is currently under discussions with industry partners for licensing. (Sauer-Budge AF, et al. PLoS ONE 2017.12.e0183625).

Smart Assistive Device

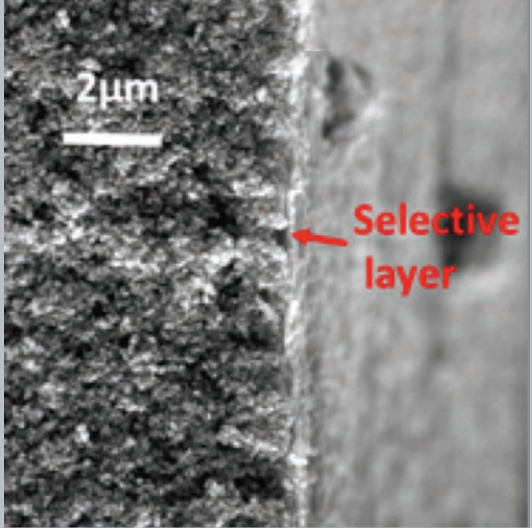
Fraunhofer CESE researcher, Gudjon Magnusson, is working with the Boston based Puffin Innovations to develop a smart assistive device to enable individuals with physical disabilities to interact with their digital devices. Frauhofer CESE is working to enhance the functionality of embedded software in the mouth-operated interface device and develop an accompanying smart phone application.

This new device will allow users to fluidly and independently interact with their digital devices, such as smart phones and laptops. The accompanying application, which will run on any modern Android device, will allow the user to monitor the status of the device and customize their experience.

Competing devices that currently exist in the market often require users to get assistance from an able-bodied person for simple and common tasks. With this new device, the aim is to give users greater independence and a better experience.

Puffin Innovations was founded by Adriana Mallozzi, a long-term advocate for people with disabilities and for the expanded use of assistive technology. She and the team at Puffin Innovation are dedicated to the goal of leveling the playing field for people with physical disabilities by giving them equal access to computers and mobile devices, both in the workplace and their personal life.

© Fraunhofer CESE, Puffin input device



SECURITY AND SAFETY

IARPA Functional Genomic and Computational Assessment of Threats (Fun GCAT)

Recent advances in genetic engineering technologies hold great promise, but also raise serious concerns of an accidental or intentional release of biological threats. Currently, biological threats are identified via string matching based on genetic relatedness to static lists of known threats. These "blacklists" however can only work for known sequences, failing to capture equally dangerous sequences in the list.

To address these emerging biosecurity concerns, Fraunhofer USA Center for Experimental Software Engineering CESE and its partners are developing next-generation computational and bioinformatics tools to improve DNA sequence screening and to, in turn, augment biodefense capabilities. Fraunhofer CESE scientists are especially focused on testing and evaluating these tools' ability to identify genes responsible for the pathogenesis and virulence of viral threats, bacterial threats, and toxins.

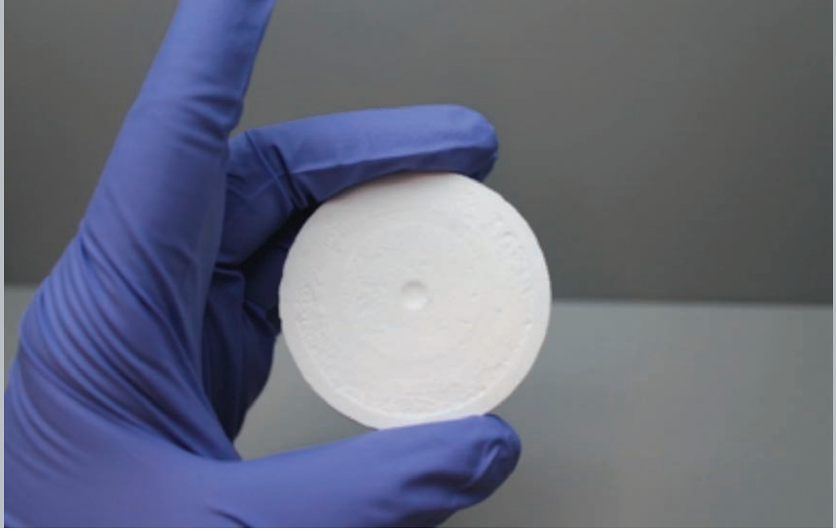
This is challenging because these tools rely heavily on machine learning algorithms, which are notoriously difficult to validate. For example, the correctness of a machine learning-based algorithm depends on the quality of the source code, but also on the data set that was used to train it. Therefore, such systems may produce acceptable results on certain data sets, but produce unacceptable results when used on new data sets. Thus, the quality of the training data set is as important as the correctness of the implementation. In order to address this problem, Fraunhofer CESE scientists are developing new testing and evaluation techniques for machine learning-based systems.

This work involves Fraunhofer CESE, along with a partner team led by Signature Science, two other life sciences companies, the University of Maryland, and the University of Virginia. The project is funded by an award from the US Intelligence Advanced Research Projects Activity (IARPA) through their Fun GCAT program. IARPA is charged with leading research to overcome difficult challenges relevant to the US Intelligence Community.

Fraunhofer CEI, The University of Connecticut, and Fraunhofer IKTS collaborate on Developing New Membrane for Organic Solvent Nanofiltration

Researchers at the University of Connecticut (UConn), Fraunhofer USA Center for Energy Innovation CEI, and Fraunhofer Institute for Ceramic Technologies and Systems IKTS have developed a new thin film composite membrane for use in organic solvent separations. Using the Inopor® ultrafiltration membranes designed by Fraunhofer IKTS, the team from UConn and Fraunhofer CEI created a new type of membrane that can remove small molecules from the harsh solvents. The membrane is made by forming a polyamide selective layer directly onto the ceramic membrane. This layer has similar chemistry to that use in thin film composite membranes for reverse osmosis. The resulting membrane has been shown to remove dye as small as 300 g/mol in molecular weight while exhibiting remarkable permeance for typical solvents. The work was recently published in the *Journal of Membrane Science* (https://doi.org/10.1016/j.memsci.2018.05.069) with Jeffrey McCutcheon (Fraunhofer CEI), Markus Weyd (Fraunhofer IKTS), and Lingling Xia (UConn).

© Fraunhofer IKTS, New thin film composite membrane.



ENERGY AND MATERIALS

Fraunhofer CSE develops Polyisocyanurate (PIR)-based Super Insulation at Atmospheric Pressure (SIAP)

Fraunhofer USA Center for Sustainable Energy Systems CSE is leading the effort to develop a polyisocyanurate (PIR)-based Super Insulation at Atmospheric Pressure (SIAP) that (1) can reach R-12 hr·ft2·°F/Btu·in (λ= 12 mW/m·K), (2) is mechanically robust and (3) is cost-competitive to conventional plastic foams by employing freeze drying instead of the supercritical drying. Freeze drying reduces capital expenditures by a factor of ten and total costs by about 70% compared to supercritical drying. Furthermore, the PIR-based SIAP does not experience thermal aging, uses no environmentally harmful blowing agents, and will have superior fire resistance compared to most conventional foams used in the US. In addition, the developed insulation is significantly stronger compared to the silica aerogels. Currently, Fraunhofer CSE is focusing its resources to attain high R-value by reducing pore gas conduction via reaching pore sizes of 20-50 nm (Knudsen regime at atmospheric pressure). Fraunhofer CSE has developed methods to control particle and pore sizes. The Center is working to simultaneously optimize the strength and thermal performance of isocyanate-derived polymer aerogels.

Super-Hard Coatings on Inner Diameter Surfaces

Over the past ten years, researchers at Fraunhofer USA Center for Coatings and Diamond Technologies CCD have developed a cathodic arc technology for producing super-hard tetrahedral amorphous carbon (ta-C) coatings. A thin ta-C layer (e.g. <30 microns) can effectively protect the working surface from wearing due to a high hardness value of >6000 Vickers compared with ~200 Vickers of 304 stainless steel. Furthermore, ta-C films can be made with low friction coefficients (~0.12 without lubricant) by tuning the surface morphology and doping chemical species during the film growth. The research team has been providing ta-C coatings on various tools for a variety of customers, who have enjoyed many of the benefits of the super-hard and low friction coatings.

Like all other physical vapor deposition (PVD) technologies, a conventional cathodic arc process relies on line-of-sight access from the source material to the substrate surface and is mostly suited to coat outside surfaces. However, there are many applications that require coatings on inner surfaces. One example is engine cylinder bores/liners. The best friction reduction properties can be achieved by coating both surfaces of a piston ring/liner couple with low-friction and wear-resistant ta-C, that is, the inside surface of the cylinder should be coated as well so that in tribological contact ta-C runs against ta-C. There is no commercial solution yet to coating inner diameter surfaces with current commercial PVD technologies due to their intrinsic line-of-sight nature.

Researchers at Fraunhofer CCD and Michigan State University (MSU) have developed a magnetic-field-driven cathodic arc plasma technology (MagArc) that can efficiently coat the inner surfaces of hollow components. During the deposition process, a MagArc cathode is inserted into the hollow region of a workpiece. While both the cathode and the workpiece are static, the arcs travel around the cathode surface and realize uniform coating of the inner surface.

© Fraunhofer CSE, Researcher holds example of PIR-based SIAP, developed by Fraunhofer CSE.

The MagArc sources can be used to deposit superhard ta-C, metals, nitrides, and oxides films onto a broad variety of substrates with superior coating adhesion. For a specific coating layer, a cylindrical target of the source material is attached to the cathode. The immediate products are ta-C coated engine cylinder bores and liners, which will lead to improved fuel efficiency and reduced toxic gas emissions. Other application examples include bearing and tubing inner surface coatings.

The MagArc can produce uniform coatings on the inner diameter surfaces without rotating the workpiece. This is realized by a moving magnetic field that effectively guides the arcs. Fig. 1 illustrates a series of arcs that evolve and travel in a clockwise direction around the cathode surface. Fig. 2a shows a Ti metal target after a few arcs. The marks show clearly the locations and trajectories of the arcs that follow the magnetic field in a helical path. Fig. 2b shows the same Ti target after 3 minutes of operation at ~2 kW power; the entire surface is uniformly etched by the arcs. Fig 2c shows the top view of the Ti target and a dummy liner, the inner surface of which has been uniformly coated with a Ti layer.

Further developments include coating the inner surfaces of various components and optimizing the processes.

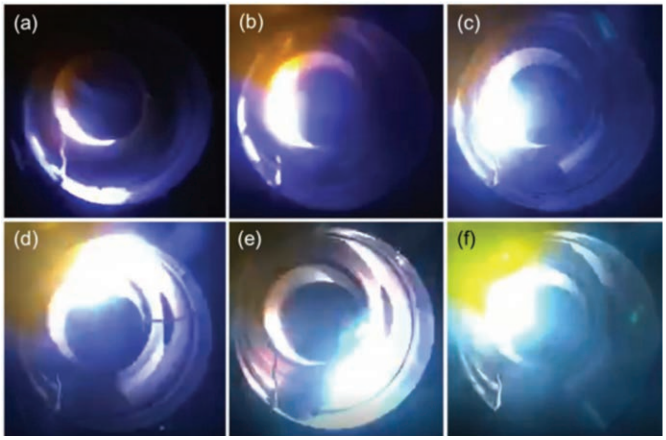


Fig. 1. Images (a) through (f) illustrate the evolution of an arc that travels in a clockwise direction.

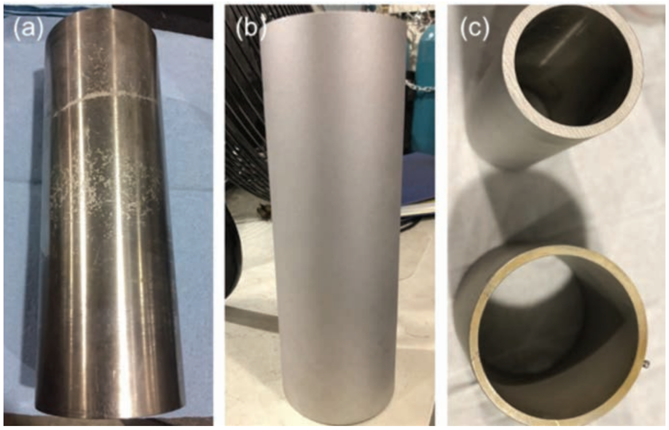


Fig. 2. (a) A cylindrical Ti target after initial arcs for a few seconds. (b) The Ti target shown in (a) after 3 minutes of operation at 2 kW power, showing that the surface is uniformly etched by arcs. (c) Top views of the Ti target (upper) and a dummy liner (lower) after 3 min deposition.

Micro Additive Manufacturing with Laser Direct Metal Deposition

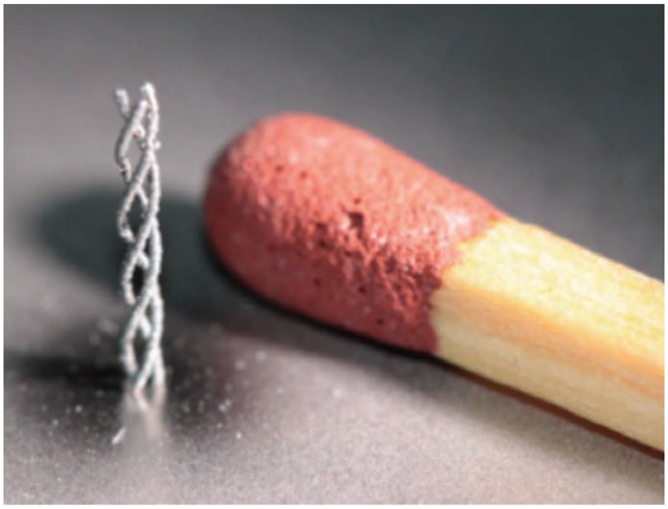
The Fraunhofer USA Center for Laser Applications CLA and Fraunhofer Institute for Material and Beam Technology IWS are actively working on the development of micro additive manufacturing processes using the laser direct metal deposition process.

A key technology for this is the Fraunhofer IWS developed Coax™ 14 nozzle which is capable of producing an extremely fine powder focus of less than 1mm which allows very precise metal deposition.

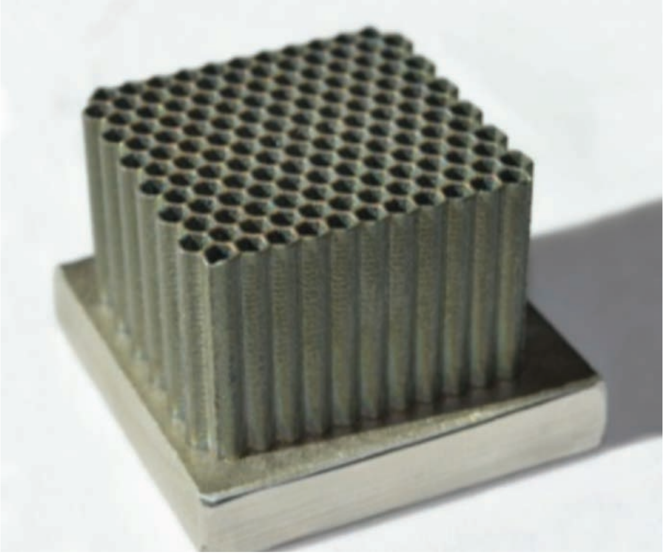
The latest high-brightness lasers enable smaller and more precise focusing of the laser beam, and this coupled with high-speed / high-accuracy motion systems facilitate the production of such complex micro parts and structures at relatively high processing rates in excess of 6 meters per minute travel speed.

Potential applications include production of filters, screens, cooling channels, and micro attachments for assembling dissimilar materials such as attaching composites to metals.

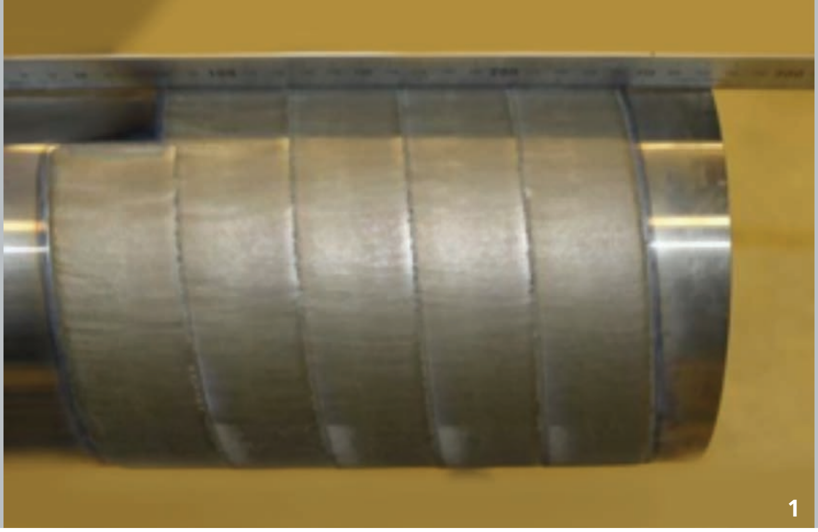
Examples of demonstration structures built so far are shown to the right, and work is ongoing in this field.



Micro scale structure built at Fraunhofer IWS.



Honeycomb structure produce by Fraunhofer CLA using Coax™ 14 nozzle technology.



High Deposition Rate Laser Cladding Technology

Laser cladding has seen a rapid growth in industrial applications over the last 10 years, in particular in industries such as oil and gas, mining and agricultural equipment sectors.

Most current industrial applications use lasers with circular focus spot sizes in the region of 3mm to 8mm, and laser powers of 3-6kW, which limits the potential clad track width to a maximum of 8mm per pass.

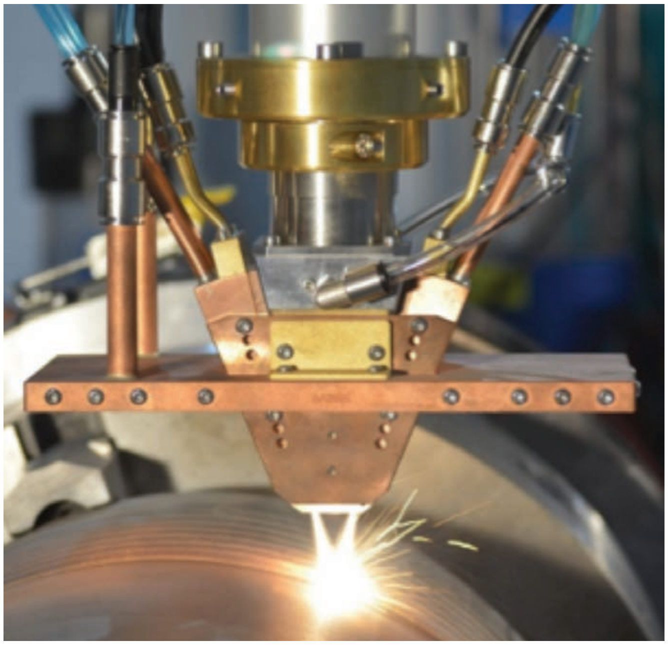
Since some applications involve cladding on extremely large-scale parts, for example on hydraulic rods and oil drilling tools which can be over 60ft long, the current process technology can sometimes require several days of processing per part.

Fraunhofer CLA and Fraunhofer IWS are actively working on the development of high deposition rate laser cladding technology in order to improve the overall process efficiency.

The latest generation of lasers and optical technology now facilitate using much higher power lasers and much larger focus spot sizes than previously possible.

The latest Fraunhofer IWS developed Coax™ 11 nozzle enables the deposition of powder into a rectangular laser focus spot geometry, with an overall clad track width ranging from 15 to 45mm which significantly increases the process deposition rate capabilities.

This technology was successfully introduced into a production application in the US by Fraunhofer CLA for the first time in 2017, where it is used to apply single pass wear resistant coatings to a cutting blade.

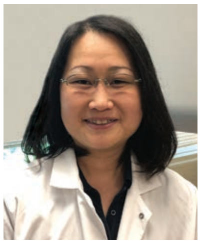


Coax™ 11 high rate deposition process.

Cross section showing excellent deposition quality achieved in a single pass.

1 © *Fraunhofer CLA, Wide beam clad deposit using Coax™ 11 nozzle.*

Yoko Shoji, Ph.D.
Scientist – Fraunhofer USA Center for Molecular Biotechnology CMB



Dr. Yoko Shoji received her Doctor Medicinae Veterinariae (DVM) degree in 2002 and Ph.D. in Veterinary Medicine in 2006 from Nihon University, Japan, focusing on immunology and virology. During her Ph.D. thesis, she studied molecular epidemiology of rabies virus to elucidate transmission patterns of the virus from animal-to-animal and from animal-to-human, and to develop measures to prevent virus transmission. During this research, she conducted field work in Brazil, including sampling viruses from wild animals, such as bats, and livestock. Along with this epidemiological research, she worked on developing a novel safe and efficient rabies vaccine by engineering the virus genome to generate a replication-incompetent vaccine virus that could provide superior protection over current killed rabies vaccines and reduce the economic burden caused by the disease.

In 2006, Yoko joined Fraunhofer CMB in Newark, Delaware, where she has been involved in developing novel vaccines against multiple infectious diseases, including influenza and anthrax. Her activities involve designing and conducting preclinical studies in animal models, developing and conducting in vitro assays under conditions of high level biosafety containment, organizing toxicology studies with contract research organizations and writing Investigational New Drug files to enable clinical trials. Her long-term dedication to improve public health contributed to the successful completion of four Phase I clinical trials overseen by the Center. Her recent focus and responsibility is heading the Immunology laboratory and designing and organizing all in vivo studies conducted for multiple projects at the Center, including testing of antimicrobial compounds for efficacy in small animal models.

While at CMB, Yoko has published 8 manuscripts in scientific journals on the Center's research and has contributed to grant applications that have brought in third party funds to the Center. She also serves on CMB's Institutional Biosafety Committee.

Sandro Mehner
Project Manager – Fraunhofer USA Center for Laser Applications CLA

Sandro Mehner received his Diploma Degree (Dipl.-Ing.) in Manufacturing Engineering from the University of Applied Sciences Dresden, Germany in 2011. During his studies he worked for the Fraunhofer Institute for Material and Beam Technology IWS, Dresden as a research assistant which sparked his interest in laser processing technologies. Sandro completed his diploma thesis at IWS on the development of induction assisted laser cladding for high deposition rates. Prior to his graduate studies, Sandro worked as a tool and die maker at Metallwerke Zöblitz GmbH, Germany.

In 2012, Sandro joined Fraunhofer CLA in Plymouth, MI where he is responsible for R&D projects in the field of laser direct metal deposition processes for cladding and additive manufacturing, laser heat treatment processes and laser scribing processes. Sandro is also responsible for the design and development of novel new processing heads for powder metal deposition and heat treatment processes.

Sandro's research interests are laser direct metal deposition processes for both large- and micro-scale applications as well as the processing of hard to weld or exotic materials. He has a high interest in aerospace and space technology, sustainable manufacturing and environmental protection. Sandro spends his free time with his family, building cedar strip paddle boats and riding custom motorcycles.

Kristofer Thorlakkson
Research Scientist – Fraunhofer USA Center for Experimental Software Engineering CESE

Kristófer Reykjalín Þorláksson began working at Fraunhofer CESE as an intern in January 2017 and was hired full-time as a Research Scientist in November 2017. He received his B.Sc. in Mechatronic Engineering and B.Sc. in Computer Science from Reykjavík University in Iceland.

His main responsibilities at Fraunhofer CESE include managing software development projects, consulting on technical phases of multidisciplinary projects and improving the technical practices of the software development life cycle, including project specification, implementation and delivery. He works on and leads technical efforts for the design and development of complex software architectures and performance-critical software systems. He also assists with the quality assurance and testing of software systems by applying modern testing techniques in projects that combine and integrate multiple technologies.

Throughout his employment with Fraunhofer CESE, Kristófer contributes to, writes, and estimates proposals for multiple projects and participates in other business development activities and technical exchanges. Having successfully ushered proposals to awards, Kristófer acts as the main customer interface on projects as either the project manager or technical lead. In addition to project activities, he assists with managing the internship program at CESE by optimizing the interview process, conducting the technical interviews, influencing hiring decisions, and performing the intern bootcamp training for new interns.

Prior to his position at Fraunhofer CESE, Kristófer was a full-stack developer at the Vigdís Finnbogadóttir Institute of Foreign Languages in Iceland. He has experience in all phases of software development, including software architecture design, software testing and integration and deployment.

Nina Baule
Project Engineer – Fraunhofer USA Center for Coatings and Diamond Technologies CCD

Nina Baule received her Master's Degree in Materials Science and Engineering from Ernst-Abbe University of Applied Sciences, Jena, Germany in 2015. In collaboration with the Leibniz Institute for Surface Modification (IOM), Leipzig, she doped phase change materials by ion implantation for rewritable disc applications. In 2016 she joined Fraunhofer IWS in Dresden to work on the characterization of diamond like carbon (DLC) coatings. To continue this work, Nina took an internship at Fraunhofer CCD in the summer of 2016, where the scope of her interests in coatings research continued to grow. Today, Nina continues to support CCD's Coatings Technology Group as a project engineer, where a main focus of her work is on the development of low-emission and anti-reflective coatings. Additionally, she works in close collaboration with Michigan State University's Electrical and Computer Engineering department on the development of high-quality aluminum nitride coatings for piezo electrics. She strives to facilitate a feedback loop between coating processes and applied analysis.

Holger Wirz
Program Manager – Fraunhofer USA Center for Manufacturing Innovation CMI

Holger Wirz received his degree in mechanical engineering from the RWTH Aachen, Germany in 1998. He joined the Fraunhofer CMI in March 1998 and has been managing the design of advanced automated systems across a variety of industrial fields, developing non-traditional manufacturing solutions.

Highlights include, a number of fiber-optic gyroscope coil winding systems and a continuous manufacturing system for solar cell wafers. He has recently been involved in developing a system for modification of building facades using laser processing techniques and is currently working on a high throughput production system for a novel boutique beverage product.

Michael Petzold
Quality Manager & Senior Project Engineer – Fraunhofer USA Center for Coatings and Diamond Technologies CCD

Michael Petzold received his Master's Degree in Mechatronics from the Technical University Dresden, Germany. While in Dresden, he worked at the Fraunhofer Institute for Material and Beam Technology IWS with Dr. Otmar Zimmer on developing Vacuum Arc Filter Technologies and droplet-free ceramic coatings. In 2009, he did a six-month internship with Fraunhofer USA at the Center for Coatings and Laser Applications CCL in East Lansing, Michigan.

In 2011, Mr. Petzold joined Fraunhofer CCD as a Project Engineer. He is supporting the Team in developing new Thin Film Coatings based on Physical Vapor Deposition (PVD) as well as focusing on coating system development and evaporation source design and testing. He is also an active member of the Society of Vacuum Coaters (SVC).

Two years into working for CCD, Mr. Petzold took over the role as the Quality Manager for the Center's ISO 9001 certification. He is leading the efforts in establishing and maintaining a process based Management System that achieves continual improvement and customer satisfaction through effectiveness, efficiency and conformity.

Kurt Roth, Ph.D.
Director, Building Energy Systems – Fraunhofer USA Center for Sustainable Energy Systems CSE

Dr. Kurt Roth has been Director of Fraunhofer CSE's Building Energy Systems Group since January 2009. Under his leadership, the team develops, analyzes, tests, evaluates, and demonstrates energy-saving building technologies. Dr. Roth is Co-PI of the Fraunhofer SHINES project with the DOE Solar Energy Technology Office, a three-year effort to develop and demonstrate integrated control of a MW-scale PV plant, load management for commercial and industrial facilities, and energy storage to enable high-penetration PV. He is also Co-PI of a DOE Building Technologies Office Building America project to perform remote home energy audits using communicating thermostat data. Prior to this, he was a Principal at TIAX LLC, where he led several US Department of Energy (DOE)-funded studies to assess the energy savings and commercialization potentials of HVAC, building controls and diagnostics, toplighting and IT technologies, as well as characterizations of building energy consumption by major end uses. Kurt has published and presented at numerous conferences and authored more than sixty "Emerging Technology" ASHRAE Journal articles. He also serves on the Advisory Board for the Worcester Polytechnic Institute (WPI) Architectural Engineering program.

Kurt received his B.S., M.S., and Ph.D. degrees from the Massachusetts Institute of Technology, all in mechanical engineering and is a member of Sigma Xi, the Northeast Sustainable Energy Association (NESEA), and the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE).

Jan Kośny, Ph.D.
Director, Building Enclosures and Materials – Fraunhofer USA Center for Sustainable Energy Systems CSE

Dr. Jan Kośny leads Fraunhofer CSE's Building Enclosures & Materials group. Jan is a civil engineer with 35 years of experience in building science. He specializes in analyzing the energy performance of buildings and development of novel building envelope materials and systems, thermal insulation and radiation control technologies, thermal storage, and building integrated solar technologies.

Prior to joining Fraunhofer in 2010, Jan spent 12 years teaching building science as a professor of the Rzeszow Technical University, Poland, and 18 years at Oak Ridge National Laboratory. He has published over 150 technical articles, 200 reports, and numerous patents related to advanced building concepts. During his work for CSE, Jan has led several research projects focused on development of low-flammable plastic foams, nanoporous insulations, and PCM-enhanced building products.

Jan received his Ph.D. in Civil Engineering from the Institute of Fundamental Technological Research, Polish Academy of Sciences in Warsaw, Poland. He is a member of ASHRAE TC 4.4 on Building Materials and Building Envelope Performance, TC 2.8 on Building Environmental Impacts and Sustainability, and TC 4.7 on Energy Calculations. He has represented the United States at many international organizations and standards bodies including Annex 24/42 (Compact Thermal Storage, Solar Heating and Cooling) and Annex 23 (Applying Energy Storage in Buildings of the Future) of the International Energy Agency. In 2018, Jan was appointed by the Fulbright Foundation World Learning Program as a Fulbright specialist.

Special Note

Jeffrey McCutcheon, Executive Director of the Fraunhofer USA Center for Energy Innovation CEI, has been elected as President of the North American Membrane Society (NAMS). NAMS is the leading scientific organization that serves the synthetic membrane community in North America. He will serve his term from June 2018 through May 2019.

FRAUNHOFER USA CENTERS

The Fraunhofer USA Center for Manufacturing Innovation CMI performs cutting edge research and development, tackling the toughest problems for both industry and government agencies. This includes developing custom automation systems, finding innovative and more efficient processes, building biomedical instruments and devices, as well as benchmarking against best practices. Fraunhofer CMI bridges the gap between academic research and industrial needs, and leverages both in doing so.

Fraunhofer CMI offers

- Custom Automation Systems
- Biomedical Instruments and Devices
- Process Management and Consulting

Custom Automation Systems

Manufacturing automation begins with a thorough understanding of the requirements of the process, followed by a review of available state-of-the-art technologies that may be incorporated. When commercially available technology is not sufficient, Fraunhofer CMI develops new custom automation systems, based on the latest emerging academic research, and provides its clients with a turnkey solution.

Fraunhofer CMI staff begin by analyzing and, if necessary, modifying the process to make it more conducive to automation. Once the manufacturing process is completely understood, staff begin the design and build process, which is comprised of a number of phases and exit points that mitigate risk for our clients.

Examples:

Fiberoptic gyroscope winding

While fiberoptic gyroscopes (FOGs) have several advantages over ring-laser gyro- scopes, the difficulties of cost-effectively winding a high-performance sensing coil has kept the cost of FOGs excessively high. In order to cost-reduce the manufacture of FOGs, Fraunhofer CMI developed a high-precision, computer-controlled winder for the production of sensing coils. With over 15 coordinated servo controlled axes, the winder is capable of cost-effectively winding – with minimal touch-labor-tactical, navigation and strategic grade coils for long-range navigation and space applications.

Biomedical instruments and devices

One of Fraunhofer CMI's core strengths is the application of advanced engineering to biological problems. Fraunhofer CMI combines multiple engineering and scientific disciplines in tackling such problems and are trusted by leading pharmaceutical and medical device companies and research collaborators to successfully carry out their project goals.

To meet these needs, CMI has over 16,000 square feet of fully-equipped laboratories including five CNC machines, which are housed adjacent to its on-site BL1 and BL2 laboratories that are capable of bacterial, viral and mammalian cell culturing. CMI's major activities include developing rapid diagnostics, exploring tissue engineering approaches, producing medical devices and building scientific instruments.

Examples:

Low-cost, real-time, continuous fl PCR system for pathogen detection.

Bacterial resistance to antibiotics is escalating, and represents a significant health threat to the human population. To address the need of rapid, portable and low-cost pathogen identification, Fraunhofer CMI has partnered with Fraunhofer IPT to create diagnostics that combines microfluidic and electronic layers into a single device. This microfluidic chip for nucleic acid testing (NAT) can identify pathogens within 20 minutes and is compatible with roll-to-roll embossing for large-scale, low cost production. Fluorescence is monitored in real-time for the quantitative detection of pathogens at concentrations as low as 10 DNA copies per microliter. (Fernández-Carballo et al. Biomed. Microdevices 2016, 18, 34).

Bioprinted hydrogels developed to improve implant integration

Fraunhofer CMI's custom-designed bioprinter is able to print multiple materials (or multiple cell types in the same material) concurrently with various feature sizes (Campbell et al. J. Nanotechnol. Eng. Med. 2015, 6, 021005).

In collaboration with Fraunhofer Institute for Production Technology IPT, CMI has generated novel scaffolds that seek to improve the biological compatibility of titanium implants, which although generally tolerated by the body, fail to adequately interface with the bone. To provide an ideal biologically-based adhesion between bone and metal, CMI used its 3D bioprinter to create a hydrogel scaffold that could be grafted to the implant. The scaffold was able to mimic the bone and trigger bone-producing cells to deposit new calcium directly onto titanium. These biologically-inspired engineering solutions pave the way towards better surgical outcomes for patients world-wide (McBeth et al. Biofabrication 2017, 9, 015009).

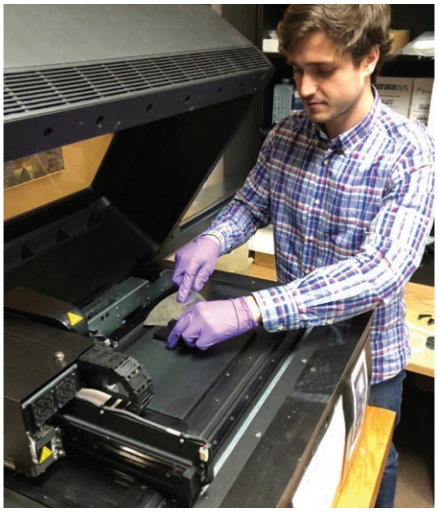
Process Management and Consulting
When faced with production challenges, established companies, startups, and governmental institutions engage Fraunhofer CMI to benchmark their current process and introduce new technologies that will address their challenges. Staff begin the process by reviewing the client's current operation and identifying challenge areas in need of improvement.

Technology scouting is used to bring together possible solutions from internal expertise, university contacts, industry experts, journal, and the scientific literature. The ideas are tabulated into technology data sheets showing the evaluation criteria including: maturity of technology, costs (investment and operational), maintenance/service, and effort of implementation. Final evaluation is performed using a two-dimensional technology assessment technique. The down-selected solutions are then proposed for implementation.

Examples:
Coin manufacturing assessment and technology development
Fraunhofer CMI has worked with a several coin mints to assess their current manufacturing operations and wear integrity of their coins to develop alternative manufacturing technologies for higher production efficiency.

Following evaluation of the current coin production facilities and methods, CMI proposed alternative technologies and evaluated the financial and technical impact of the proposed technologies. Staff then prototyped solutions and tested the quality of the coin blanks produced with these alternative solutions. Technologies explored included laser processing as a means of streamlining coin blanking.

Industries Served
- Aerospace
- Biotech/Biomedical
- Consumer products
- Energy
- Fiber optics/photonics



Fraunhofer CMI Research Intern removing the product of the 3D printer.

Header Photo: © *Fraunhofer CMI, Microfluidic platform for rapid antibiotic susceptibility diagnostics.*

FRAUNHOFER USA CENTER FOR COATINGS AND DIAMOND TECHNOLOGIES CCD

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The Fraunhofer USA Center for Coatings and Diamond Technologies CCD performs applied research and development contracts with industry and government organizations. Customers include companies from industry sectors such as manufacturing, semiconductor, biomedical and energy. Fraunhofer CCD is a confident and reliable partner providing proprietary and competitive R&D services based on core competences in diamond and coating technologies. CCD's quality management system is certified according to the standard ISO 9001:2015.

Our customers know that maintaining a leadership position in today's competitive business environment requires ever more rapid innovation cycles and sustainable manufacturing solutions. Fraunhofer aims at accelerating innovation for its customers by driving technologies faster along the technology-readiness-level chain from basic research toward commercialization. Fraunhofer CCD connects with world-class basic research through its close partnership with Michigan State University in East Lansing, Michigan, USA. The Center shares 20,000 square feet of laboratory and office space and is fully integrated with the College of Engineering with access to faculty, students and additional research facilities. Fraunhofer CCD is also closely affiliated with and offers access to the Fraunhofer Institute for Material and Beam Technology IWS in Dresden, Germany.

Engaging with Fraunhofer CCD in Applied Research and Development Work

Fraunhofer CCD works closely with its customers to determine specific project objectives and requirements. Prior to commencing work, every project is structured with mutually agreed upon deliverables, schedules, milestones and costs. CCD's customers are provided with access to the extensive laboratory and engineering resources. Project results are treated with strict confidentiality. CCD recognizes the need to protect intellectual property rights for its customers and staff work with customers to negotiate mutually acceptable terms and conditions so that the developed solutions can be readily deployed.

Core Competence: Coating Technologies at Fraunhofer CCD

Surface coatings are an enabling technology across industrial sectors. Surfaces of parts, devices, components and tools need to be engineered so that they can perfectly function in the environment of a specific application. By providing engineered surface properties, coatings enable high performance applications that would otherwise only be possible with expensive bulk materials. Such functionalities include, for example, improved wear and corrosion resistance, reduced friction, biocompatibility or, in some cases, simply a specific appearance. CCD's coating technologies focus on applications of physical and chemical vapor deposition (PVD and CVD coatings) process and systems technologies and materials know-how. The Center works with its customer to identify and develop the best coating solutions for their applications and supports them to deploy the developed processes and materials in manufacturing.

Core Competence: Diamond Technologies at Fraunhofer CCD

Diamond is a crystalline allotrope of carbon and the material with the highest atomic density found in nature. As such it is an extraordinary material with a unique combination of extreme properties such as highest hardness, highest thermal conductivity and highest dielectric breakdown strength, to name a few. The field of diamond synthesis and applications is undergoing a spectacular period of transformation as the ability to deposit high-quality monocrystalline diamond materials advances. CCD develops processes and systems to synthesize diamond and to make it accessible to customers for integrating it in applications in optics, electronics and electrochemistry. Diamond is not expensive. In fact, at Fraunhofer CCD the material is synthesized by chemical vapor deposition using a process very like depositing coatings from other materials.

It is used by our customers in the form of coatings such as poly- and nanocrystalline diamond fields or a poly- or monocrystalline bulk material.

Project Briefs

Boron-doped diamond electrochemistry: Boron-doped diamond (BDD) is a new electrode material for electrochemical applications. Due to the fabrication from methane and hydrogen gases boron-doped diamond electrodes are less expensive than platinum electrodes. Yet BDD by far exceeds the electrochemical performance of metal-based electrodes. The wide electrochemical potential window, the low background current and the low adsorption make BDD electrodes particularly valuable for electrochemical trace analysis and neuro- chemistry. The material can be applied to a variety of substrates and shapes made from silicon, quartz, metals, and diamond. Fraunhofer CCD researchers developed fabrication processes to reliably custom tailor BDD electrodes for applications ranging from heavy metal detection in tap water to building flexible diamond-polymer thin film electronics for electrical and chemical sensing of brain signals (NIH funded).

Increased gas mileage and reduced emissions due to powertrain coatings: Fraunhofer CCD researchers developed a carbon-based coating to lastingly reduce friction and wear for powertrain components that experience highly loaded contact situations. By coating engine components, Fraunhofer engineers demonstrated a 3% horsepower increase across the usable speed range thus enabling the engine to achieve the same performance at lower revolutions per minute. These results demonstrate the tremendous potential to conserve fuel and reduce carbon dioxide emissions.

Diamond for power and high temperature electronics: Fraunhofer CCD and Michigan State University researchers develop diamond-based power electronics. The exceptional semiconductor properties of diamond have enormous potential for high-power electronics technology with applications in transportation, manufacturing, and energy sectors. The team develops synthesis processes for doped and intrinsic electronic-grade wide bandgap diamond materials and works on manufacturing process flows to build power electronic devices such as vertical Schottky diodes.

Manufacturing cost savings through 300% increase in tool life: Meritor Inc., a global leader in providing advanced drivetrain, mobility, and braking and aftermarket solutions for commercial vehicle and industrial markets, collaborated with Fraunhofer engineers to test new high-performance ceramic coatings for high temperature forming processes. Spindle punches were coated using a physical vapor deposition process developed in collaboration with the Fraunhofer Institute for Materials and Beam Technology IWS in Dresden, Germany. The punches are used for hot forging of steel parts at an operating temperature of 1950 °F (1065 °C). Compared to uncoated spindle punches, the best performing coated tools lasted three times as long while enabling tool changes once a day rather than every shift.

Anti-reflective coatings for transit bus windshield: Fraunhofer CCD researchers work with The Mackinac Technology Company (MTC) and the University of Michigan Transportation Research Institute on developing an anti-reflective windshield coating for transit bus windows. Interior lighting reflects off the windshield and obscures the driver's vision. The team demonstrated that an innovative ultra-low refractive index material made of amorphous carbon could be deposited in nanometer thin layers to the surfaces of windshield glass to significantly reduce reflection of visible light and improve driver vision.

The Fraunhofer USA Center for Coatings and Diamond Technologies CCD is the go to location for your materials technology needs.

1 © *Fraunhofer USA, A brilliant cut single crystal diamond on top of a Diamond-like-Carbon coated end mill.*

2 © *Fraunhofer USA, CCD Engineer prepares to diamond coat silicon wafers in a hot filament diamond system.*

FRAUNHOFER USA CENTER FOR LASER APPLICATIONS CLA

The Fraunhofer USA Center for Laser Applications CLA has been operating in the US for over 20 years developing and commercializing laser applications and technology. Fraunhofer CLA's state-of-the-art Plymouth Michigan facility conducts contract research and development in the field of laser materials processing.

With extensive experience and expertise in laser applications development for processes such as welding, cutting, and additive manufacturing, Fraunhofer CLA is your ideal partner for laser applications development.

Fraunhofer CLA offers contract research and development, process development, prototyping and consulting services, technical support and pilot production systems.

Laser Cladding and Additive Manufacturing

- Additive manufacturing
- Rapid prototyping
- Coatings for wear and corrosion
- Remanufacturing of worn parts
- ID (internal diameter) cladding
- Induction assisted laser cladding
- Diamond cladding
- Powder and wire fed processing heads
- Process monitoring and control

Laser Welding and Joining

- Laser beam welding
- Remote laser welding
- Laser hybrid welding
- Laser brazing / laser soldering
- Glass welding
- Plastic welding
- Process monitoring and control

Laser Heat Treatment

- Laser hardening and softening
- ID (internal diameter) laser hardening
- Laser assisted forming
- Color marking

Laser Cutting and Drilling

- 5 Axis 3D laser cutting
- Remote laser cutting
- Micromachining / drilling

Laser Sources

Fraunhofer CLA's state-of-the-art laser application facility features the latest and greatest in laser technology with a wide range of lasers from 1 watt to 16 kilowatt output power.

High Power CW and Pulsed Lasers:

- 16kW Laserline fiber coupled diode laser
- 10kW Laserline fiber coupled diode laser
- 4kW Laserline fiber coupled diode laser
- 8kW TRUMPF TruDisk 8001 disc laser (100 micron fiber capable)
- 6kW TRUMPF TruDisk 6001 disc laser (100 micron fiber capable)
- 6kW IPG YLS 6000 fiber laser (100 micron fiber capable)
- 6kW Rofin Sinar DC060W slab CO_2 laser

Low Power Pulsed and CW Lasers:

- 850W / 1030nm Trumpf TruMicro 7060
- 70W pulsed 1030 nm Jenoptik IR70 Disc
- 17W @1064nm and 5W @ 355nm pulsed Spectra-Physics HIPPO
- 200W / 1064 nm LASAG KLS 246 YAG
- 100W pulsed Rofin Sinar SCx10 CO_2
- 500W 1070 nm IPG YLR Single mode
- 25W cw 1070 nm JDSU Single mode fiber
- 20W cw 430 nm Fraunhofer Blue diode

Additional Equipment

Fraunhofer CLA utilizes additional robotic systems (Kuka) and multiple CNC machines and an onsite metallographic laboratory.

Industries Served

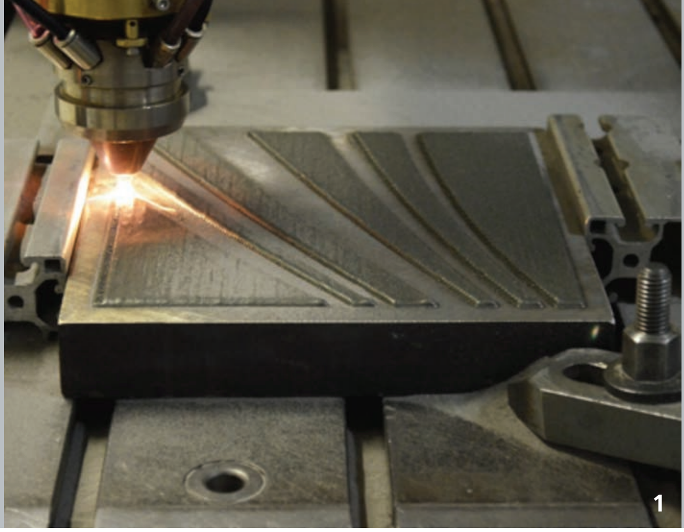
- Automotive
- Aerospace / Space
- Oil and Gas
- Power Generation
- Agricultural and Mining Equipment

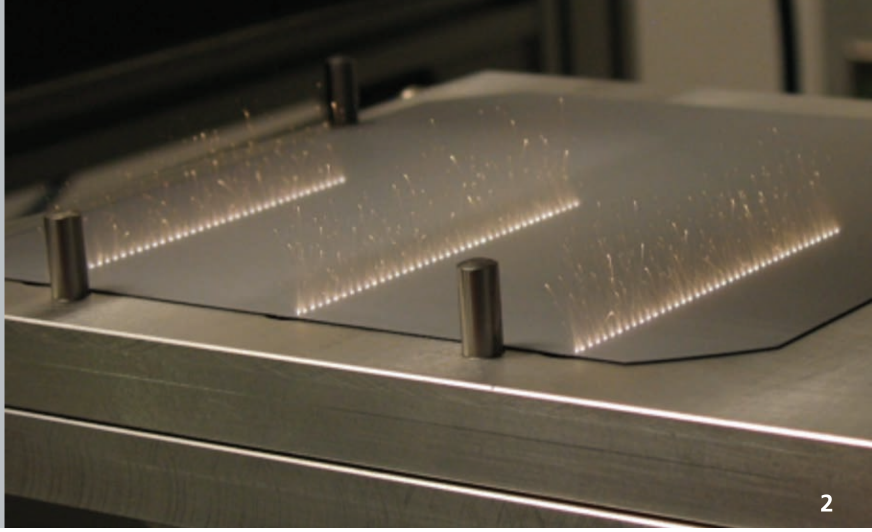
Application Examples

Laser Welding

Laser welding offers the potential to join parts with high speed and precision with minimal heat input and distortion.

Difficult to weld materials such as higher carbon steels and cast irons can now be successfully laser welded. Filler wire and / or induction preheating can be used to change the microstructure of the weld metal, preventing the formation of hard and brittle phases. A conventional bolting





process was replaced with laser welding for an automotive gear component. Significant cost savings were achieved through reduced material and processing costs and an overall part weight reduction was accomplished with a more efficient production method using laser technology.

Remote laser welding is another laser welding process which dramatically reduces welding cycle times compared to conventional welding. Motorized optics are utilized in order to rapidly scan the laser beam across the workpiece over large distances both for high speed and for high precision point to point movement.

Process Monitoring

Fraunhofer CLA has developed a high-speed camera vision system which can record the welding process in high clarity and provide both image and video data from the process. Using customized image processing software algorithms, it is possible to detect many common welding defects automatically. Fraunhofer CLA is also working together in partnership with Fraunhofer IWS to develop new applications for their 'EMAQS' camera based process monitoring system. In particular this is now being developed into an extremely useful tool for laser cladding and additive manufacturing processes where the melt pool size can be continually monitored, and the laser power can then be closed loop controlled in order to maintain constant build quality of each deposited metallic layer.

Additive Manufacturing and Cladding

In the Laser Metal Deposition process (LMD) metal powder is fed coaxially through a nozzle and then melted by the laser beam to form a fully bonded metallic layer (Fig. 1). The deposited layer has a small heat affected zone with minimal dilution. It has been developed for production of wear and corrosion resistant coatings and for repairs and remanufacturing applications. The same process can also be used for generation of complete components from scratch in the form of additive manufacturing where parts are built using layer by layer deposition.

Two other variations of LMD – hot / cold wire cladding and internal diameter cladding – have now evolved into successful industrial processes and are now widely used in industry.

Micromachining

The latest generation of lasers with pulse lengths from millisecond all the way to femtosecond has led to a rich pipeline of innovations impacting virtually every manufacturing industry. One such innovation is large area coating removal for paint stripping, deoxidization, cleaning or localized removal of special coatings. Another example of innovation is the ability to drill high aspect ratio holes at extremely high speeds. One such application developed by Fraunhofer was able to achieve drilling of up to 15,000 per second in a silicon wafer material (Fig. 2).

The Fraunhofer USA Center for Laser Applications CLA utilizes its experts and state-of-the-art equipment to maximize the quality of the customer deliverables.

Coaxial wire deposition head.

1 © *Fraunhofer CLA, Coaxial powder metal deposition process.*

2 © *Fraunhofer CLA, High speed laser drilling of silicon.*

Applied R&D Services for the Sustainable Energy Industry

The Fraunhofer USA Center for Sustainable Energy Systems CSE is an applied research and development laboratory dedicated to building tomorrow's energy future today. Fraunhofer CSE staff'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.

Fraunhofer CSE's mission is to secure America's clean energy future and drive economic development by supporting the commercialization of technologies that will fundamentally transform the energy industry.

Fraunhofer CSE offers comprehensive support for development, testing, evaluation, education, and marketing around new technologies, with considerable flexibility for project structure and intellectual property concerns. Fraunhofer CSE works with a wide variety of customers, ranging from Fortune 500 companies and national labs to university spin-outs and start-ups.

Building Energy Systems Research Facilities

- Data Acquisition Lab
- Human Behavior Lab

Building Enclosures and Materials Research Facilities

- Thermal and Hygrothermal Test Labs
- Outdoor Exposure Facility
- Material Characterization Lab
- Two Field Testing Sites (Boston, MA; Albuquerque, NM)

Solar PV Research Facilities

- PV Module Fabrication Lab
- PV Durability Lab
- Rooftop Mockup
- Outdoor Test Sites
- Building Integrated Photovoltaics (BIPV) Lab

Grid Integration Research Facilities

- Energy Storage Integration Lab
- Battery Storage Testbed
- Module Level Power Electronics Testbed
- Field Testing of Storage Integration

Inside the Living Lab

Fraunhofer CSE and its industry partners established a Living Lab for energy efficient building technologies in Boston's Seaport District. The retrofit building combines the historic architecture of a >100-year-old warehouse with cutting-edge design concepts and energy technologies to drastically reduce the building's energy consumption. The Living Lab houses CSE's research facilities, including a pilot solar module fabrication line, extensive characterization / environmental testing resources and a platform for evaluating energy storage systems in residential and light commercial applications.

Fraunhofer TechBridge Program

The Fraunhofer TechBridge Program works with corporations and startup companies to identify and de-risk promising technologies to solve industry challenges. By performing targeted technical searches and conducting validation and demonstration work, TechBridge evaluates and prepares innovative early-stage products for investors and industry by:

- Optimizing and testing prototypes according to industry-standard protocols
- Providing third-party validation of economic viability and performance
- Fielding demonstrations of prototypes in real-world conditions
- Integrating components into a system-level environment
- Evaluating for manufacturability

Building Energy Systems

- Test, demonstrate, and evaluate the performance of emerging building technologies in the field
- Develop building performance assessment and control algorithms
- Evaluate the impact of people and behaviors on energy consumption
- Characterize building energy consumption to inform policy decisions

- Assess building technologies to identify high-impact opportunities

Building Enclosures and Materials
- Applied R&D of novel energy-efficient materials and systems, including advanced thermal insulations and environmental barriers, phase change materials (PCMs), advanced ventilation strategies, and systems to control radiation heat transfer
- Deployment and integration of these technologies
- Development and testing of novel building-integrated solar systems
- Advanced thermal, hygrothermal modeling
- Whole building energy analysis
- Laboratory thermal / hygrothermal testing
- In situ performance, monitoring and long-term evaluations

Photovoltaic (PV) Technologies
- Module and system performance assessment, based on outdoor exposure testing and characterization
- Module reliability, including accelerated stress tests
- Failure analysis and materials characterization
- Assessment of new module materials for conventional and lightweight modules
- Module prototyping
- Novel approaches to power electronics
- PV system integration
- Novel PV mounting approaches
- Demonstrations and pilots

Grid Integration (Distributed Energy Resources)
- Field demonstrations and pilots of novel technologies in controlled and “real- world” environments
- Technology assessment and characterization of DER technologies, including analytic assessment, benchtop testing, hardware-in-the-loop evaluation, and field trials
- Systems integration and implementation of reference technology platforms to support development and testing of integrated storage systems.
- Development of control, analysis, and monitoring software for controlling and monitoring DERs on embedded, mobile, and cloud-based platforms.

1 © *Fraunhofer CSE/Trent Bell, In addition to contract research, Fraunhofer CSE’s scientists conduct extensive engineering and R&D on sustainable technologies.*

2 © *Fraunhofer CSE, Fraunhofer CSE Plug and Play PV system installation and commissioning takes less than one day.*

FRAUNHOFER USA CENTER FOR EXPERIMENTAL SOFTWARE ENGINEERING CESE

The Fraunhofer USA Center for Experimental Software Engineering CESE conducts applied research to support the software-enabled innovations created by our customers in industry, government, and academia. Fraunhofer CESE develops and uses advanced, effective, and scalable approaches to software and systems engineering, delivers powerful testing and verification strategies and tools, and uses state-of-the-art measurement and analysis methods to support its customers' challenges.

Working closely with customers in the aerospace and medical industries, government agencies, research organizations, and universities; Fraunhofer CESE evaluates, develops, and utilizes cutting-edge tools and technologies to support customer decision-making and implementation in systems, software, and acquisition areas. Fraunhofer CESE provides critical skills and guidance that allows its customers to ensure the viability and reliability of their systems and software and enables them to identify and prevent security-related vulnerabilities. In addition to applied research, Fraunhofer CESE also conducts innovative basic research projects under research grants funded by the government and other research institutions.

Fraunhofer CESE Vision

Fraunhofer CESE accelerates its customers' economic and industrial development by using innovative model-based methods to develop and assure complex software intensive systems.

Fraunhofer CESE Mission

- Serve as a trusted source for technology transfer and innovation to our government, academic and industrial customers across the nation
- Maintain a workplace culture of innovation that supports, rewards, and holds our team members accountable for creating new ideas that work

Fraunhofer CESE Offers:
Model-Based Development and Testing

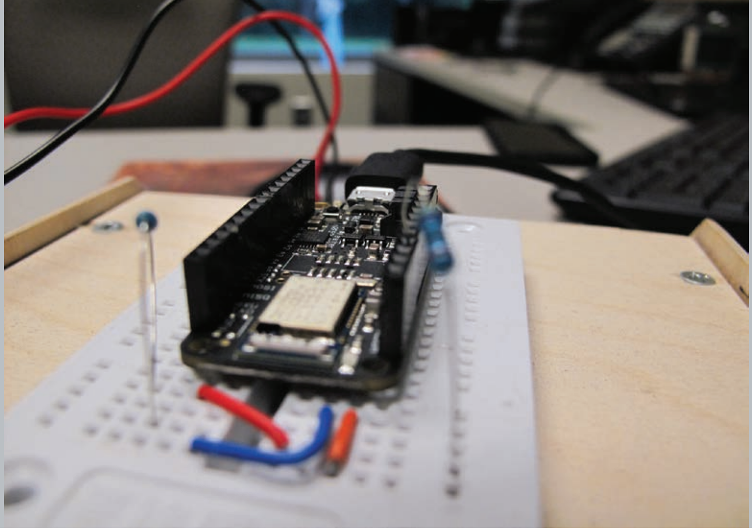
- Use analysis tools to automatically extract and visualize software architecture in source code
- Evaluate software architecture to locate policy deviations
- Create software architecture design models to generate test cases, analyze test results, and conduct code inspections
- Reverse-engineer models of code and system traces to identify inefficiencies and liabilities
- Perform architecture-driven verification and validation, analyze systems for architectural risk, and test behaviors of software
- Define and evaluate strategies for automated verification and validation and identify mechanisms that capture and check requirements
- Deploy tools and train personnel on automated testing and verification methodologies, best practices, and secure programming principles

Software Safety and Security Analysis

- Analyze algorithms and architecture to measure impact of upgrading and optimizing systems
- Apply formal modeling methods to evaluate system security and safety
- Evaluate open-source components for integration with commercial systems, with a focus on risk and benefit analyses
- Model reliability data to predict fault-prone binaries in development
- Create risk and safety measurement and management programs to gain insight into safety, security, and reliability
- Quantify software safety risk by analyzing development artifacts
- Collaborate with customers to develop training materials that specify causes and remediation of weak security policies.

Rapid Prototyping of Mobile and Web Applications

- Design and facilitate user focus groups and empirical experiments to validate customer innovations
- Conduct technology evaluations in cloud, mobile, and other emerging platforms and suggest solutions based upon discovery



- Provide project management support including agile and scrum methodologies – to mitigate risk, manage cost and schedule, and ensure delivery
- Evaluate and create software engineering approaches and tools to improve software development productivity

Software Engineering Analytics
- Assess software processes and artifacts to ensure sound design and architecture, use of best practices, and regulatory compliance
- Apply best practices (e.g., CMMI, scrum) to systems acquisition and development
- Build process performance baselines and models to manage development projects
- Implement tools and processes for data collection, analysis, and reporting on products and processes
- Oversee design and development to mitigate risks related to requirements creep, software growth, and schedule changes

Cybersecurity and Embedded Systems
- Model-based automated penetration testing and vulnerability analysis of hardware and software systems
- Compliance testing of security standards and standard practices for embedded safety systems

Offensive and Defensive Penetration Testing for Medical, Automotive, Industrial Control, and Wireless Network Infrastructure Systems
- Hardware, software, and communications protocol reverse engineering for command and control systems
- Integration of cybersecurity practices and technologies for industrial process control and manufacturing systems
- Conventional and model-based secure system design and security requirements engineering
- Cybersecurity Awareness, Training, Education, and Workforce Development

Digital Transformation
- Offer a service suite of Industry 4.0 technologies, methods that move industry's products and processes from independent, disconnected platforms to "smart" interoperable, synchronized and connected platforms
- Assist industry to develop "data as a service" and as an added revenue stream using unique techniques for data capture from existing products, analysis, visualization and interpretation providing added value offerings to the client
- Enable smart, in situ processes for predictive diagnostics to monitor real-time machine performance and maintenance
- Employ Digital Twin Test Bed methods that allows clients to manipulate, test and evaluate a virtual, cyber-physical model of a product, process or platform before moving into production, reducing risk prior to physical production.
- Assessment of threat surfaces created through wireless control entry points and building defensive systems to secure process controls

Project Measurement and Analytics

Fraunhofer CESE offers experienced project management expertise in the start-up, deployment and management of complex, critical systems, including:
- Risk assessment
- Regulatory compliance
- Project management consulting
- Strategy innovation
- Technology and capability evaluation
- Process assessment

Data Protection Policy Effectiveness
- Craft data protection and privacy policies to satisfy corporate and regulatory needs
- Analyze data protection processes for effectiveness and improvement
- Create executive-level dashboards on data protection effectiveness across the enterprise
- Identify data protection policy gaps and recommend process improvements

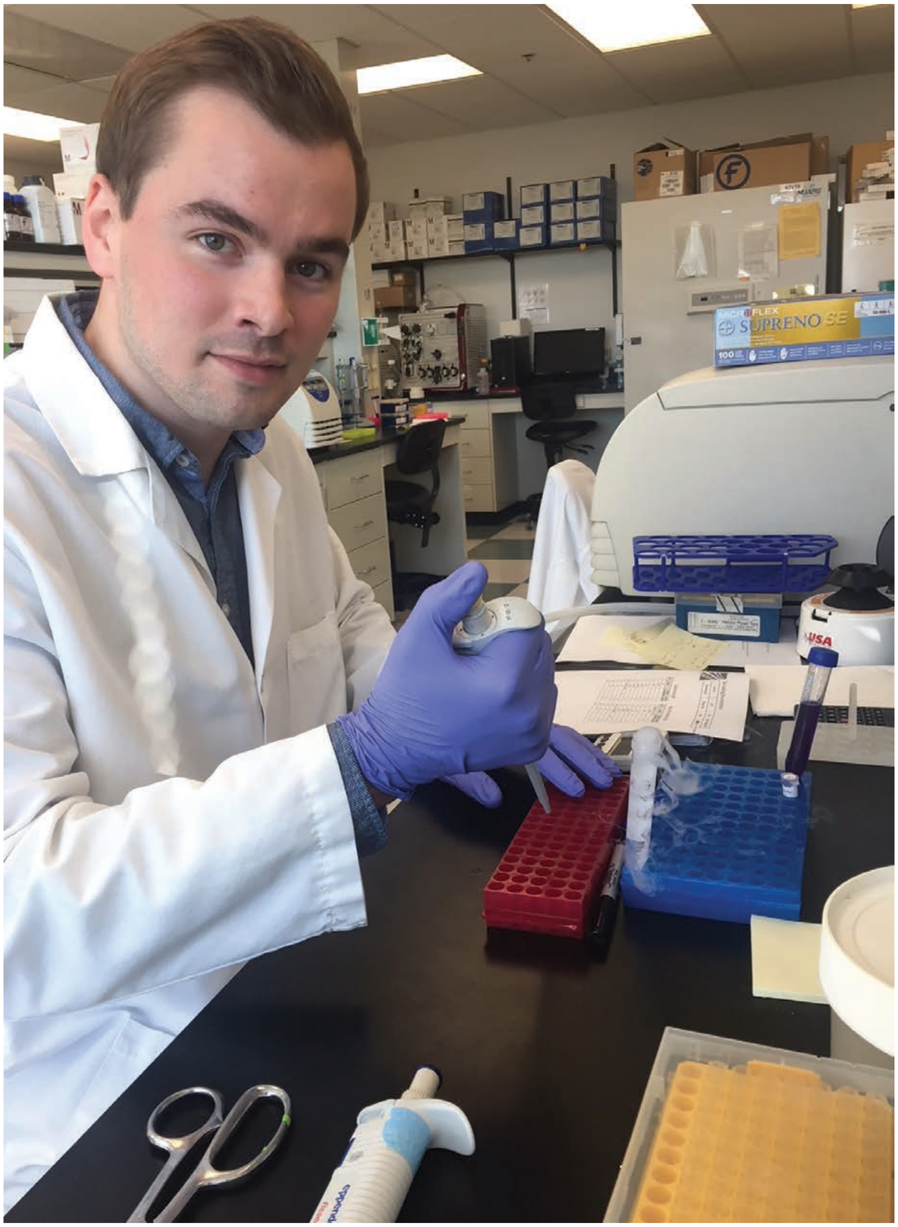
© Fraunhofer CESE, Microcontroller that processes mouse commands and transmits them wirelessly.

FRAUNHOFER USA CENTER FOR MOLECULAR BIOTECHNOLOGY CMB

The Fraunhofer USA Center for Molecular Biotechnology CMB is working in the area of biotechnology development, primarily emphasizing applications in human health. The Center is currently focusing on the discovery of novel anti-microbials and on the development of thermostable formulations for vaccines.

Despite ongoing efforts, the number of new antibiotics approved annually in the United States continues to decline. In addition, fewer new antibiotics are in late - phase clinical trials, and nearly all of them belong to existing classes. At the same time, infections caused by multi-drug-resistant pathogens are continually on the rise. This is a worldwide threat, with diseases that have long been held at bay again having potential to affect the health of millions.

Over the last year, Fraunhofer CMB has continued to expand its microbial library, using the quarum quenching technology for which Fraunhofer owns the IP to culture previously uncultured microbes. Screening of this library has identified some lead components with anti-microbial activity and these are being assessed for efficacy through in vitro and in vivo studies. In addition, their structures are being elucidated.



Fraunhofer CMB intern working on assignment.

FRAUNHOFER USA CENTER FOR ENERGY INNOVATION CEI

The Fraunhofer USA Center for Energy Innovation CEI performs applied research, feasibility studies, and demonstration testing of membrane separation processes, providing energy effective separation processes and processes integration across industrial sectors. This includes laboratory and pilot scale demonstration testing of liquid and gas separation applications.

Fraunhofer CEI Offers Customized Separations Solutions for:

- Water treatment and reuse
- Membrane process engineering
- Resource recovery
- Membranes energy efficiency and production
- Non-aqueous liquid separations
- Vapor and gas separations

Technology Platforms

- Ceramic membranes
- Polymeric membranes

Ceramic Membranes

Ceramic membranes offer capabilities for separation applications where polymeric membranes cannot operate. For example, ceramic membranes can operate at temperatures, pressures, pH levels, and in abrasive environments where polymeric membranes would fail. Fraunhofer CEI has the knowledge and resources to demonstrate the capabilities of ceramic membranes for aqueous and organic filtration applications. Fraunhofer CEI's collaborative partner, Fraunhofer Institute for Ceramic Technologies and Systems IKTS, fabricates the most selective ceramic filtration membranes on the market. They are the only provider of nanofiltration ceramic membranes. Other inorganic membranes are also available for vapor and gas separations. These include membranes made from zeolites, carbon materials, and perovskites.

Polymeric Membranes

Fraunhofer CEI has extensive expertise with polymeric membranes for liquid separation applications. Application experience includes desalination, water treatment, reuse, water softening, dewatering processes, and organic solvent purification. The team has experience in reverse osmosis, forward osmosis, nanofiltration, and membrane distillation.

Membrane Process Engineering

Fraunhofer CEI can assemble customized membrane separations systems that are designed for client needs. Fraunhofer CEI partner Fraunhofer IKTS offers scaled-membrane manufacturing capabilities for element and module design and fabrication.

High temperature membranes for catalysis and oxygen generation.

Joint Development Opportunities

Fraunhofer CEI welcomes joint development projects with industrial clients. These range from membrane design and module prototyping to system piloting.

Separation Equipment and Analytical Resources

Separation Equipment

Fraunhofer CEI has access to state-of-the-art separations test equipment designed to accept different types of membranes and modules. These systems are designed for aqueous, organic, vapor, and gas separations processes.

Analytical Resources

Fraunhofer CEI has access to the state-of-the-art research infrastructure at the University of Connecticut to perform a variety of analytical testing. Extensive materials characterization and liquids / gas analysis facilities are available for a fee.

© Fraunhofer IKTS,Ceramic membranes available in numerous geometries for liquid and gas separations.

FRAUNHOFER USA DIGITAL MEDIA TECHNOLOGIES DMT

Fraunhofer USA Digital Media Technologies DMT promotes and supports the audio and media technologies of the Fraunhofer Institute for Integrated Circuits IIS in the United States.

When it comes to advanced audio and video technologies for the rapidly evolving media world, Fraunhofer IIS stands alone. Spanning from the creation of mp3, the co-development of AAC, and building the DCI test plan for the worldwide interchangeability of digital cinema movies, to designing the future of audio and video entertainment, Fraunhofer IIS' Audio and Media Technologies division has been an innovator in sound and vision for over 25 years.

Today, audio technologies such as Fraunhofer Cingo® for immersive VR audio, Fraunhofer Symphoria® for automotive 3D audio, AAC-ELD and EVS for telephone calls with CD-like audio quality, xHE-AAC for streaming and digital radio, and the MPEG-H TV Audio System, that allows television viewers to adjust dialogue volume to suit their personal preferences, are among the division's most compelling new developments.

In the field of moving picture technologies, latest achievements include easyDCP for the creation and playback of digital cinema packages and master formats, as well as Realception®, a tool for light-field data processing. In addition, Fraunhofer is developing new image coding systems based on JPEG2000 and JPEG XS.

© Fraunhofer IIS, MPEG-H allows viewers to select different audio mixes from a menu or even make their own mix.

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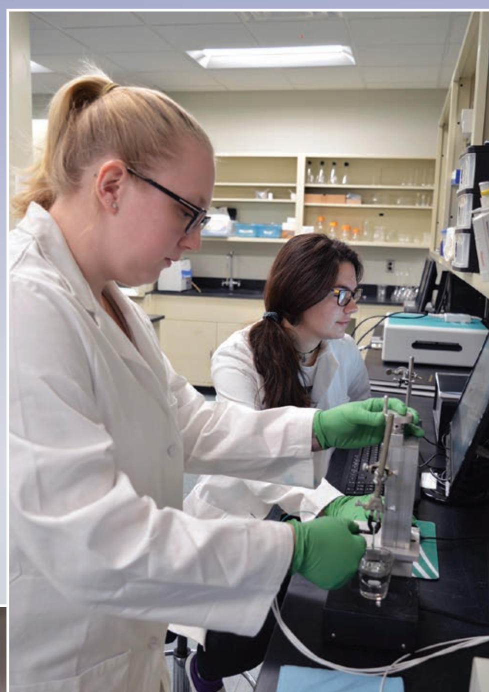

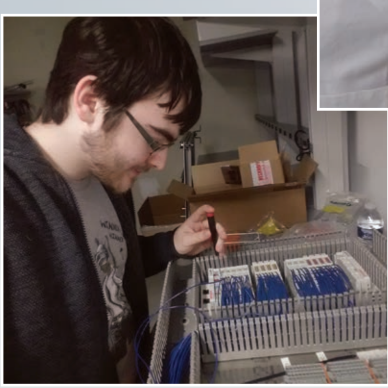

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