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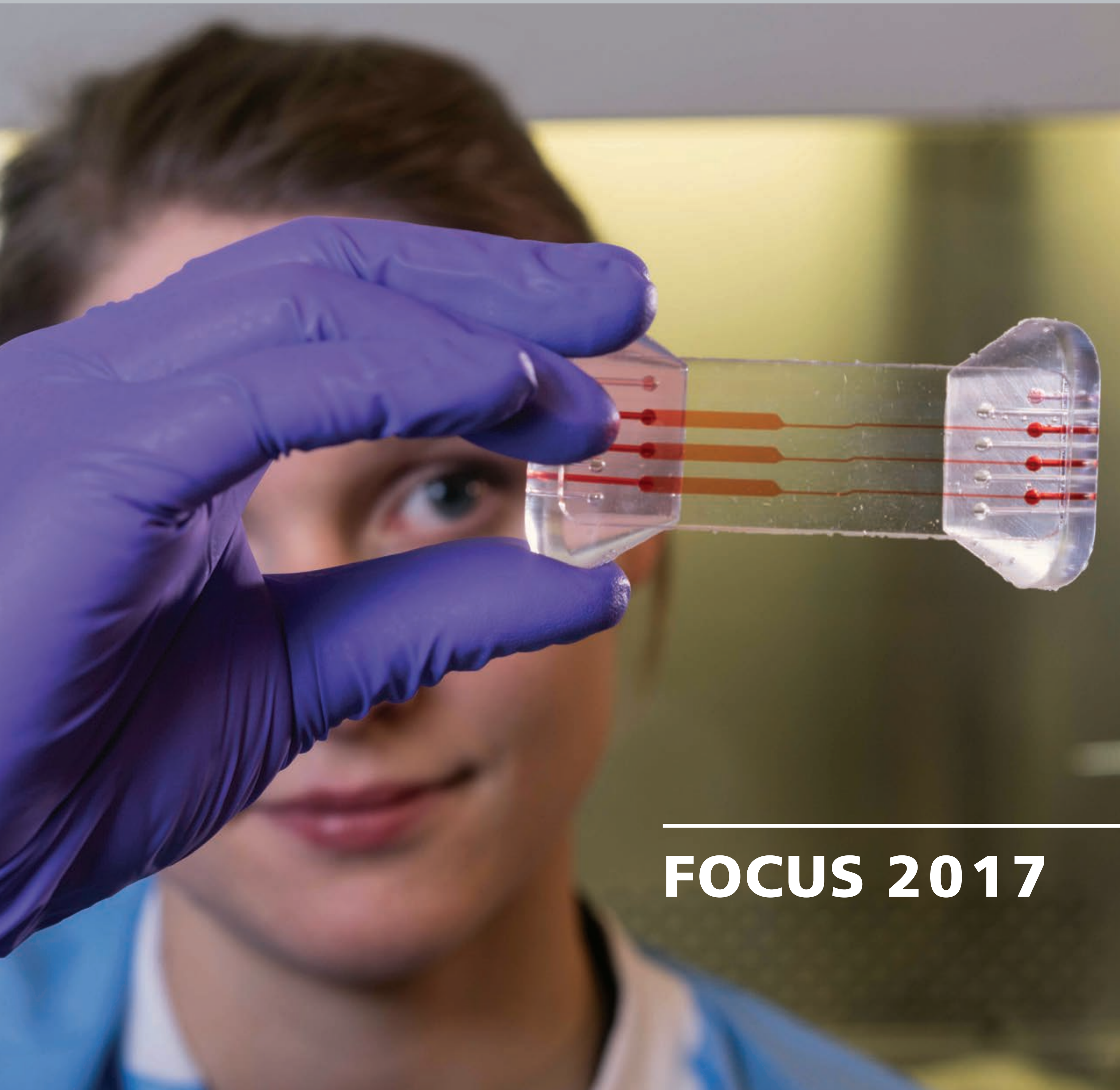

FOCUS 2017

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Welcome to the Fraunhofer USA Focus 2017.
Sustaining Prosperity by Advancing Technologies

"Technology made large populations possible; large populations now make technology indispensable" – Joseph Wood Krutch.

Not many people are aware of the fact that the "millennial generation" (born around 1980-1995) in the United States today is over 83 million people strong. It is significantly larger than the baby boomer generation (born 1945-1965). The current US population is circa 325 million; in 1960, it was 179 million. The world population increased in the last 50 years, from 3 billion to over 7.5 billion. As populations and standards of living steadily increase, communities around the world strive for their 'fair share'. Demand threatens our planet's resources. "Make more with less!" is the manufacturing economy's battle cry of the 21st century. Sustainability, life-cycle-management, digitization, Manufacturing 4.0 and Industrie 4.0 are the key words and strategic tools. Linear supply and value chains become digitized cycles as economies become circular ones.

At Fraunhofer USA we work together with our customers and partners to create technology-based innovation that makes way for new business models and environmentally sustainable prosperity. This starts, for instance, by developing coatings to reduce friction and wear and extend machine durability, or by developing biomolecular techniques to produce proteins cheaper and faster, or by making simple 'plug-and-play' solar panels that bring down installation costs, or engineering software to optimize building management concepts and reduce urban consumption and waste. Other examples are new laser welding and cladding techniques for additive manufacturing to save material and reduce costs, or new anode materials to increase energy storage capacity and battery charging cycles. It includes meta-programs to increase cybersecurity, or creating new medical sensors for faster health care diagnostics. These are just a few examples of what Fraunhofer USA does together with its partners. Society is challenged to focus on

efficiency and sustainability. The economy is challenged to maintain prosperity. These challenges are our chances. Together we can deliver.

This Fraunhofer Focus 2017 highlights who we are, presents selected projects and portrays some of our excellent employees. I hope you enjoy the read.

Sincerely,

Prof. Dr. Patrick Bressler,
Executive Vice President

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MANAGEMENT REPORT

Strategic Development

"There is nothing permanent except change"
– Heraclitus (535 BC-475 BC).

Fraunhofer USA embraces this philosophy in its strategic planning. Strategic planning for the organization is comprised of both short-term and long-term horizons and commensurate milestones and measurables.

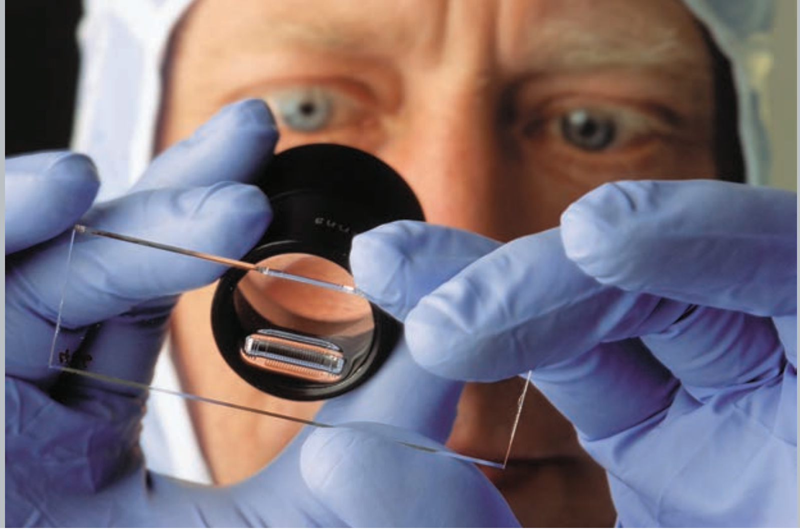
Fraunhofer's goal is to advance applied research and technology-based innovation as a service to society by supporting local, regional and global academic and industrial environments. This requires a delicate and diverse portfolio of scientific excellence and expertise, technical skills and state-of-the-art equipment. Fraunhofer serves a diverse community of customers and maintains a healthy mix of government (long term) and industry (short term) projects. Too rich in government contracts leads to susceptibility to reduction in funding of certain agencies, government budget sequestration, and political focus changes. Yet more significantly, it leads to more fundamental research and less applied research, less economic relevance and impact. Too rich in industry contracts leads to an unhealthy dependency on short term "application fixes" and sectoral business cycles, yet, more importantly, to a loss of the scientific-technical excellence and the innovative capability to adopt, develop and apply new technologies.

Fraunhofer USA reviews the blend of its research and development portfolios to maintain a sustainable knowledge and customer base that ensure its potential to advance applied research in the future.

Fields and focus of science and engineering are constantly changing. The Fraunhofer USA Centers plan ahead to embrace future emerging technologies. For example, the Fraunhofer USA Center for Coatings and Diamond Technologies (CCD) recently established a new 3-D Printing research and development group.

The Fraunhofer USA Center for Manufacturing Innovation (CMI) made additional investments in its R & D portfolio by integrating manufacturing expertise with biology knowhow. The center has created a unique pool of highly skilled engineers and biologists who work together in the rapidly developing advanced field of medical diagnostic devices.

The Fraunhofer USA Center for Experimental Software Engineering (CESE) is expanding its research and development tool box to address the real and exploding threat of cyber-attacks and data breaches that make governments, companies and individuals alike vulnerable.



Operating Objectives

Fraunhofer USA provides contract research and technology development and validation to customers from industry and state and federal governments. The organization finds itself well positioned to act as an external R & D lab for companies or agencies that do not have specific labs or the knowhow internally. Unique assets of Fraunhofer USA have always been its flexibility, its broad expertise and its mix of scientist and engineering staff leading to strong and fast responsiveness to a myriad of technology challenges.

The objective of Fraunhofer USA is to utilize its assets to move forward progress in the fields of science and engineering, always with the integral concepts of societal impact and sustainability. Fraunhofer USA also provides young scientists and engineers with hands-on experience through internships or employment. All scientists and engineers at Fraunhofer USA enjoy a high degree of autonomy, which promotes the best outcomes for the customer. Creativity and entrepreneurial spirit are encouraged and rewarded.

Fraunhofer is a unique organization that provides a critical service to the research and development community. The organization seeks to promote and promulgate high technology and its application to improve the human condition. The increasing demand and consumption of resources is leading to alarming concerns for the future. Fraunhofer researchers and engineers provide solutions.

As a 501 (c) (3) non-profit organization, Fraunhofer USA is committed to fiscally responsible operation and undergoes an external audit each year to ensure complete and accurate accounting of financial information.

Contract Research

The Fraunhofer organization exists to support and enhance applied science and technology with relevance and impact that benefit society. The types of contract research that Fraunhofer-Gesellschaft and Fraunhofer USA work on are a microcosm of what is on the cusp of the "next generation". Fraunhofer has a full spectrum of customers. Some customers have already identified a specific potential solution. The Fraunhofer Center then works to find the appropriate technical recipe and implementation. Other customers come to Fraunhofer USA to help them find a solution for a problem for which the solution is not clear, the customer only knows they have a problem that could be solved by science or engineering process development and they are looking for the best provider to work with.

Fraunhofer USA has the technological capability and scientific excellence to solve these problems. This is why customers as diverse as the US Mint and a clothing manufacturer seek out Fraunhofer. The Fraunhofer R & D portfolio is ever expanding and changing. As solutions are found, the bandwidth of Fraunhofer expertise increases. The contract research capabilities of the organization are further supported and expanded by the cooperation and partnerships with universities and the access to the Fraunhofer-Gesellschaft parent organization, based in Germany.

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

1

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. The centers also have access to additional equipment and resources through the partnerships with universities and the network of 69 institutes and research units at our parent organization in Germany.

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

2

Human Resources

Fraunhofer USA is able to attract and retain employees who are world class scientists and engineers. The unique nature of Fraunhofer, which is working on solutions for the constant influx of tough and unique challenges faced by its customers, is a thriving environment for curious minds. Our technical staff is never bored and indeed enjoys much latitude in creativity and innovation.

Each Fraunhofer USA center has a staff of employees with education and experience that enables the center to take on very diverse projects. For example, one of our centers has staff members with science degrees in chemistry, physics and materials, and engineering degrees in mechanical and electrical engineering, and computer science. The interdisciplinary knowledge and skill set of these employees enables the centers to approach customer problems from a variety of angles and provide an innovative and customized solution.

In 2016, Fraunhofer USA employed over 250 highly trained and qualified people. In our Faces at Fraunhofer section, we are pleased to highlight some of our staff members.

1 © *Fraunhofer USA, team brainstorming at Fraunhofer CMI*
2 © *Fraunhofer CLA, Fraunhofer Coax Wire System with Emaqs process monitoring camera*

Dr. Christine McBeth
Research Scientist CMI

Dr. Christine McBeth received her B.S. degree in Microbiology from Brigham Young University and her Ph.D. in Molecular and Cellular Biology from the University of Washington. Her doctoral thesis work focused on investigating degenerate recognition in the immune system uncovering new mechanisms for how your body knows that you're you and not a pathogen. Dr. McBeth then moved to Boston, MA for a post-doctoral fellowship at Harvard Medical School to investigate how bacteria sabotage human cells.

In 2014, Dr. McBeth joined the engineering and research scientist teams at the Fraunhofer USA Center for Manufacturing Innovation (CMI) in their work to get biomedical diagnostics and devices market ready. Many of her activities involve in-house research with 3D bioprinting of tissues, rapid antibiotic susceptibility testing via microfluidics, and point-of-care diagnostic development. For the rest, she partners closely with the talented CMI engineers to help top biotech companies move their favorite R&D projects to the industrial scale. Dr. McBeth also enjoys helping train the next generation of scientists as she mentors and works with the young student researchers at CMI.

Mr. Frank Herman
Managing Director CESE

Mr. Frank Herman is the Managing Director of the Fraunhofer USA Center for Experimental Software Engineering (CESE). Frank is experienced in a wide variety of software disciplines including the development of real-time operating systems, weapon control systems, software project management, space communications, database applications and software tools such as compilers, computer simulators, reverse engineering and static analysis. Prior to his position at Fraunhofer USA, Frank was Vice President and General Manager of the BAE Systems Land & Information Management Division, Program Manager at the Office of Naval Intelligence, Principal Software Engineer at Vitro Corporation and Chief software engineer for the design and development of the US Navy Terrier & Tartar Weapon Direction Systems. Frank holds a Bachelor of Science Degree in Computer Science from the Florida Institute of Technology.

At Fraunhofer USA in addition to his responsibilities for the financial management of CESE, Frank is providing expertise to the NASA Space Network Ground Segment Sustainment (SGSS) Project in the oversight of the SGSS development contractor's system and software processes, design, implementation and quality. This involves assessing the system and software design, assessing cost and schedule estimates, monitoring cost and schedule performance, overseeing software processes and quality, etc. to identify risks associated with the system's ability to meet functional, interface and performance requirements and the contractor's ability to meet cost, schedule and quality objectives. Applying research from the CESE team, Frank makes recommendations to the SGSS Project Office, NASA HQ and the contractor to mitigate program risks.

Dr. Anne-Marie Baker
Grants and Contracts Manager CSE

Dr. Anne-Marie Baker has been the Grants and Contacts Manager for the Fraunhofer USA Center for Sustainable Energy Systems (CSE) since 2013. Prior to that, she oversaw programs funded by a wide array of agencies ranging from the Department of Commerce to the Department of Energy in a portfolio which included several significant industrial development contracts. Anne-Marie's experience began with a Bachelor of Science degree in Chemical Engineering from UMass Amherst, followed by a doctorate in Plastics Engineering from UMass Lowell.

Her expertise in regulatory compliance, coupled with her technical background, makes her uniquely qualified to liaise between government and industry partners to negotiate and execute complex contract requirements. In addition to ensuring that the work conducted is in regulatory compliance, she also continually meets and exceeds partners' expectations as CSE strives to deliver industrially-relevant technology development and deployment. Anne-Marie derives tremendous satisfaction from her contributions to the furtherance of clean energy technologies; by ensuring contractual compliance in order that the technical staff can focus on the ground-breaking developments which are so important to a sustainable future.

Anne-Marie is not only an essential component to the CSE team, but can also always be counted on for positive input and an encouraging word. She lives with her husband Frank and their two dogs and two cats.

Dr. Cory Rusinek
Scientist CCD

Dr. Cory A. Rusinek received his B.A. in Chemistry from Case Western Reserve University and his Ph.D. in Chemistry from the University of Cincinnati under the direction of Prof. William R. Heineman. While in Cincinnati, he worked on the development of electrochemical sensors for a wide variety of applications. One project included the development of disposable sensors for point-of-care detection of heavy metals in blood and water and another included a spectroelectrochemical sensor for the detection of polycyclic aromatic hydrocarbons (PAHs). The latter of which he collaborated with engineers at the Fraunhofer USA Center for Coatings and Diamond Technologies (CCD).

In May 2016, Dr. Rusinek joined CCD as a scientist to begin an electrochemical group within the center. The group has quickly sprawled into many facets of electrochemistry including sensor development, water treatment, and corrosion. Some projects include the development of a boron-doped diamond (BDD) based microelectrode array for ultra-sensitive determination of lead (Pb^{2+}), BDD sensors on flexible substrates for neurotransmitter stimulation and sensing, development of BDD and tetrahedral amorphous carbon (ta-C) electrodes for water treatment applications to remove contaminants such as per- and polyfluoroalkyl substances (PFASs), removal of ammonia (NH_3) from agricultural wastewater using electrochemical oxidation, and the development an electrochemical process to efficiently strip thin-film coatings from various substrates. Dr. Rusinek is also an active member of American Chemical Society (ACS), International Society of Electrochemistry (ISE), and Society of Electroanalytical Chemistry (SEAC).

Mr. Rahul Patwa
Project Manager CLA

Rahul Patwa received his Master's Degree in Mechanical Engineering from Purdue University, West Lafayette, Indiana in 2004. During his graduate studies, he worked as a graduate teaching assistant for an 'automatic control systems' course to senior students. During his master's thesis he worked on a project funded by the state of Indiana's 21st century Research and Technology Fund to develop a 'thermal-kinetic' numerical model for laser processing and verified it using non-intrusive temperature sensing devices and an IR camera. He published this work in the *International Journal of Machine Tool and Manufacture*, where it was recognized as one of the top 10 cited papers over a period of 5 years. After graduating, Rahul joined Wabash National where he worked as a principal engineer for automation and laser systems and provided support for programming and system integration in high volume automotive production.

In 2006, Rahul joined Fraunhofer USA Center for Laser Applications (CLA) in Plymouth, MI, where he supports laser processing, process monitoring, software integration and system development. He developed laser and process monitoring technology for advanced manufacturing of batteries through a sponsored program from the state of Michigan (MEDC). He led a team to develop a high speed camera system hardware and ThirdEye software to monitor and detect defects during the laser process and correct the error and achieve high yield. He worked with a multidisciplinary research team from Wayne State University in developing joining techniques for the assembly of biomedical implants to meet stringent demands of joints regarding consistent quality and reliability using state-of-the-art laser and vision systems. This research has been published in high impact journals such as the *Journal of Material Science and Applied Surface Science*. As a part of a center called Alternative Energy Technologies for Transportation (AETT), an international collaboration between the University of Michigan and Fraunhofer, he further implemented laser cutting and monitoring technology for electrode manufacturing using spectral sensors and advanced signal processing software. As a part of a team on a Department of Defense (DoD) project on Multi-Beam Laser Additive Manufacturing, he integrated system hardware and software and performed application development. An ArpaE funded project on PV solar cells was a joint effort between Solarworld, Xerox PARC, Fraunhofer and the University of Washington, where Rahul worked with the team to develop next generation solar cell technology. Rahul is a Certified Vision Professional (CVP - Advanced) from AIA. He has published 50+ peer-reviewed conference articles, magazine articles and high-impact journal papers, has 200+ citations and is regularly invited to speak at industry leading conferences and trade shows.

Rahul is currently pursuing doctoral studies with RWTH Aachen, Germany on the topic of intelligent monitoring software systems. Rahul's personal interest is to develop intelligent laser processes and control systems using machine learning and artificial intelligence technology that can further accelerate their industrial adoption. In his free time Rahul enjoys reading, visiting friends and spending time with his family.

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

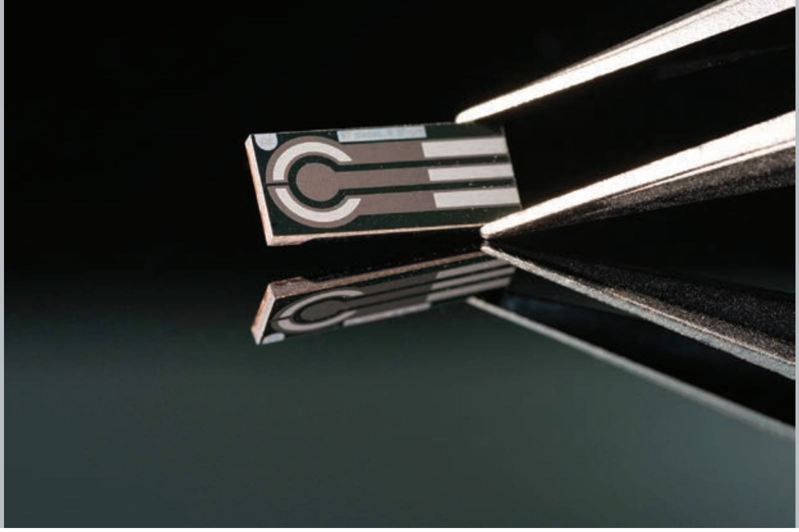
On Site Diagnosis for Rapid Response

The United States government has established a Biodefense Priority Pathogens list in an effort to focus research and development efforts to rapidly identify, contain, and treat these severe infectious diseases. The greatest level of concern is for those in Category A because they result in high mortality rates and because person-to-person transmission can be immense. Many of these Category A Priority Pathogens, such as the Ebola, Lassa, and Dengue viruses, cause viral hemorrhagic fevers. While these viruses can have severe outcomes for infected patients, the initial symptoms are largely limited to fever and general malaise. Such nondiscriminatory symptoms make it extremely difficult for first responders to take appropriate action that is required for these severe infections. The current practice for diagnosing Category A pathogens is to send clinical samples to large, international reference laboratories. These samples are processed by cell culture methods and require Biosafety Level 4 containment to prevent subsequent infection and outbreaks. While diagnosis of infection is definitive via these methods, turn-around time to the clinic at the point-of-care is extremely slow which allows for ongoing spread of disease.

Ongoing work at the Fraunhofer USA Center for Manufacturing Innovation (CMI) addresses this problem by developing technologies that target users in the field, where complicated laboratory equipment is simply not available. This use case presents design constraints that place a premium on devices that are compatible with industrial-scale manufacturing processes and simple detection schemes. As viral detection moves from expensive centralized hospitals out into the community, health care workers and epidemiologists can provide the immediate care and countermeasures that are so desperately needed during an outbreak.

For any pathogen diagnostic, there are four main steps – collection, sample preparation, amplification, and detection – that must be included in the overall device. In designing POC devices for low-infrastructure use cases, the biological and manufacturing demands of the device are often in opposition to each other. With respect to the biological assay, temperatures need to be consistently controlled, detection signals must be high above background, and the pathogen-specific information needs to be isolated from the raw sample. With respect to the manufacturing process, virtual detection platforms already exist for large hospitals. In these environments, trained technical personnel are available to carefully perform the assay and expensive instrumentation is able to detect very small quantities of sample. In the field, where POC diagnostics are needed to run on minimal instrumentation by users with little to no technical expertise, compatible choices in each of these steps must be made.

CMI has developed a substantial core expertise in designing biological assays to be compatible with large-scale manufacturing. The three constraints of instrumentation, consumables, and technical personnel are highly interrelated and can be overcome through the integration of the following technologies: ultra-thin microfluidics with printed layers, isothermal assays, and novel optics.



Rapid Detection of Lead at Home, on the Road, or in the Field

Lead (Pb) exposure from contaminated drinking water has become a profound issue facing people across the world. An Environmental Protection agency (EPA) regulated group A-2 carcinogen, Pb affects almost every organ with chronic exposure. These affects are significantly magnified in children where irreversible damage to the central and peripheral nervous system can occur. Issues include learning disabilities, behavioral issues, impaired formation and function of blood cells, and impaired hearing, among others. Furthermore, approximately 500,000 children in the United States have blood lead levels above the 5 µg/dL reference level that the Center for Disease Control (CDC) recommends for public actions to be initiated, no "safe" level has ever been determined. These are few of the many reasons why rapid, reliable detection of Pb in drinking water has become crucial. Researchers at Fraunhofer USA's Center for Coatings and Diamond Technologies (CCD) have developed a boron-doped diamond (BDD) based electrochemical sensing device capable of detecting Pb in drinking water at levels 55x below the EPA action limit of 15 ppb with a measurement time of only 2 minutes. The intrinsic sensitivity and selectivity of the method also allows for the detection of other toxic heavy metals such as cadmium (Cd), mercury (Hg), and Arsenic (As). The quick measurement time and simple sample pre-treatment render the BDD device capable of Pb detection at home, on the road, or in the field.

Oxidative Destruction of Ground Water Contaminants with Diamond Electrodes

Roughly 600 sites across the United States have been categorized as Fire/Crash/Training areas under the Defense Environmental Restoration Program (DERP). Many of which, due to long-term use of aqueous film forming foams (AFFFs), have resulted in groundwater contamination with elevated levels of per- and polyfluoroalkyl substances (PFASs). AFFFs are pre-cursors to PFASs, recalcitrant compounds that bioaccumulate in the human body and cause a number of adverse health issues upon various exposure pathways. These complications have led the Environmental Protection Agency (EPA) to establish health advisory levels of 70 parts per trillion (ppt). Unfortunately, the extreme stability of PFASs under environmental conditions has rendered remediation methods such as biodegradation, photo-oxidation, hydrolysis, and direct photolysis ineffective. Electrochemical oxidation, however, is a simple and effective method for destruction of PFASs and corresponding co-contaminants. To combat this issue, CCD has partnered with researchers at the University of Tennessee to develop an electrochemical oxidation reactor with boron-doped diamond (BDD) electrodes. BDD provides a combination of rigidity, high oxygen over-potential, and overall electrode lifetime, which makes it an attractive option for an electrochemical treatment system. To date, the BDD electrodes developed at CCD are capable of PFAS destruction with extreme stability, where complete removal has been observed in 1 hour of experiment time. Capitalizing on BDD's intrinsic properties will allow CCD to provide long-term PFAS destruction to produce a cost-effective and efficient electrochemical system.

© Fraunhofer USA, Fraunhofer CCD – boron-doped diamond electrode

SECURITY AND SAFETY

Safety and Security for Medical Devices

As we move into a world with increasingly connected intelligent devices (such as mobile and cloud interfaces), the amount of software in medical devices is rapidly increasing. While this connectivity opens up innovative new therapies, treatments, and diagnostics, provides convenience to users (patients and caregivers), and reduces overall health care costs due to integrations and non-duplication of effort, it also introduces new security challenges. Interfaces that allow for flow of control and data between devices and infrastructure (e.g. remote controls, electronic health records, interoperable middleware, cloud and mobile infrastructures) lead to new security vulnerabilities that previously did not exist in stand-alone, non-networked devices.

What makes medical devices particularly challenging is that unlike traditional information technology (IT) systems, they are almost exclusively safety-critical systems. Connected to (and sometimes implanted in) human beings, the consequence of illicit control of these devices can be severe, sometimes fatal, and often irremediable. Post-facto detection and remediation, as is often the standard practice in IT security breaches, is often not possible, since lives cannot be restored and injuries may cripple the patient while they heal. The ability to directly affect human safety not only provides greater motivations for malicious agents to attack medical device systems, but also makes several traditional IT security countermeasures infeasible.

Mitigating controls cannot be passive, and must actively block detected attacks before they cause any harmful effect. Additionally, patient data is valuable on the black market, orders of magnitude higher than credit card numbers, which banks can easily invalidate in case they are compromised (unlike patient data), further increasing the attractiveness of medical devices for malicious agents. The need for “designed-in security” thus becomes even more imperative to ensure security controls are properly implemented. Medical devices must perform safely and effectively, and assuring acceptable security properties in them is an increasingly crucial part of it.

Incorporating security from the very beginning of the design process starts from understanding the threats or potential attacks that the devices face, the implication of such attacks, and defining appropriate responses and mitigations for the attacks, which then are turned into security requirements.

Other approaches for eliciting security requirements, such as threat modeling and misuse cases, have been widely used in traditional IT system contexts. While these approaches are useful, a systematic approach that focuses on the safety implications is needed for addressing the critically required security in medical devices.

At the Fraunhofer USA Center for Experimental Software Engineering (CESE), we look instead at the application of the Sequence-Based Enumeration (SBE) approach, a systematic approach for defining complete system behavior commonly used in formal software development approaches, and previously used for developing medical device requirements.

SBE is typically used to specify "nominal" functional behavior of a system under design. It is supported by the RealSBS tool to perform its requirement elicitation and analysis steps. At CESE, we have extended the SBE approach and its supporting tool to enable the analyst to identify what possible malicious behaviors (as captured in the form of off-nominal behavior) are detected, their safety impact on the system, and to specify what mechanism is needed to detect, avoid, or mitigate the danger to patients. We have used this modified approach to a medical device to assess its safety against attacks.

Our approach is focused on the first aspect of the requirement elicitation process, i.e., understanding the security needs of the system by enumerating the threats or potential attacks that the devices face, and defining appropriate responses and mitigations.

The two main contributions of our approach are:

- Aiding the device developers/analysts to better qualify the safety implications their system faces given the identified security threats.
- Relatedly, assisting the developers to identify which components in their system that have the most safety risk.

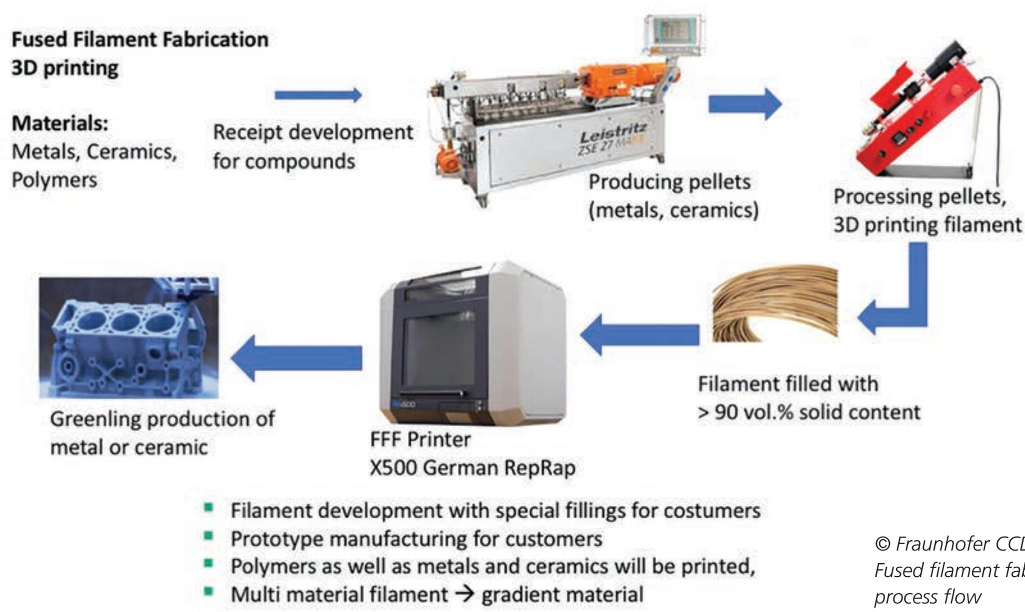
This information enables developers to identify where security mechanisms are needed, and to prioritize their attention depending on the components which have the highest safety consequences.

PRODUCTION AND SERVICES

Additive Manufacturing Low Cost Technology for Production Savings

The rapidly developing field of additive manufacturing (AM) encompasses numerous 3D printing approaches and covers a wide range of materials and systems technologies. The appeal of 3D printing is based on its enormous production flexibility and the inherent efficient use of raw material resources. Polymer based processes (e.g. stereolithographic printing) are well established, however, many real-world applications require metal or ceramic materials to build useful parts. Such materials can be fused with powder bed techniques (e.g. selective laser and electron beam melting). These techniques are becoming well established but generally process just one material in one step. Also, such systems are still very expensive, which reduces their appeal for many applications.

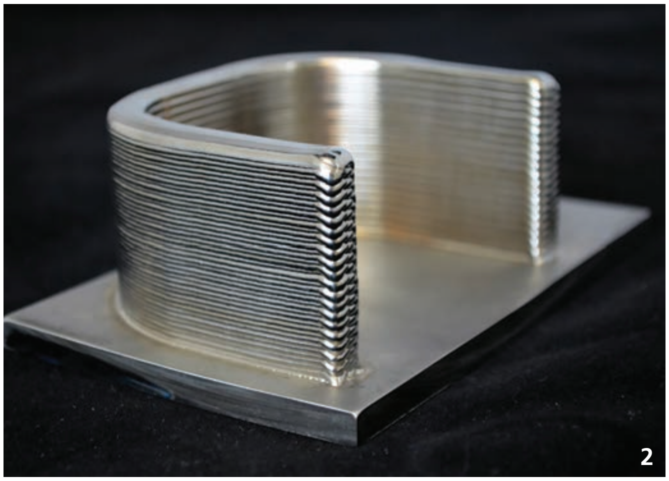
Fraunhofer USA Center for Coatings and Diamond Technologies (CCD), in collaboration with Michigan State University, is developing a cost-efficient 3D printing technology to process a variety of materials including polymers, metals and ceramics in the same system. Two different materials can be processed in parallel with this technology and it is also possible to print parts with material transitions, e.g. connecting polymers with metals in one part. This filament based fabrication technology (i.e. fused filament fabrication) offers a wide range of applications in the field of additive manufacturing and enables also the processing of composite materials. The team works on filament development and 3D printing process optimization.



© Fraunhofer CCD, 3D Printing Fused filament fabrication process flow

Lasers for Additive Manufacturing

Laser additive manufacturing or 3D printing as it has also become known, involves the construction of parts layer by layer. This can be accomplished by powder bed and direct metal deposition processes. Whilst powder bed technology offers high resolution and the ability to produce complex geometries, the overall size of the component which can be built is typically limited to less than 400mm x 400mm x 400mm and the build rate is relatively slow. The direct metal deposition process however can utilize Fraunhofer's coaxial powder or wire process technology integrated into large scale robotic or CNC machines with potential build volumes of over 2000mm x 2000mm x 2000mm. This technology opens up the possibility to produce large scale, high value components at significantly higher build rates than what is achievable using the powder bed process. The Fraunhofer USA Center for Laser Applications (CLA) is actively engaged in a wide range of research programs, where prototype parts are being built for aerospace applications using titanium, Inconel and other nickel based alloys. The potential benefits of this approach are the ability to produce light weight components faster with less machining time, and with reduced tooling lead times compared to conventional technologies such as casting.



Coloring with Lasers

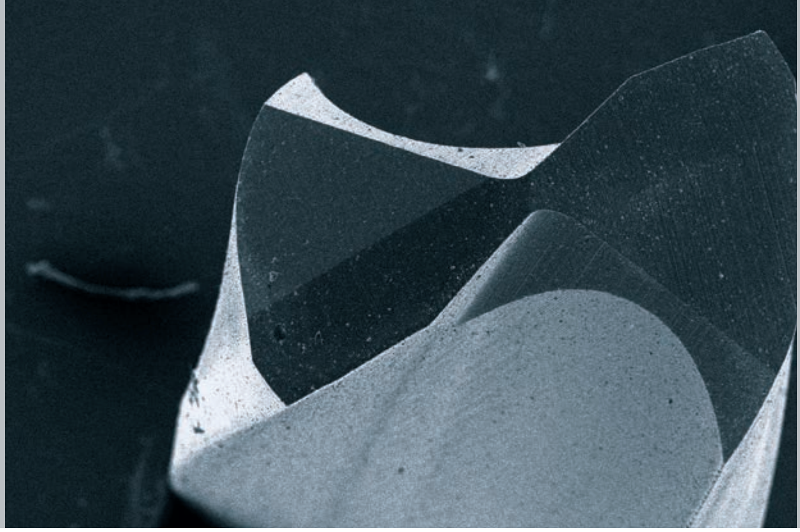
Lasers can be used to create permanent color marking on a metal surface. The process is based on surface oxidation and thin film effects and does not require any chemicals, coatings or tools. Different colors ranging from silver and gold to blue and green can be created, usually on materials such as stainless steel and titanium.

CLA uses state-of-the-art high beam quality laser sources with independent pulse parameter adjustment in order to produce an array of different colors. Only laser parameter changes are needed to produce the different colors.

A camera based system has also been developed to monitor the process and measure the laser produced color mark against the RGB model color chart. Potential applications for this technology include medical instruments and implants, consumer electronics, and appliances.

1 © *Fraunhofer CLA, laser color marking of Fraunhofer name*

2 © *Fraunhofer CLA, titanium demonstrator part*



ENERGY AND MATERIALS

BAM – A Material with Extraordinary Properties

Aluminum magnesium boride or for short, “BAM” has been shown to have remarkable mechanical properties such as hardness approaching that of diamond or diamond-like carbon and low friction values comparable to Teflon®. At the Fraunhofer USA Center for Coatings and Diamond Technologies (CCD), BAM is explored as a thin film material (micrometer range) for industrial wear applications. It has been shown to reduce cutting tool wear, in particular for machining Ti alloys and composite materials. The material’s hardness and chemical inertness provide alternatives to plating or anodizing of lightweight components to protect them against erosion and corrosion. The deposition process is being further developed to match the thin coatings more and more with the extraordinary properties of bulk BAM and to scale up the deposition technology to open up a wider range of applications.

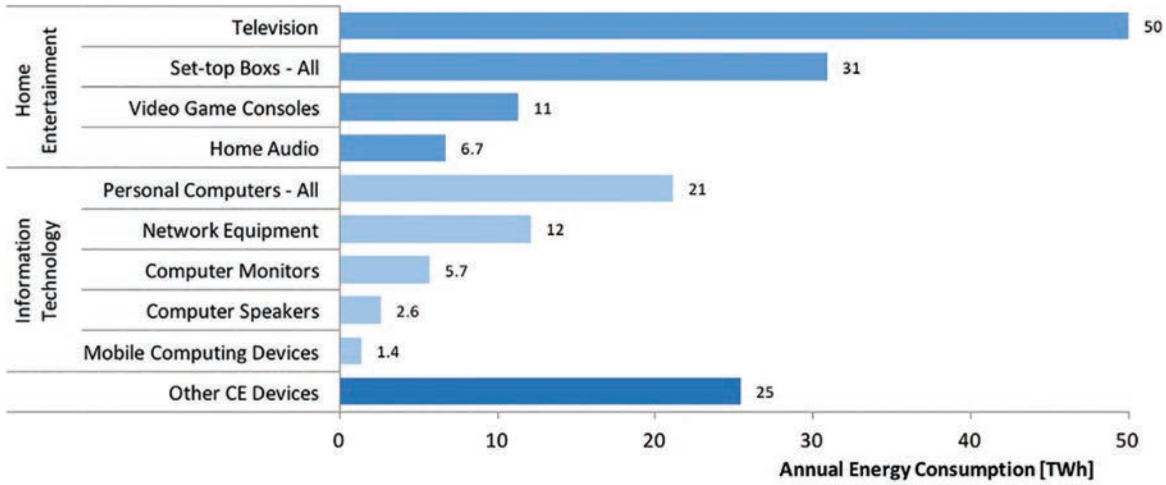
Energy Consumption Measurements for Beneficial Data Collection

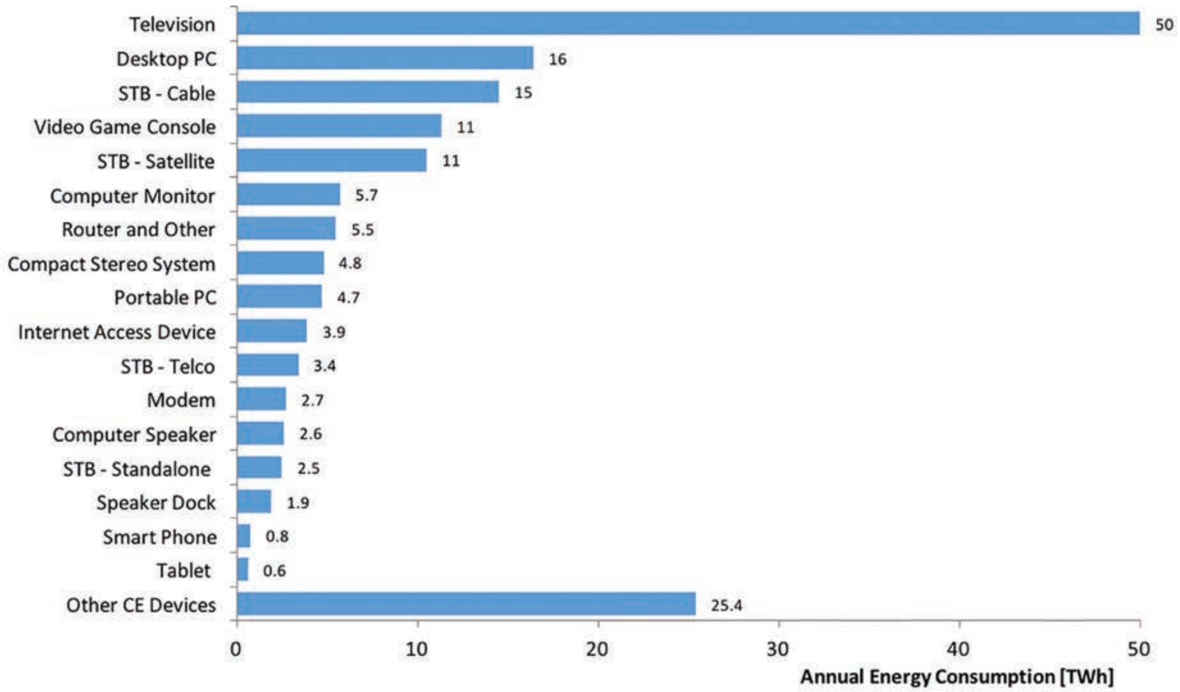
The Fraunhofer USA Center for Sustainable Energy Systems (CSE) performed a study for the Consumer Technology Association (CTA®) to quantify the electricity consumption of consumer electronics (CE) in US households in 2013. Relative to other energy end uses, the characteristics of CE typically change very quickly due to short product cycles and lifetimes, evolving usage patterns and dynamics, and rapid technology adoption that can strongly influence device power draw by mode. As a result, the characteristics of the installed base of most CE can change dramatically in a few years. Such rapid changes in the energy consumption characteristics of CE make it essential to develop up-to-date and accurate assessments of CE energy consumption. If older data is used to analyze potential energy policy decisions, such as voluntary or mandatory regulatory programs, it can lead to less effective policy decisions that may not achieve their end goals.

CSE used a bottom-up approach to characterize US residential consumer electronics energy consumption in 2016, focusing on 17 priority categories. For each CE category, CSE used a range of sources to develop estimates for the installed base and average power draw and annual usage by mode.

Overall, CSE scientists estimate that the 3.8 billion CE in homes consumed 167 TWh in 2013, an amount equal to 12% of residential electricity consumption and 8.3% of residential primary energy consumption. This represents a 13 percent decrease from our study for 2010, which is primarily due to: 1) a decreased installed base of TVs that has also shifted from CRT to more efficient LCDs; 2) the migration of the installed base of computers away from desktops to much less energy-intensive tablet and notebook formats, and 3) a decrease in the installed base and power draw of computer monitors.

© Fraunhofer CCD, BAM coated micro drill





© Fraunhofer CSE, building monitoring performed by Fraunhofer CSE staff

Development of a Non-corrosive and Bio-based Phenolic Foam Thermal Insulation for Buildings

Research Team: Fraunhofer CSE, University of Tennessee, Knoxville; Atlas Roofing Corporation

Among the conventional plastic foam insulations used in the US building sector, phenolic foam is the only one that can attain a thermal conductivity as low as 0.018 W/m-K. Phenolic foam also inherently satisfies the fire safety codes without the need for adding toxic and expensive fire retardants. Despite these benefits, phenolic foam is rarely used in US buildings due to its corrosion potential caused by the usage of strong sulphonic acid in its chemistry and poor mechanical characteristics, which led to nationwide failures of metal roof decks during 1980-90s.

In a project funded by the US Department of Energy, Fraunhofer CSE led the development of a novel non-corrosive, biobased, mechanically stronger and low-cost phenolic foam insulation derived from inexpensive components, including biomass lignocelluloses. The acidity was substantially mitigated by using biobased organic acid catalysts, resulting in a pH of >4.5 for the produced phenolic foams in comparison to the pH of 1.5-2.5 obtained for the traditional phenolic foams synthesized using sulphonic acid catalysts. Lignin, a rich source of phenol, was used to synthesize biobased phenolic resin, while light-weight nanocellulose fibers were added to mechanically reinforce the foam matrix.

Truck PV Study on Cabot Creamery Trucks in the U.S.

The study phase has ended for the solar photovoltaic (PV) integrated reefer truck rooftops in the United States. Fraunhofer CSE (in Boston, MA) and Fraunhofer ISE (in Freiburg, Germany) worked in cooperation with Agri-Mark/Cabot Creamery Cooperative, based in Vermont, on the US study of an installation of solar PV modules onto two Cabot Creamery refrigerated trucks. This study recorded the amount of potential energy that could have been produced by the Cabot delivery trucks while driving their delivery routes if rooftop mounted solar PV modules had been installed.

These PV modules would help power the refrigeration system whether the trucks are in motion or are stopped. As the ambient temperature rises with solar irradiation, the solar power supply overlaps with cooling demand, reducing the need for large amounts of storage capacity. The resulting decrease in fuel consumption reduces cost as well as local pollution.

It was determined that overall, there is a significant fuel savings potential for this kind of commercial vehicle. However, the savings potential strongly depends on the truck's route and time spent in the home port. For the Cabot trucks, 290 gallons of Diesel could have been saved in one year, if the full roof area of the trailer would have been covered with PV.

© Fraunhofer CSE, bio-based phenolic foam

COMMUNICATION AND KNOWLEDGE

MPEG-H TV Audio System becomes ATSC Standard

First next-generation audio system to go on air and first to be used in Olympic broadcasts

The MPEG-H TV Audio System has been confirmed as an official standard for use in ATSC 3.0 Digital Television. The audio system, predominantly developed by Fraunhofer IIS and Fraunhofer USA Digital Media Technologies (DMT), received ATSC approval in March 2017. It became the first next-generation audio system worldwide to go on air 24/7 as South Korea launched its 4K UHD TV service on May 31, 2017. Not only will this new, ultra-high definition television service deliver pin-sharp pictures, it also brings with it new audio features for viewers, thanks to the MPEG-H TV Audio System.

Viewers can hear immersive sound from overhead speakers, soundbars, or earphones. They can adjust elements of the audio program with preset mixes provided by the content producer or make their own mix during playback. Audio objects in the system allow the viewer to hear their home team announcer or listen to their favorite race driver’s radio, for example. The system also tailors the sound presentation for the best listening quality on each type of playback device.

The new TV experience will first be available in the Seoul capital area, and will be extended to the metropolitan areas and the venue cities of the Olympic Games in Pyeongchang in 2018. By 2020, the service is scheduled to be available nationwide.

Korean consumers can purchase a growing number of MPEG-H enabled TVs from Samsung and LG today. SBS, the largest commercial broadcaster in South Korea, will be providing immersive and interactive sound with its broadcasts of the Olympic Games in 2018.

DMT helped get the standard adopted by building a “test bed” demonstrated to the broadcast industry and ATSC members at trade shows and standards meetings in Las Vegas and Atlanta. The test bed demonstrated the viability of the MPEG-H system by simulating transmission of a live broadcast from a sports event through a TV network operating center, and then a local affiliate TV station to a consumer living room.

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

2 © *Fraunhofer IIS, DMT’s Jim Hilson mixes a simulated live broadcast in test bed*

FRAUNHOFER USA CENTERS

Fraunhofer CMI, in collaboration with Boston University, conducts applied research and development leading to the deployment of technological solutions that enhance the productivity and competitive position of its customers, while educating engineering students in the process. Focused on automation and instrumentation, CMI develops next generation automation, instruments, and devices for the biotechnology/biomedical, consumer products, aerospace, photonics and renewable energy markets.

CMI has a unique combination of expertise that includes both engineering and biological sciences. It is one of the few places where staff can engineer devices and instrumentation in the onsite machine shop, then walk across the hall and hand them to the biologists and chemists developing novel assays in biosafety level one and two laboratories. CMI leverages its expertise in engineering design and biological sciences to develop cutting edge solutions in the biotech/biomedical space, and is highly active in the areas of microfluidics, point-of-care in-vitro diagnostics, biosensors, medical devices, tissue engineering, and laboratory automation.

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 Offers

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

Custom Automation Systems

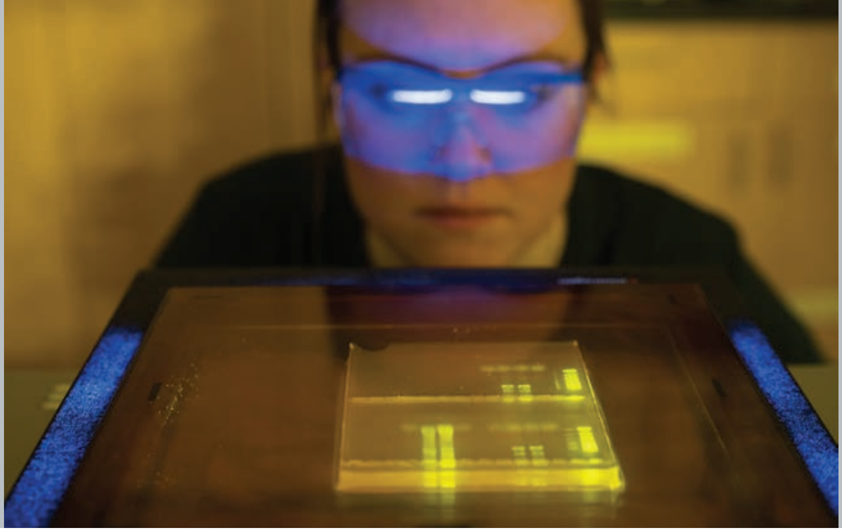
Manufacturing automation begins with a thorough understanding of the requirements of the process, followed by a review of available state-of-the-art technologies that may be incorporated. When commercially available technology does not suffice, CMI develops new custom automation systems, based on the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

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

Examples:

Fiber Optic Gyroscope Winding

While fiber optic gyroscopes (FOGs) have several advantages over ring-laser gyroscopes, the difficulty 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, 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 the center's core strengths is the application of advanced engineering to biological problems. CMI combines multiple engineering and scientific disciplines in tackling such problems, and is trusted by leading pharmaceutical and medical device companies and research collaborators to successfully carry out their project goals.

To meet these needs, the center 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. Major activities include developing rapid diagnostics, exploring tissue engineering approaches, producing medical devices and building scientific instruments.

Examples:
Low-Cost, Real-Time, Continuous Flow 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, 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).

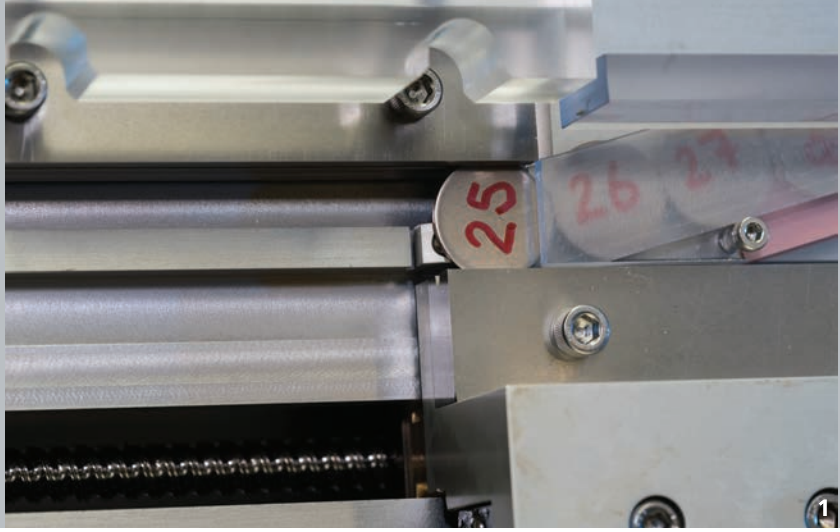
Bioprinted Hydrogels Developed to Improve Implant Integration
CMI's custom-designed bio-printer is able to print multiple materials (or multiple cell types in the same material) concurrently with various feature sizes (Campbell et al. J. Nanotechnol. Eng. Med. 2015, 6, 021005).

In collaboration with Fraunhofer 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 staff used the center's 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 CMI to benchmark their current process, and introduce new technologies that will address their challenges. CMI 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, journals, 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.

© Fraunhofer USA, Fraunhofer CMI – student examines gel electrophgoresis results



Examples:

Coin Manufacturing Assessment and Technology Development

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. CMI then prototyped solutions and tested the quality of the coin blanks produced with these alternative solutions. Technologies explored included laser processing.

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1 © *Fraunhofer USA, Fraunhofer CMI – metal blank rimming system*

2 © *Fraunhofer USA, Fraunhofer CMI facilities*

FRAUNHOFER USA CENTER FOR COATINGS AND DIAMOND TECHNOLOGIES (CCD)

Fraunhofer CCD performs applied research and development contracts with industry and government organizations. Industry customers include companies from sectors such as manufacturing, semiconductor, biomedical and energy amongst others. 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 ISO 9001 certified.

CCD's 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. CCD connects with world-class basic research through its close partnership with Michigan State University (MSU) 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. CCD is also closely affiliated with and offers access to the Fraunhofer Institute for Materials and Beam Technology (IWS) in Dresden, Germany.

Currently, CCD is in its second year of a five-year joint expansion plan with partner MSU. This expansion has the goal to further grow the successful collaboration that has been in place since 2003. Following the agreement, the university hired two additional professors assigned to the center. Two more hires are expected to start in August 2017. In April 2017, MSU's board of trustees approved a $6.5 million dollar expansion of CCD's laboratory facilities to be completed in early 2018.

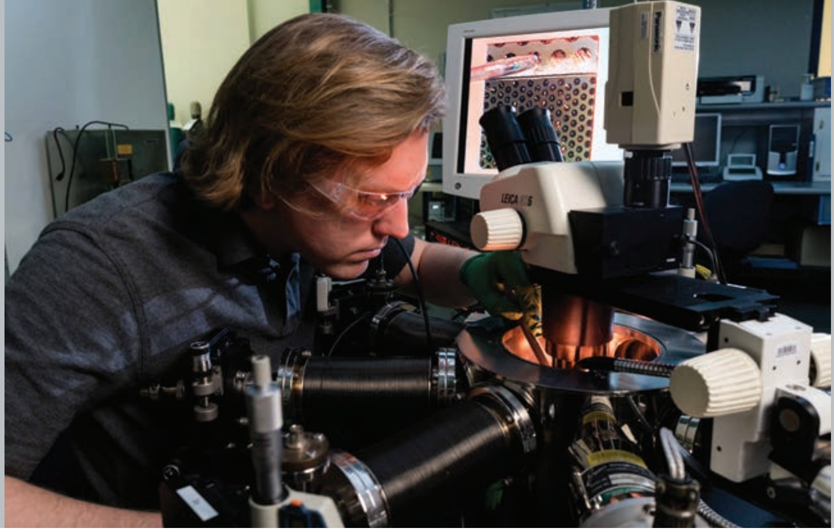
Engaging with CCD in Applied Research and Development Work

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. Customers are provided with access to the extensive laboratory and engineering resources. Project results are treated with strict confidentiality. The center recognizes the need to protect intellectual property rights for its customers and work with them 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 knowhow. 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.

© Fraunhofer USA, Fraunhofer CCD – brilliant cut diamond crystal on top of titanium-aluminum-nitride coated endmill



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 CCD the material is synthesized by chemical vapor deposition using a process very like depositing coatings from other materials. It is used by CCD customers in the form of coatings such as poly- and nanocrystalline diamond films or a poly- or monocrystalline bulk material.

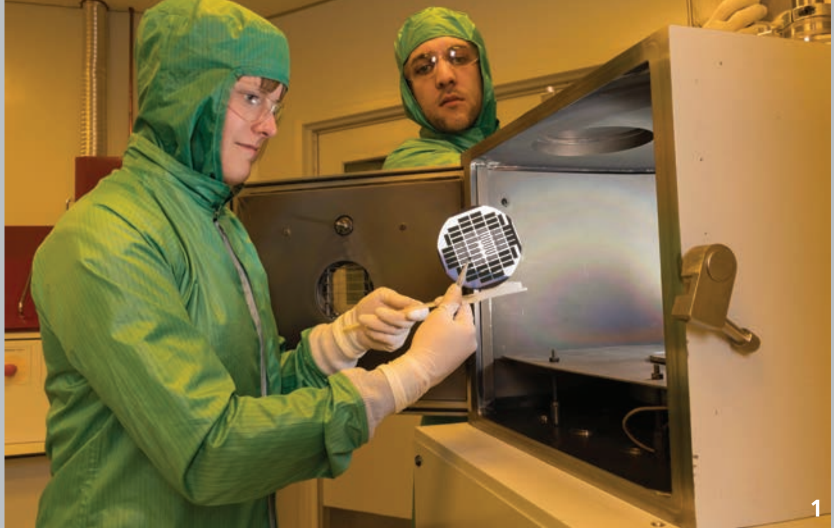
Project Briefs
Boron-doped diamond electrochemistry: Boron-doped diamond (BDD) is a new electrode material for electrochemical applications. Due to the fabrication from methane and hydrogen gases, boron-doped diamond electrodes are less expensive than platinum electrodes. Yet BDD by far exceeds the electrochemical 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 neurochemistry. The material can be applied to a variety of substrates and shapes made from silicon, quartz, metals, and diamond. 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: 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, CCD 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 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 production shifts instead of only one.

© Fraunhofer USA, Fraunhofer CCD – probe station used to test diamond devices



Anti-reflective coatings for transit bus windshield: 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.

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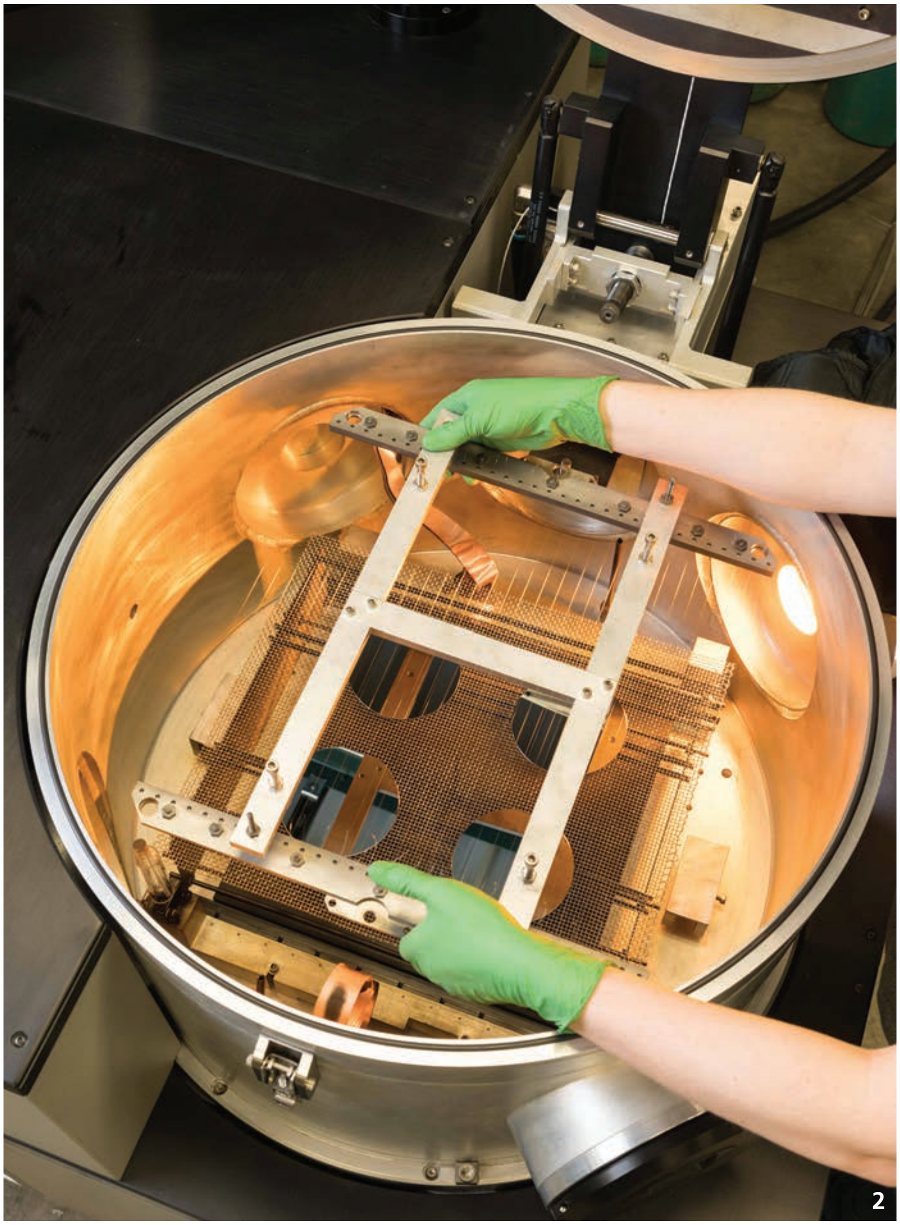


1 © *Fraunhofer USA, Fraunhofer CCD engineers working in CCD's cleanroom loading a PVD sputter system*

2 © *Fraunhofer USA, Fraunhofer CCD engineer preparing a hot filament diamond system with 6'' silicon wafers*

Fraunhofer CLA operates a world class research and development facility in one of the primary manufacturing technology regions of the USA in the suburbs of Detroit, Michigan.

The mission of CLA is to be the leading laser applications research facility in North America.

The center has been conducting contract research and development in the field of laser materials processing for over 20 years and has built a network of high profile clients and gained a well-earned reputation as the ‘go to’ place for laser process technology development.

The main technical focus is laser materials applications development which can include processes such laser welding, cutting, drilling, cladding, micromachining and additive manufacturing.

Together with its partner institute Fraunhofer IWS, the center also develops novel laser processing equipment solutions which have resulted in several patent awards.

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 Sources
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

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.

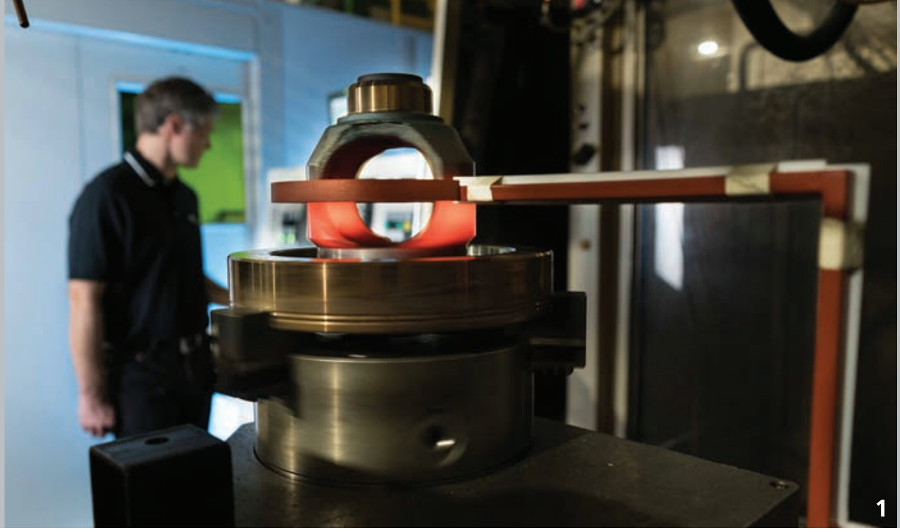
Process Monitoring

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. 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. 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.

© Fraunhofer USA, Fraunhofer CLA – laser cutting of sheet metal component



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 application developed by Fraunhofer was able to achieve drilling of up to 15,000 per second in a silicon wafer material.

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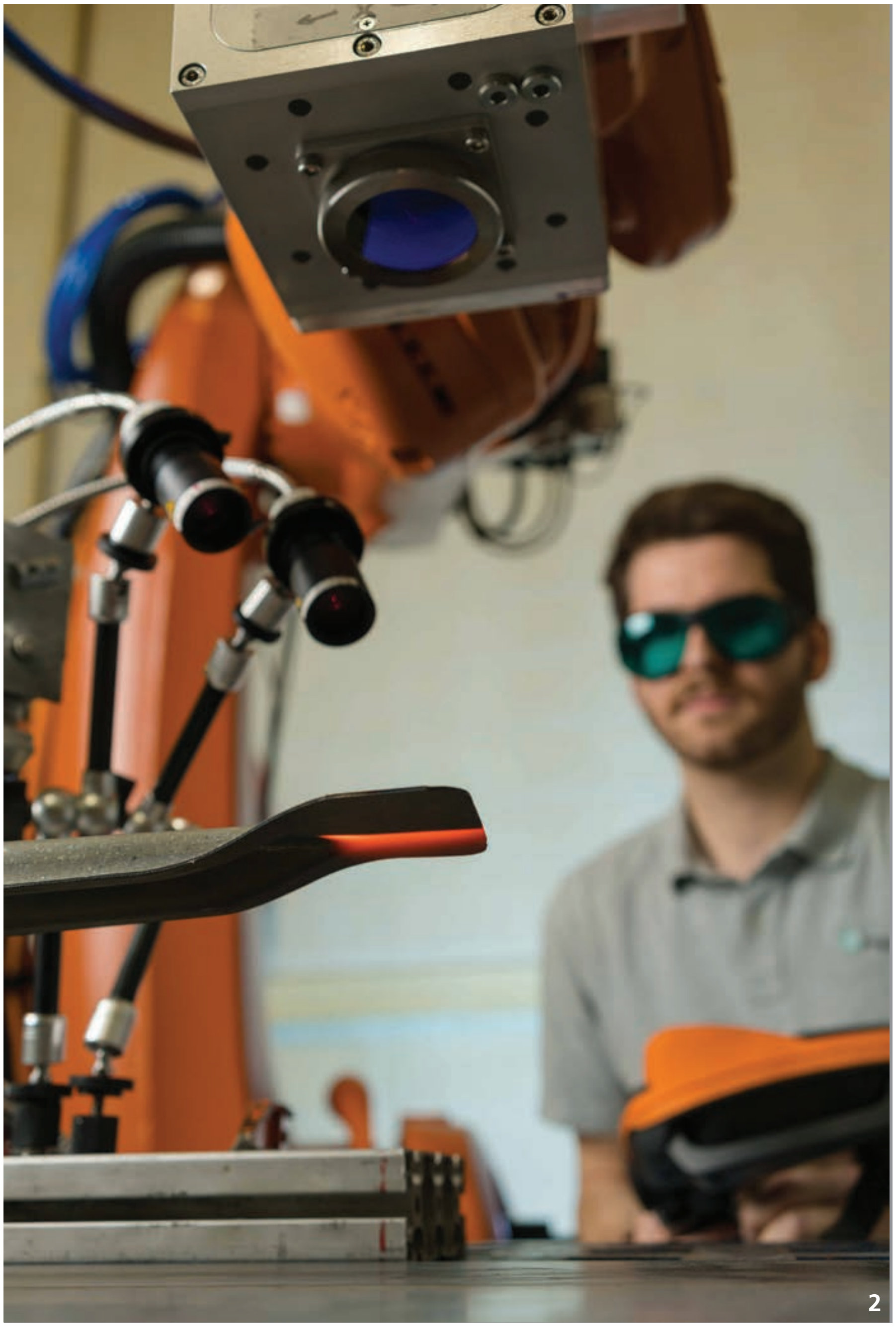

1 © *Fraunhofer USA, Fraunhofer CLA – induction heating of automotive part*

2 © *Fraunhofer USA, Fraunhofer CLA – laser heat treatment of automotive part*

FRAUNHOFER USA CENTER FOR SUSTAINABLE ENERGY SYSTEMS (CSE)

Fraunhofer CSE accelerates the adoption of sustainable energy technologies through scientific research and engineering innovation. Our 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. CSE operates out of Boston, MA, and Albuquerque, NM. With its work, the center explores ways to integrate distributed energy resources and match energy supply and demand in the 21st century electric grid.

Fraunhofer CSE Offers

Building Energy Systems

- Testing, demonstration, and evaluation of the performance of emerging building technologies in the field
- Development of building performance assessment and control algorithms to identify energy savings opportunities
- Behaviorial analysis of the impact of people on building energy consumption and adoption of sustainable energy technologies.
- Assessment of building technologies for government and industry to identify high-impact opportunities
- Building energy consumption characterization to inform policy decisions

CSE performs field testing to evaluate the performance of emerging building technologies in occupied residential and commercial buildings across the US CSE's Building Energy Systems research facilities include a data acquisition lab and a human behavior lab.

Building Enclosures and Materials

- Research and development of novel energy-efficient materials and systems
- Advanced thermal, hygrothermal modeling and laboratory testing of material properties
- Whole building energy simulations and energy consumption analysis
- Deployment, integration, and demonstration of energy-efficient building envelope technologies and materials
- Development and testing of novel building-integrated solar systems

Building Enclosures and Materials facilities include a materials lab, thermal and hygrothermal property characterization test labs, an environmental exposure research lab, and outdoor test huts in two field testing sites (Boston, MA and Albuquerque, NM).

Photovoltaic (PV) Technologies

- Module design, fabrication and prototyping
- Building integrated PV (BIPV)
- Module and material characterization
- Accelerated aging and testing
- Outdoor exposure and performance testing
- Quality analysis

Solar PV research facilities include a PV module fabrication lab, PV durability lab, a rooftop mock up, outdoor test sites in Revere, MA, and Albuquerque, NM, and a building integrated photovoltaics (BIVP) lab.

© Fraunhofer USA, Fraunhofer CSE – adhesive mounting of lightweight solar photovoltaic (PV) modules

Grid Integration (Distributed Energy Resources)

- System design and feasibility assessment for deployment of distributed energy resources
- Field and laboratory testing, validation, and demonstration support of power conversion, smart grid, and distribution automation technologies
- Data acquisition, monitoring, and control solutions for integrated energy systems in both real-world and laboratory contexts
- Policy and technology assessment of systemic impacts of renewable generation, distributed energy resources, and smart grid technologies

Grid Integration research facilities include a resilient power grid lab, an experimental microgrid site, and a software laboratory for the operations and maintenance of renewables.

Fraunhofer TechBridge Program – Technology Commercialization

Launched at CSE in 2010, the Fraunhofer TechBridge Program provides an open innovation and technology validation platform for investors and industry sponsors. Conducting targeted technical searches in TechBridge Challenges, the program identifies and de-risks promising technologies, leveraging the extensive resources of CSE and the greater Fraunhofer network, including the Fraunhofer Energy Alliance.

At the core of TechBridge is the design and execution of development and demonstration projects that:

- Optimize and test prototypes
- Provide third-party validation
- Perform field demonstrations
- Evaluate manufacturability

Funding for TechBridge projects is provided directly by public and private sector sponsors to make Fraunhofer projects accessible to startups.

TechBridge runs "TechBridge Challenges" for our partners to perform technical validation projects that prepare the startup(s) for partnership and provide the sponsor with actionable information about the latest innovations in relevant areas.

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1 © *Fraunhofer USA, Fraunhofer CSE – climate chamber for photovoltaic (PV) module and material testing*

2 © *Fraunhofer USA, Fraunhofer CSE – weathering chamber for photovoltaic (PV) module and material testing*

FRAUNHOFER USA CENTER FOR EXPERIMENTAL SOFTWARE ENGINEERING (CESE)

Fraunhofer CESE conducts applied research to support the software-enabled innovations created by our customers in industry, government, and academia. 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; CESE evaluates, develops, and utilizes cutting-edge tools and technologies to support customer decision-making and implementation in systems, software, and acquisition areas. 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, CESE also conducts innovative basic research projects under research grants funded by the government and other research institutions.

Fraunhofer CESE Offers

Model-Based Development and Testing

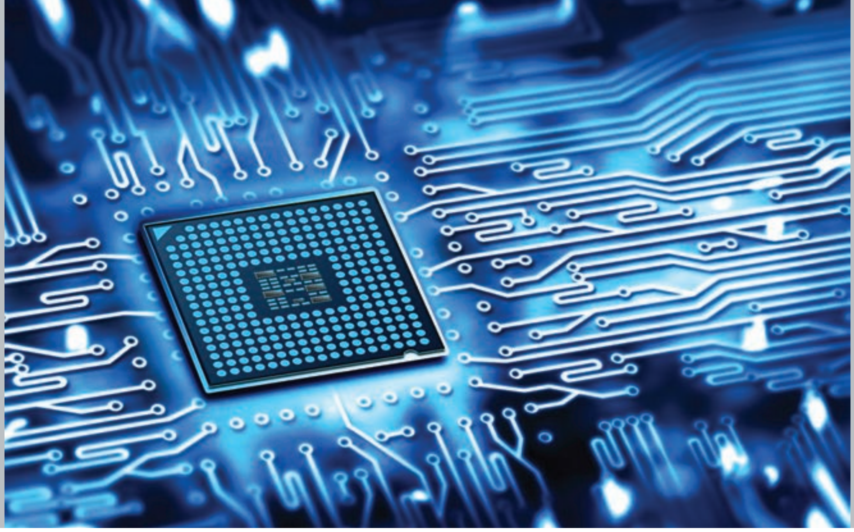
- Use analysis tools to automatically extract and visualize software architecture in source code
- Evaluate software architecture to locate policy deviations
- Create software architecture design models to generate test cases, analyze test results, and conduct code inspections
- Reverse-engineer models 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 & Analytics

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

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FRAUNHOFER USA CENTER FOR MOLECULAR BIOTECHNOLOGY (CMB)

Fraunhofer CMB is a unique institution conducting research and development in the areas of plant and microbial biotechnology. Established in 2001 as a partnership with the state of Delaware, CMB contains the complete range of capabilities from process development, characterization, cGMP manufacturing, quality control, testing and regulatory approval necessary to develop vaccines, therapeutics and diagnostics to address human health issues.

The Center's diverse staff has expertise in plant virology, molecular biology, plant biology, biochemistry and immunology, with core research groups specializing in expression technologies, protein target design, plant tissue culture, engineering and biomass production, downstream processing and analytical biochemistry, immunology and formulation. CMB has continued to improve its core technology for transient gene expression and an application to the development of new products.

CMB occupies a 56,000 square feet facility, of which approximately 14,000 square feet is dedicated to a facility to produce material under cGMP for early phase clinical trials. The building contains the complete range of equipment to provide protein production services from target expression to final product including quality assurance, quality control and regulatory management.

CMB has moved targets from molecular engineering through to pilot scale manufacturing in plants under good manufacturing practices. The center's approach has been validated by the successful completion of five phase 1 clinical trials.

In 2011, the University of Delaware, joined the partnership, adding their strong complement of life-sciences core instrumentation centers. Many of these centers are located at the Delaware Biotechnology Institute, directly adjacent to CMB. These instrumentation centers include state-of-the-art facilities for bioimaging, sequencing and genotyping, proteomics, bioinformatics and others. The partnership has resulted in a number of collaborative research projects including work on novel carrier molecules and development of poultry vaccines against avian influenza.

Fraunhofer CMB Offers

- Research and development
- GMP manufacturing
- Quality
- Regulatory support

Research and Development

CMB's scientific staff, with expertise in diverse fields, including recombinant protein production and molecule discovery, combined with our state-of-the-art infrastructure and equipment, well positions the Fraunhofer Center for Molecular Biotechnology to provide R & D services including:

- Proof of concept
- Process development
- Formulation development
- Analytical services
- Preclinical evaluation

© Fraunhofer USA, Fraunhofer CMB – GMP purification

GMP Manufacturing
Fraunhofer CMB's GMP bioprocessing facility is a validated Phase I and II compliant facility for the production of biopharmaceuticals using a plant based expression platform which has been licensed to Fraunhofer USA. The GMP manufacturing facility yields gram quantities of target proteins.

The facility consists of a class 100,000 fermentation suite and buffer preparation suite, a class 10,000 purification suite, and other controlled but non-classified areas. The key processing areas in the pilot plant include:
- Plant growth
- Fermentation
- Infiltration and protein accumulation
- Tissue harvesting
- Protein purification
- Fill and finish

Quality
CMB's quality department consists of fully staffed Quality Assurance (QA) and Quality Control (QC) groups with trained personnel experienced in cGMP compliance. QC/QA capabilities include:
- Product release testing
- Product stability testing
- Document control system
- Batch record review
- Product release
- Internal / external auditing
- Review and approval of standard operating procedures (SOP)
- Ongoing validation

Regulatory Support
As a full capability service provider, CMB also has in-house expertise to facilitate regulatory approval for taking potential products to the clinic, including preparing all regulatory packages to obtain approvals and permits including FDA approval for conducting Phase I and Phase II clinical trials.

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1 © *Fraunhofer USA, Fraunhofer CMB – GMP microbial fermentation*
2 © *Fraunhofer USA, Fraunhofer CMB – GMP facility growth units*

FRAUNHOFER USA CENTER FOR ENERGY INNOVATION (CEI)

Fraunhofer CEI in Storrs, Connecticut conducts applied research and development in energy and materials related technologies. Partner University is the University of Connecticut (UConn), Partner Institute is the Fraunhofer Institute for Ceramic Technologies and Systems (IKTS) in Dresden, Germany. CEI develops advanced technologies for clean and efficient energy conversion (e.g.: fuel cell technologies), large scale energy storage, and power distribution for urban applications. Another area is water reclamation from waste streams using ceramic membrane filtration systems. The use of ceramic membranes in water filtration offers potential for a wide range of industrial applications ranging from laundry, dairy, and water clean-up in many other areas yet to be explored and understood. After a change in management in 2017 CEI is currently reviewing its activities and strategic targets.

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Developing glass compositions

FRAUNHOFER USA OFFICE

Fraunhofer USA Digital Media Technologies (DMT) promotes and supports the audio and media technologies of Fraunhofer IIS in the United States.

When it comes to advanced audio and video technologies for the rapidly evolving media world, the Fraunhofer Institute for Integrated Circuits (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.

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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 capabilities 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, located on the university's Charles River campus.

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

By sharing logistic and intellectual resources, our affiliations have fostered cooperative relationships and have expanded the capabilities of all parties involved. The process of turning research innovations into functional products that can serve real societal needs is chaotic and lengthy. Innovative ideas often linger too long in the research phase. The BU – Fraunhofer Alliance for Medical Devices, Instrumentation and Diagnostics was created to accelerate the development and deployment of medical innovation from the laboratory to the patient point-of-care. Working closely with the principal investigators, CMI engineers develop these ideas into functional instruments and devices that can attract investment from VC's for a new venture creation or be licensed to existing companies in their space. This program is funded jointly by Fraunhofer and Boston University

University of Maryland: The Fraunhofer USA Center for Experimental Software Engineering (CESE) has collaborated with the University of Maryland since 1997.

In mutual acknowledgement of the benefits derived from their long-term strategic partnership, the University of Maryland, College Park (UMD) and Fraunhofer USA renewed their 5-year Memorandum of Understanding. The MOU serves to reinforce the strategic working relationship between the institutions and sets the stage for new opportunities to jointly perform advanced scientific research in all areas supported by systems and software engineering. The MOU addresses a wide span of topics that govern the strategic relationship and encourages further collaboration, including: Increasing access to each other's experts; expanding joint research through support for UMD researchers; providing unique internship opportunities for UMD students, and clarifying financial support commitments and rules on the ownership and use of intellectual property.

Operating under this MOU, CESE, located in the University's M Square Research Park, will work with UMD researchers and university affiliates to provide software engineering support for multiple ongoing projects including brain imaging control software, tracking infectious disease transmission, rapidly assessing the threats posed by new synthetic gene sequences, providing foreign language instruction using mobile devices, among many others. These projects are funded by a diverse group of federal agencies – DoD, DARPA, IARPA, NIH, etc. – that are increasingly interested in leveraging advanced IT methods and approaches to solve complex, interdisciplinary problems. CESE is also pursuing both new and follow-on research projects in collaboration with UMD promising increased cooperation with UMD well into the future. In addition to its ongoing work with researchers in the University's College of Computer, Mathematical and Natural Sciences, UM's School of Engineering is a new partner to this collaboration and seeks to work with CESE on a range of engineering topics.

Michigan State University: Since 2003, the Fraunhofer USA Center for Coatings and Diamond Technologies (CCD) and Michigan State University (MSU) have closely collaborated on applied research and development projects in the areas of diamond and coatings technologies. MSU frequently ranks among the top 30 public universities in the United States, and the top 100 research universities in the world. In April 2017, MSU's Board of Trustees authorized the administration to proceed with the project entitled »Engineering Research Complex – Addition and Renovations (Fraunhofer Center Expansion)«, with a project budget of $6.4 million. CCD, in collaboration with Michigan State University and its College of Engineering, provides innovative research and development services based on its expertise in coatings and diamond technology. This collaboration has recently been expanded to support advanced scientific research in coatings, diamond electronics, and other diamond applications. This expansion will provide additional opportunities for internships, work-study, and other educational programming for MSU students. It will also contribute to the economic development of Michigan. To support this enhanced collaboration, the center will need more and improved space at the Engineering Research Complex. The Engineering Research Complex is located on Engineering Research Court in the south academic district. The project will convert space in the Engineering Research Complex (ERC) to build a laboratory addition with minor office upgrades elsewhere in the building. The project will also upgrade existing electrical service, and consolidate chillers, increasing energy efficiency and allowing space to be better used.

University of Delaware: The Fraunhofer USA Center for Molecular Biotechnology (CMB) partners with the University of Delaware (UD) to expand the innovation pipeline by enhancing technology and product development activities. UD is classified as a research university with very high research activity by the Carnegie Classification of Institutions of Higher Education. CMB's partnership with UD provides access to core facilities and capabilities amounting to $1.5 million as an in-kind contribution per year. The agreement between CMB and UD has been amended to extend the partnership to 2022. Under this partnership agreement CMB's scientists continue working closely with the UD faculty on multiple joint projects. CMB continues to enjoy benefits of access to UD's core facilities.

University of Connecticut: The Fraunhofer USA Center for Energy Innovation (CEI) was founded in 2013 in partnership with the State of Connecticut-Department of Energy and Environmental Protection (DEEP), the University of Connecticut (UConn), and Fraunhofer USA. CEI's research facility is located in Storrs, Connecticut on the campus of UConn. CEI conducts applied research and development in the field of ceramic based technologies for materials and energy systems and environmental sustainability in collaboration with the Fraunhofer Institute for Ceramic Technologies and Systems (IKTS) in Dresden and Hermsdorf, Germany, and the Department of Engineering at UConn.

Currently, CEI is streamlining its strategy under its new management to strengthen its portfolio in advanced technologies for clean and efficient energy conversion, large scale energy storage, power management and distribution, and filter technologies. CEI will offer even better technology development and validation services to industry and commercial enterprises in the years to come.

Other University Joint Projects:

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

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

State Support and Collaborations

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

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

Fraunhofer Partnerships and Cooperation

Fraunhofer Centers in the U.S. and their Parent Fraunhofer Institutes in Germany

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

Fraunhofer USA centers also work and collaborate with other partners within the 69 institutes and research units network of Fraunhofer-Gesellschaft in Germany.

Fraunhofer USA, Inc.

Balance Sheet
As of December 31, 2016

Assets	
Current Assets	
Cash and Cash Equivalents	$ 15,799,987
Accounts Receivable	6,487,408
Investments	672,709
Prepaid Expenses and Other Current Assets	969,865
Total Current Assets	23,929,969
Property and Equipment - Net	45,159,039
Intangible Assets	273,849
Long-Term Receivable	1,782,672
Total Assets	$ 71,145,529
Liabilities and Net Assets	
Current Liabilities	
Accounts Payable	$ 991,342
Deferred Revenue	1,556,203
Accrued Liabilities and Other	18,851,712
Total Current Liabilities	21,399,257
Long-Term Obligation	15,651,959
Total Liabilities	37,051,216
Net Assets	
Unrestricted	
Undesignated	2,478,769
Increase (Decrease) in Undesignated Assets	1,287,803
Designated	29,871,196
Decrease in Designated Assets	(823,038)
Temporarily Restricted	
Temporarily Restricted	2,641,759
Decrease in Temporarily Restricted Assets	(1,362,176)
Total Net Assets	34,094,313
Total Liabilities and Net Assets	$ 71,145,529

Fraunhofer USA, Inc.

Statement of Activities and Changes in Net Assets
Year Ending December 31, 2016

Contract Revenue	
Industry	$ 8,522,233
Government & Universities	11,368,172
Fraunhofer Institutes	2,730,692
Miscellaneous	130,367
Total Contract Revenue	22,751,464
Support	
Base Funding	11,853,763
In-Kind Contributions	3,764,858
Other	724,407
Total Support	16,343,028
Funds Released from Restrictions	1,691,452
Total Undesignated Revenue, Support and Released Funds	40,785,944
Labor Costs	21,546,291
Undesignated Other Expenses	
Administrative Expenses	11,743,548
Cost of Goods Sold - Excluding Labor	5,904,916
Depreciation and Amortization	303,386
Total Undesignated Other Expenses	17,951,850
Total Labor Costs and Undesignated Other Expenses	39,498,141
Increase (Decrease) in Undesignated Assets	1,287,803
Undesignated Net Assets	2,478,769
Designated Revenue	1,664,376
Designated Expenses	(2,487,414)
Decrease in Designated Assets	(823,038)
Designated Net Assets	29,871,196
Temporarily Restricted Revenue	329,276
Funds Released from Temporary Restriction	(1,691,452)
Decrease in Temporarily Restricted Assets	(1,362,176)
Temporarily Restricted Net Assets	$ 2,641,759

OUTLOOK

Though it is too early to draw conclusions on the trends in federal funding for research and development, first indications are that support for science and technology will remain at a commensurate level. The technology and production foundations of the US economy are still strong.

In particular, applied R & D to strengthen manufacturing in the United States is expected to increase. Cyber-Physical systems and the digitization of production capabilities (see Industrie 4.0, Manufacturing USA Institutes) are driving a US manufacturing renaissance. Digitized manufacturing promises to drive energy and resource efficiency, enables tailored large-scale production of customized unique products and a more circular economy.

Fraunhofer USA translates applied research into technologies and provides services of technology validation to the industrial community in the US. Together with our institutes in Europe we also offer transatlantic partnerships in leading technologies. Our centers enable industrial customers to keep pace with the most modern trends and applications as the US continues to attract innovative companies from industries around the world.

We look forward to partnering with industry to drive technology-based economic growth in the United States. The outlook is good.

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Executive Vice President Technology Marketing and Business Models, Fraunhofer-Gesellschaft e.V.

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