MATERIALS SCIENCE & ENGINEERING
at Duke University

2020 ANNUAL REPORT
"The holy grail of materials science has long been to be able to understand and predict all physical properties of a material based on composition and processing."

**Cate Brinson**
Donald M. Alstadt Chair and Sharon C. & Harold L. Yoh, III Distinguished Professor, Thomas Lord Department of Mechanical Engineering & Materials Science
## Contents

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welcome</td>
<td>5</td>
</tr>
<tr>
<td>Investing in Materials Science &amp; Engineering</td>
<td>6</td>
</tr>
<tr>
<td>External Research Support</td>
<td>7</td>
</tr>
<tr>
<td>Collaborations</td>
<td>8</td>
</tr>
<tr>
<td>Soft Matter &amp; Biomaterials</td>
<td>10</td>
</tr>
<tr>
<td>Energy Materials</td>
<td>12</td>
</tr>
<tr>
<td>Computational Materials</td>
<td>13</td>
</tr>
<tr>
<td>Metamaterials</td>
<td>14</td>
</tr>
<tr>
<td>Electronics, Photonics &amp; Quantum Materials</td>
<td>15</td>
</tr>
<tr>
<td>Sustainable Materials</td>
<td>16</td>
</tr>
<tr>
<td>Materials Science &amp; Engineering Education</td>
<td>17</td>
</tr>
</tbody>
</table>
#12 national university

TOP 15 U.S. research medical school

TOP 25 U.S. graduate engineering school

60 faculty members from 9 university departments
Welcome to the Duke Materials Initiative!

FROM HARVESTING green energy economically, to securing cyberspace, to developing more effective medical treatments, the world today faces grand challenges in which new and fundamentally improved materials will play an essential role. We established the Duke Materials Initiative (DMI) to create these materials through bold and transformative advances in materials science and engineering that are only possible when we cross and extend beyond the boundaries of traditional departmental disciplines. DMI harnesses Duke’s distinct combination of paradigm-shifting education, interdisciplinary expertise in technical and societal disciplines, and advanced experimental and computational tools to foster innovation and sustained excellence.

DMI builds on collaborative practices cultivated over the past decade through inter-university materials research programs centered at Duke and supported by over $53 million in federal grants. In addition, DMI leverages shared resources, such as the Duke Shared Materials Instrumentation Facility, and collaborates with other Research Triangle-based institutions, including North Carolina State University and the University of North Carolina at Chapel Hill, through the NSF-funded Research Triangle Nanotechnology Network.

In this inaugural annual report, we introduce you to the people and the work of our diverse, vibrant and interdisciplinary community of materials scientists, engineers and educators. Thank you for your interest in learning more about the work and achievements of the Duke Materials Initiative. We invite you to contact and engage with us.

Sincerely,
Stefan Zauscher
Director, Duke Materials Initiative
DUKE UNIVERSITY continues to deepen its research strength with new faculty hires. Among them are internationally respected thought leaders at the forefront of materials research and innovation:

NEW FACULTY  [ hired since 2017 ]

Gaurav Arya  
Associate Professor of Mechanical Engineering & Materials Science

Matthew L. Becker  
Hugo Blomquist  
Distinguished Professor of Chemistry

Cate Brinson  
Donald M. Alstادt Chair and Sharon C. & Harold L. Yoh, Ill Distinguished Professor, Thomas Lord Department of Mechanical Engineering & Materials Science*

Po-Chun Hsu  
Assistant Professor of Mechanical Engineering & Materials Science

Natalia Litchinitser  
Professor of Electrical & Computer Engineering

Christine Payne  
Yoh Family Associate Professor of Mechanical Engineering & Materials Science

Michael Rubinstein  
Aleksander S. Vesic Distinguished Professor of Mechanical Engineering & Materials Science, Professor of Biomedical Engineering, Physics and Chemistry; MEDx Investigator**

Christoph Schmidt  
Hertha Sponer Distinguished Professor of Physics

Tatiana Segura  
Professor of Orthopaedic Surgery, Biomedical Engineering and Mechanical Engineering & Materials Science; MEDx Investigator**

Shyni Varghese  
Professor of Orthopaedic Surgery, Biomedical Engineering and Mechanical Engineering & Materials Science; MEDx Investigator**

NEW BUILDING

$115M Construction Costs
150K Square Feet
35 Lab Modules
+50% Expansion of Engineering Student Space

“The new engineering building is central to Duke’s vision for the future. In our strategic plan we emphasize the importance of creating strong intellectual communities, and this space represents a real hub where faculty and students can congregate and work together on important issues. We’re also investing heavily in science and technology, and the engineering building offers us a wonderful avenue to help attract the best and brightest faculty and students in those fields to move with Duke into the future.”

Sally A. Kornbluth  
Provost of Duke University

*As of Fall 2020, renamed the Thomas Lord Department of Mechanical Engineering & Materials Science.

** MEDx Investigators have joint primary appointments in the Schools of Medicine and Engineering.
Fifteen Duke Materials Scientists, Engineers and More Than $7 Million in NSF DMREF Awards

“Designing Materials to Revolutionize and Engineer our Future” (DMREF) is the primary program by which the National Science Foundation participates in the Materials Genome Initiative for Global Competitiveness, or MGI. MGI recognizes the importance of materials science and engineering to the well-being and advancement of society and endeavors to accelerate development and deployment of advanced materials at a fraction of the cost. Fifteen Duke materials scientists and engineers have active or recently completed major interdisciplinary projects funded by more than $7 million from this highly competitive award program. They include experts in computation, soft matter, biomaterials, metamaterials, photonics, energy, physics and chemistry. In addition, these projects draw talented students who wish to gain practical lab experience while training to become leaders in the next generation of materials science and engineering.

Predicting and Designing Nanoscale Building Blocks for Assembly into Mesoscale Architectures

Duke University’s Gaurav Arya has won a National Science Foundation Materials Research Science and Engineering Center (MRSEC) award in conjunction with colleagues at the University of California San Diego. His portion of it ($600,000 over six years) is in “predictive assembly.” He and his team will build new computational tools for understanding, predicting and designing nanoscale building blocks composed of engineered proteins and nanocrystals that dynamically assemble into complex mesoscale architectures with novel and emergent properties.

Filling an AI and Materials Science Training Gap

The $3 million, five-year, NSF-funded research training grant, AI for Understanding and Designing Materials (aiM), led by Cate Brinson, director, in collaboration with fellow Duke materials scientists, plus experts in computer science, mathematics and statistics, will fill a vital workforce gap in the new convergent field of materials and computer science research. It will train 50 PhD students total at the nexus of AI and materials.

Transforming Polymer and Materials Chemistry

The NSF-funded Center for the Chemistry of Molecularly Optimized Networks (MONET), led by Duke and featuring prominent chemists from MIT and Northwestern, is developing an open polymer network database, training future scientists and driving innovation. Stephen Craig, director, and Michael Rubinstein are among the five founding members. MONET is transforming polymer and materials chemistry by developing the knowledge and methods to enable molecular-level, chemical control of polymer network properties.

Medically relevant active material: stem-cell derived cardiomyocyte with fluorescent z-bands.

Duke materials scientists attract significant competitive research funding each year. Shown here are some of our most recent awards. For more information, please visit dmi.duke.edu.
COLLABORATION is our core strength. The Duke Materials Initiative was created to enable the necessary bold, innovative and transformative materials science and engineering advances that are only possible when extending beyond the boundaries of traditional disciplines.
A Duke researcher uses a photomask aligner in the photolithography process to pattern microscale features onto a substrate in the Shared Materials Instrumentation Facility (SMIF) cleanroom.

Duke University Shared Materials Instrumentation Facility (a core facility of RTNN)

SMIF is the Duke Nanotechnology core facility that enables materials, devices and integrated systems research in a variety of fields that includes fabrication and characterization shared equipment for nanotechnology, biomaterials and biomedical engineering, optoelectronics, sensor technology, and renewable energy.

All trained students, staff, faculty and researchers have access to 7,000 sq. ft. of clean room fabrication space and nearly 3,000 sq. ft. of specialized lab space for characterization and imaging equipment. The SMIF bio-bay was one of the first bio-bays integrated into a cleanroom in the nation and provides a unique capability for the integration of biotechnology with semiconductor, sensing and photonic devices and systems.

Capabilities include: electron microscopy (SEM, ESEM, TEM and Cryo-TEM), MicroCT imaging, atomic force microscopy (AFM), X-ray photospectroscopy (XPS), X-ray diffraction (XRD), optical characterization (Raman/PL, FTIR, and UV-Vis) and the Triangle Small Angle X-Ray Scattering (SAXS) facility, as well as back-end processing and sample preparation, including lapping and polishing, dicing, wire bonding, sputter coating, critical point drying and cryo sample preparation.

Research Triangle Nanotechnology Network

RTNN, is one of 16 nanotechnology university sites nationwide that comprise the National Science Foundation-sponsored National Nanotechnology Coordinated Infrastructure (NNCI) program. A partnership between North Carolina State University, Duke University and the University of North Carolina at Chapel Hill, RTNN includes eight open-access nanofabrication and materials characterization facilities with 230+ tools across 33,000 sq. ft. of space. More than 30 expertly trained staff assist in supporting and advancing basic materials research at the nanoscale, as well as development and commercialization of innovative nanotechnologies. NSF recently renewed the RTNN $5.5-million, five-year grant.

Duke MEDx

MEDx (Medicine + Engineering at Duke) enhances existing ties and fosters new interdisciplinary collaborations between the School of Medicine and Pratt School of Engineering. It creates research opportunities between physicians, engineers, computer scientists, researchers and innovators, as well as trains the next generation. MEDx Investigators have joint primary appointments in the Schools of Medicine and Engineering.

Duke Energy Initiative

The Duke University Energy Initiative is a university-wide interdisciplinary collaboration focused on advancing an accessible, affordable, reliable and clean energy system. Faculty in engineering, the sciences, environment and other Duke schools are developing innovative applications of energy materials and pooling resources and expertise to demonstrate materials solutions for cost-competitive, stable, clean and equitable energy supply.
DUKE IS HOME to a diverse and influential science and engineering research community focusing on soft materials, polymers and biomaterials. They are pioneering the molecular design of soft materials, nanomaterials, immune-active materials, scaffolds for tissue engineering and basic investigations into the complex mechanisms by which materials engage biology. Interests also include the design of “smart” biomolecular nanostructures, characterization of soft-wet materials on surfaces and interfaces, biomolecular sensors, and biointerfaces. Here are highlights from only a few of our researchers. For a complete listing of all faculty who work in Soft Matter & Biomaterials, visit dmi.duke.edu/research/soft-matter-biomaterials.

Leading Interdisciplinary Soft Matter Activities Internationally
The Duke Soft Matter Center facilitates research and educational programs and collaborations between faculty in Duke’s Pratt School of Engineering, the Trinity College of Arts & Sciences Departments of Chemistry, Physics, Biology and Mathematics, and Cell Biology in the Duke School of Medicine. Led by Michael Rubinstein, it fosters an environment for multi-investigator, interdisciplinary center grant proposals, while also building sponsor and industrial connections. As home to the Soft Matter Working Group of the International Union of Pure and Applied Physics, it coordinates and leads soft matter activities spanning the globe, as well as efforts at the national and local levels.

Michael Rubinstein
Aleksander S. Vesic
Distinguished Professor of Mechanical Engineering & Materials Science, Professor of Biomedical Engineering, Physics and Chemistry, 2019 Royal Society Chemistry Soft Matter and Biophysical Chemistry Award; Research cited over 25,000 times; Director, Duke Soft Matter Center, MEDx Investigator

Building Tools and Concepts to Understand Active Materials in Biology
Applying traditional and new tools of physics, materials science, cell and molecular biology to investigate biological and soft materials, Christoph Schmidt’s lab conducts experiments to understand the physical functions of systems ranging from single molecular motors, polymer networks, the cell cytoskeleton, to bacteria, single heart muscle cells, tissues and developing fruit flies. Current work especially focuses on non-equilibrium materials and mechanosensory mechanisms. His work with colleagues in engineering and medicine advances basic understanding of soft and biological materials, and has the potential to fuel advancements in medical technology.

Christoph Schmidt
Hertha Sponer Distinguished Professor of Physics Fellow, APS

Accelerating Bone Repair by Engineering Bandages That Trap the Body’s Own Healing Biochemicals
Shyni Varghese’s lab designed a biomaterial bandage to apply directly to broken bone that contains boronate molecules. It traps the body’s natural surge of adenosine, which promotes healing following an injury, and keeps it near the site to accelerate bone repair. Advanced Materials, 2019 DOI: 10.1002/adma.201906022

Shyni Varghese
Professor of Orthopaedic Surgery, Biomedical Engineering and Mechanical Engineering & Materials Science, MEDx Investigator

A sketch of the cell cytoskeleton as an active material from the Schmidt lab showing how motor proteins (brown) travel on microtubules (green), which are vigorously and randomly moved by actin filaments (red) that, in turn, are activated by myosin motors. Both movements can be tracked in living cells using single-walled carbon nanotubes (white) as fluorescent labels. DOI: 10.1126/science.1250170
Addressing Unmet Needs in Medicine With Organic Materials
The Becker Laboratory for Functional Biomaterials is a multidisciplinary organic materials group working at the interface of chemistry, organic materials and medicine. It is developing families of degradable polymers with highly tunable physical and biological properties that are being applied to unmet needs in bone, soft tissue, neural and vascular tissue engineering. It also actively engages in additive manufacturing and the development of custom inks that are enabling unique solutions to challenging design paradigms in biomaterials and drug delivery.

Matthew L. Becker
Hugo L. Blomquist
Distinguished Professor of Chemistry, Carl S. Marvel Award in Creative Polymer Chemistry, Fellow, ACS, AIMBE, RSC

Building Tools and Concepts Creating Cartilage-Mimicking Hydrogel Strong Enough for Knees
Led by Duke chemistry and materials scientists Benjamin Wiley and Ken Gall, a team of researchers have created an experimental gel that’s the first to match the strength and durability of cartilage. The materials made of water-absorbing polymers could one day offer an alternative to the 600,000 knee replacement surgeries performed annually in the U.S. Advanced Functional Materials, 2020 DOI: 10.1002/adfm.202003451

Benjamin Wiley
Professor of Chemistry, Top 1% of Highly Cited Researchers (Clarivate)

Ken Gall
Professor of Mechanical Engineering & Materials Science, Associate Dean for Engineering Entrepreneurship

Developing Chemotherapeutic Platforms from Polymerized Nucleotides
Funded by an NIH Trailblazer grant, the Zauscher and Chilkoti labs collaborate on developing anti-cancer and antiviral chemotherapeutic platforms derived entirely from polymerized nucleotides. Their “one-pot” enzymatic reaction approach offers a new, dramatically simplified and innovative route for the design and synthesis of micellar “all nucleotide” drug delivery platforms.

Stefan Zauscher
Professor of Mechanical Engineering & Materials Science and Director, Duke Materials Initiative, Fellow AVC, NIH Trailblazer Award

Ashutosh Chilkoti
Alan L. Kaganov Distinguished Professor and Chair, Professor of Biomedical Engineering, Fellow, AAAS, AIMBE, IUSBE Member, National Academy of Inventors

Engineering Materials for Brain and Skin Repair
With more than $6 million total from three NIH R01 grants, Tatiana Segura is exploring how to use biomaterials to harness the body’s own immune system to heal damaged brain tissue after stroke and skin tissue after injury. The materials will thicken and mimic surrounding brain tissue, providing a scaffold to support growth of new neurons and blood vessels into the cavity; create new blood flow to the brain; and promote skin wound regeneration without inflammation.

Tatiana Segura
Professor of Biomedical Engineering, Professor of Neurology, MEDx Investigator Fellow, AIMBE, 2020 Acta Biomaterialia Silver Medal Award

Pioneering Engineered Nanoparticles to Deliver Cancer Treatment Without Debilitating Side Effects
Jennifer West’s lab pioneered the use of nanoparticles in advancing cancer diagnostics and therapeutics with some of the very first publications in engineered nanoparticles, as well as clinical translation of nanoshells for cancer therapy. The AuroLase Therapy—using gold nanoparticles to heat and destroy tumors, co-invented by West—has shown positive results in an ongoing multi-site clinical trial among prostate cancer patients, without the debilitating side effects associated with chemotherapy, invasive surgery and radiation. PNAS, September 10, 2019 DOI: 10.1073/pnas.1906929116

Jennifer West
Fitzpatrick Family University Distinguished Professor of Engineering Member, National Academy of Engineering and National Academy of Inventors

Taking a Crack at the Glass Problem
Patrick Charbonneau and colleagues recently managed to quantitatively match simulation results with a leading theoretical description to understand glass transition. Although only achieved in high spatial dimension, it nonetheless highlights a robust pathway toward finding a solution. Physical Review Letters, 2020 DOI: 10.1103/PhysRevLett.125.108001

Patrick Charbonneau
Associate Professor of Chemistry
WHETHER DEVELOPING new materials for energy devices, using new techniques to build more efficient energy systems, or imagining new applications for existing technologies, Duke researchers capitalize on a depth and range of expertise and strong interdisciplinary collaboration. Here are highlights from only a few of our researchers. For a complete listing of all faculty who work in Energy Materials, visit dmi.duke.edu/research/energy-materials.

Leading National Effort to Explore Novel Uses and Properties of an Emerging Class of Materials to Accelerate Development of Renewable Energy
Three Duke engineers are working in the $11.75-million U.S. Department of Energy Center for Hybrid Organic-Inorganic Semiconductors for Energy (CHOISE) led by the National Renewable Energy Laboratory (NREL), aimed at exploring novel uses and properties of an exciting class of hybrid semiconductors for future energy technologies. David Mitzi and Adrienne Stiff-Roberts lead Thrust 1, “Crystalline Hybrid Semiconductor Design, Synthesis, and Structure/Property Relationship”, to achieve novel physical behaviors, high-quality crystal/films, characterization and building of nanostructured components with unique functionality. Volker Blum, head of Duke’s Ab Initio Materials Simulations Group and HybriD³, provides computational materials expertise to this effort.

HybriD³: Accelerating the Design, Discovery and Dissemination (D3) of New Crystalline Organic-Inorganic Semiconductors Controlled at the Atomic Scale
Six teams of researchers at three major universities in North Carolina’s Research Triangle—Duke, University of North Carolina Chapel-Hill and NC State University—contribute to this NSF-funded HybriD³ project led by Volker Blum. The group carries out a computational, synthetic and spectroscopic exploration of the materials space of hybrid semiconductors, including an open, community-focused database of existing, predicted and newly synthesized hybrid materials and their properties.

Engineering Nanostructured Materials to Keep You Cool
Part of a string of recent hires focusing on wearable technology, Po-Chun Hsu develops nanofabricated materials with tailored heat transmission properties for applications ranging from walking down the street to walking on Mars. He developed a nanoporous polyethylene textile that is breathable and scatters visible light but is completely transparent to thermal radiation. His group at Duke is taking steps further to fabricate the dynamic thermal textile that can expand the users’ adaptability to ambient temperature change.

David Mitzi
Simon Family Distinguished Professor, Mechanical Engineering & Materials Science
2020 ACS National Award for Chemistry of Materials
Top 1% of the world’s most highly cited researchers (Clarivate Analytics)

Adrienne Stiff-Roberts
Jeffrey N. Vinik Professor of Electrical & Computer Engineering

Volker Blum
Associate Professor of Mechanical Engineering & Materials Science
Leader of HybriD³ NSF-DMREF Collaborative Project

Po-Chun Hsu
Assistant Professor of Mechanical Engineering & Materials Science
RESEARCHERS AT DUKE are accelerating discoveries of materials for tomorrow’s technologies by combining theoretical models and experimental data with machine learning to generate “recipes” for promising new materials compounds. This work drives discovery of materials for sustainable energy, medical devices and more. Here are highlights from only a few of our researchers. For a complete listing of all faculty who work in Computational Materials, visit dmi.duke.edu/research/computational-materials-science.

Data-Driven Discovery of Polymers
A $5-million NSF-funded nationwide collaboration, called the NanoMine, is spurring data-driven discovery of new polymer nanocomposites and metamaterials. Led by Cate Brinson, it is populating a searchable database with curated literature data on composition, processing, structure and properties of nanocomposites. This enables design of performance materials via a suite of data, analytic and physical computational tools.

Cate Brinson
Donald M. Alstadt Chair and Sharon C. & Harold L. Yoh, III Distinguished Professor, Thomas Lord Department of Mechanical Engineering & Materials Science

Searching for Safer, More Efficient Rechargeable Batteries
Olivier Delaire’s group, using data from experiments at Oak Ridge and Argonne National Laboratories, ran quantum simulations of the atomic behavior of superionic crystals containing CuCrSe2 to determine how the material’s copper ions achieve liquid-like properties while still a solid. Their findings provide clues to the behavior of similar materials in future electronic applications. Nature Physics. DOI: 10.1038/s41567-018-0298-2

Olivier Delaire
Associate Professor of Mechanical Engineering & Materials Science

Predicting Properties of Future Materials
With an $8.6-million grant from the Department of Defense’s Multidisciplinary University Research Initiative, the Center for Autonomous Materials Design, led by Stefano Curtarolo, maintains the Automatic – FLOW for Materials Discovery online database. An international consortium of 15+ institutions input data into AFLOW about two- and three-element compounds that lets users predict the properties of yet-to-be-discovered materials. Two new grants totaling $2.8M are spurring the design of practical metallic glasses by computationally and experimentally exploring the processing-structure-properties space and improving the AFLOW framework and database.

Stefano Curtarolo
Professor of Mechanical Engineering & Materials Science
Created the first-ever supercomputer-generated recipes for two new kinds of magnets. Science Advances, DOI: 10.1126/sciadv.1602241

Predicted a new class of carbides that could be the hardest, most heat-tolerant ever created. Nature Communications, DOI: 10.1038/s41467-018-07160-7

Demonstrated Advantages of Incorporating Organic Building Blocks into Hybrid Perovskites
Using their electronic structure-based materials modeling software on a supercomputer, experimental scientists at Purdue and computational researchers at Duke in Volker Blum’s group introduced new materials with improved stability and safety that can improve optoelectronic devices such as solar cells, LEDs and optical computers. Nature Chemistry, DOI: 10.1038/s41557-018-0354-2

An artistic rendition of the intriguing superionic crystalline structure of CuCrSe2, which has copper ions that move like liquid between solid layers of chromium and selenium, giving rise to useful electrical properties. Oak Ridge National Laboratory/Jill Hemman
DUKE UNIVERSITY is home to world leaders in metamaterials and metasurfaces. Our faculty members demonstrated the world’s first negative refractive index metamaterial in 2000, and in 2006, invented a metamaterial “invisibility cloak” that renders objects undetectable at microwave frequencies. Currently, a $7.5 million Department of Defense investment funds our proving ground for acoustic metamaterials, while eight companies — and counting — have grown from our pioneering research in machine learning. Here are highlights from only a few of our researchers. For a complete listing of all faculty who work in Metamaterials, visit dmi.duke.edu/research/metamaterials.

Harvesting Energy
Duke engineers harnessed the power of machine learning to design dielectric (non-metal) metamaterials that absorb and emit specific frequencies of terahertz radiation. The design technique changed what could have been more than 2,000 years of calculation into 23 hours, clearing the way for the design of new, sustainable types of thermal energy harvesters and lighting. Optics Express, DOI: 10.1364/OE.27.027523

Willie Padilla
Professor of Electrical & Computer Engineering
Top 1% of Highly Cited Researchers (Clarivate)

Pioneering in Machine Learning
Engineers from Duke and the Institut de Physique de Nice in France developed a new method to identify objects using microwaves that improve accuracy while reducing the associated computing time and power requirements. The system could provide a boost to object identification and speed in fields where both are critical, such as autonomous vehicles, security screening and motion sensing. Advanced Science, DOI: 10.1002/advs.201901913

David R. Smith
James B. Duke Distinguished Professor of Electrical and Computer Engineering
Italy Award Fellow, APS, OSA
Top 1% of Highly Cited Researchers (Clarivate)

Bending Light Around Tight Corners Without Backscattering Losses
Natalia Litchinitser and her team have demonstrated a device that can direct photons of light around sharp corners with virtually no losses due to backscattering, a key property that will be needed if electronics are ever to be replaced by light-based devices. By carefully controlling the geometry of a crystal lattice, they blocked light from traveling through its interior while transmitting perfectly along the surface. Nature Nanotechnology, DOI: 10.1038/s41565-018-0297-6

Natalia Litchinitser
Professor of Electrical & Computer Engineering
Italia Award Fellow, APS, OSA
Senior Member, IEEE

Controlling Angle of Reflection of Sound Waves
Researchers at Duke and Aalto Universities (Finland) have constructed a “meta-mirror” device capable of perfectly reflecting sound waves in any direction. While the prototype device is specifically tailored to one frequency and angle of reflection, the researchers plan to pursue a dynamic device that could change shape to reflect different frequencies in different directions. They also plan to work on similar devices for underwater acoustics applications. Science Advances, 2019. DOI: 10.1126/sciadv.aau7288

Steve Cummer
William H. Younger Distinguished Professor of Engineering
Fellow, IEEE
Top 1% of Highly Cited Researchers (Clarivate)

An illustration of a dielectric metamaterial with infrared light shining on it, from Willie Padilla’s publication (top left).
DUKE RESEARCHERS are developing new materials and imagining new applications for existing technologies. This work ranges from basic science at the atomic and molecular levels to diagnostic tools, chemical and gas sensors, and other novel discoveries about light and electronic sensors. Here are highlights from only a few of our researchers. For a complete listing of all faculty who work in Electronics, Photonics & Quantum Materials, visit dmi.duke.edu/research/electronic-photonic-materials.

Discovering New Quantum States in Sheets of Copper with Chemical Doping

Sara Haravifard led an international collaborative research team from Duke University, National High Magnetic Field Laboratory, Los Alamos National Laboratory, École Polytechnique Fédérale de Lausanne, University of Amsterdam and École Polytechnique Fédérale de Lausanne to discover a new state of matter in sheets of copper oxide as a function of non-magnetic chemical doping. The underlying physics of the discovered states are closely related to Bose-Einstein condensation phenomena and provide a platform to tune such emerging states and gain a better understanding of the underlying science. Nature Communications, DOI: 10.1038/s41467-019-10410

Designing Optical Sensing Platforms to Detect Cancer Biomarkers

Using silver-plated gold nanostars, a team of Duke biomedical engineers led by Tuan Vo-Dinh have engineered a method for simultaneously detecting the presence of multiple specific microRNAs in RNA extracted from tissue samples without the need for labeling or target amplification. Under laser excitation, the nanostars emit amplified light which signals the presence of the microRNAs. The technique could help identify early biomarkers of cancer and other diseases without the need for the elaborate, time-consuming, expensive processes and special laboratory equipment required by current technologies. Analyst, 2020. DOI: 10.1039/D0AN00193G

Hyperspectral Camera

Maiken Mikkelsen, also a key member of Duke’s metamaterials group, led a team of researchers at Duke and Stanford in demonstrating on-chip, wide-spectrum photodetectors by using photonics to tailor specific sections to specific frequencies. This discovery could enable lightweight, inexpensive multispectral cameras for applications such as cancer surgery, food safety inspection and precision agriculture. Nature Materials, DOI: 10.1038/s41563-019-0538-6

Stretching Supercapacitors to Power Tomorrow’s Wearable Devices

Jeff Glass led researchers at Duke and Michigan State Universities in engineering a novel type of supercapacitor that remains fully functional even when stretched to eight times its original size. It does not exhibit any wear and tear from being stretched repeatedly and loses only a few percentage points of energy performance after 10,000 cycles of charging and discharging. They envision it being part of a power-independent, stretchable, flexible electronic system for applications such as wearable electronics or biomedical devices. Matter, 2020. DOI: 10.1016/j.matt.2020.02.024

When carbon nanotube forests are placed on an elastomer substrate prestretched in two directions, it creates a maze of spaghetti instead of rows, improving the stretchable supercapacitor’s performance.
**Sustainable Materials**

**DUKE ENVIRONMENTAL** engineers in collaboration with scientists from Duke’s Nicholas School of the Environment (ranked 8th globally, *U.S. News & World Report*) and through the Duke Superfund Research Center focus on understanding current and emerging threats materials pose to human and environmental health. Here are a few highlights from only a few of our researchers. For a complete listing of all faculty who work in Sustainable Materials, visit dmi.duke.edu/research/sustainable-materials.

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**Set the International Standard**

The $29 million **Center for Environmental Implications of Nanotechnology**, an international NSF-funded consortium, led by Mark Wiesner, has for over a decade contributed much about what we know about how industrial nanomaterials affect complex natural environments. With support from the EPA and European Union, CEINT’s shared database, the “Nanoinformatics Knowledge Commons,” has been adopted as an international standard for continued research.

**Mark R. Wiesner**

*James B. Duke Distinguished Professor and Chair, Department of Civil & Environmental Engineering*

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**Turning Waste to Resources**

Heileen Hsu-Kim’s group has focused on NSF- and DOE-funded research into the separation and purification of rare earth elements (REEs) from coal combustion ash and other energy-related residuals. REEs are essential materials for modern technologies across many sectors, including consumer electronics, alternative energy, transportation and defense industries.

**Heileen Hsu-Kim**

*Sternberg Family Professor of Civil & Environmental Engineering*

**Developed a new approach to precision bioremediation** of PAH-contaminated soils using microbes found on-site (Hsu-Kim, Ferguson, Gunsch, *J. of Hazardous Materials*, DOI: 10.1016/j.jhazmat.2019.120859)

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**A National Leader in Environmental Exposomics**

The $5 million NIH-funded **Duke Environmental Analysis Laboratory** uses advanced analytical methods and computational resources to identify and characterize unknown chemicals in environmental samples and evaluate their impacts on human health. It supports sample tracking and data transfer among NIH’s nationwide network of Human Health Exposure Analysis Resource hubs and serves as a key resource to ongoing and new environmental health research studies nationwide.

**Lee Ferguson**

*Associate Professor of Civil & Environmental Engineering; Co-Director, DEAL*

**Heather M. Stapleton**

*Ronie-Richele Garcia-Johnson Distinguished Professor, Nicholas School of the Environment; Co-Director, DEAL*

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In the **Duke Superfund Research Center**, engineers partner with environmental scientists and physicians to study environmental exposures and their consequences, operating one of the most advanced analytical chemistry laboratories in the world devoted to assessing contaminants in soil, water, and human and animal tissues. Duke faculty are also finding ways to clean up contaminated sites using innovative approaches that incorporate nanotechnology and biological agents.

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The CEINT Mesocosm Facility is home to 30 complex simulated wetland ecosystems, enabling a wide array of uniquely realistic investigations into the mechanisms that govern nanomaterial transport, transformation, ecological interactions, biouptake and biological interactions.
DUKE IS A multidisciplinary university with graduate degree programs that take advantage of these strengths across the university to train the next generation of materials scientists and engineers. Duke offers a wide array of pathways to graduate programs in materials science and engineering. The umbrella University Program in Materials Science & Engineering (MSE) offers a unified curriculum where PhD students feed from one of eight departments (see graphic); MS students apply directly to the program. The integrated Thomas Lord Department of Mechanical Engineering and Materials Science (MEMS) offers three flexible curriculum tracks in materials science at the PhD level and two master’s-level degree programs in materials science. Both MSE and MEMS offer “4+1” bachelor’s and master’s programs. Additionally, many of the other seven partner departments offer degree programs which can emphasize materials science within the context of their disciplines.

The University Program in Materials Science & Engineering
(PhD students are admitted through a participating academic department.)
Materials Science & Engineering Education

MASTER’S DEGREES THAT MATCH YOUR CAREER GOALS

MASTER OF SCIENCE (MS) IN MATERIALS SCIENCE AND ENGINEERING
An advanced degree culminating in a research project

MASTER OF ENGINEERING (MEng) IN MATERIALS SCIENCE AND ENGINEERING
An advanced engineering degree that includes business courses, technical training and an internship

’4+1’ BACHELOR AND MASTER’S (4+1)
Earn an undergraduate and a master’s degree (MS or MEng) in five years

OTHER DUKE OPPORTUNITIES:
Many of our participating departments offer degree programs and certificates that include materials science and/or engineering within the context of their disciplines. Please visit their individual department websites for more information.

“I chose the Materials Science and Engineering program because it allows me to work on fundamental science towards a tangible engineering-based application instead of being forced to choose between the two.”

Niara Wright, PhD ’23
Conducting Research in the Department of Electrical & Computer Engineering

“Because of the smaller program and class sizes, I have the opportunity to meet many distinguished researchers and professors one-on-one to discuss my interests and to be part of a very close and tight-knit group of highly motivated materials science students.”

Vasishta Somayaji, MS ’21
Conducting research in the Department of Chemistry
"I was drawn to this Duke because of my position's 50/50 split between the engineering school and the medical school. It seemed like a very natural fit. It gives me easier access to my needs such as tissue samples and allows me to learn firsthand about new problems clinicians are facing so that I can find solutions."

Shyni Varghese
Professor of Orthopaedic Surgery, Biomedical Engineering and Mechanical Engineering & Materials Science; MEDx Investigator