DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

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More Information: http://engineering.case.edu/emse/

Materials science and engineering is a discipline that extends from understanding the microscopic structure and properties of materials to designing materials in engineering systems and evaluating their performance. Achievements in materials engineering underpin the revolutionary advances in technology that define the modern standard of living. Materials scientists and engineers *understand* how the properties of materials relate to their microscopic structure and composition and *engineer* the synthesis and microstructure of materials to advance their performance in conventional and innovative technical applications.

The Department of Materials Science and Engineering of the Case School of Engineering offers programs leading to the degrees of Bachelor of Science in Engineering, Master of Science, and Doctor of Philosophy. The technological challenges that materials engineers face demand knowledge across a broad spectrum of materials. The Department conducts academic and research activities with metals, ceramics, semiconductors, polymers, and composites. Timely research and education respond to the demands for new materials and improved materials performance in existing applications, often transcending the traditional materials categories.

While a discipline of engineering, the field brings *basic science* to bear on the technological challenges related to the performance of industrial products and their manufacture. Materials science draws on chemistry in its concern for bonding, synthesis, and composition of engineering materials and their chemical interactions with the environment. Physics provides a basis for understanding the atomistic and electronic structure of materials and how they determine mechanical, thermal, optical, magnetic, and electrical properties. Mathematics, computation, and data science provide quantitative physical theories and modeling of the atomistic and electronic structure and provide advances in methods for microstructural analysis, materials design, and manufacturing processes.

Mission

The Department of Materials Science and Engineering engages faculty, students, postdoctoral researchers, engineers, and staff in developing and understanding relationships between processing, structure, properties, and the performance of materials in engineering applications. The Department provides a research-intensive environment that encourages collaboration and underpins modern education of undergraduate and graduate students as well as professionals in the field. This environment provides a strong foundation for advancing the frontiers of materials research, developing important technical innovations, and preparing engineers and scientists for challenging leadership careers.

Research Areas

Deformation and Fracture

Stress–strain relations during elastic and anelastic deformation. Plastic deformation mechanisms controlled by dislocation activity, twinning, or transformation-induced shear mechanisms, as well as by creep and viscous flow mechanisms under uniaxial, biaxial, and triaxial stress states, in particular in plane-strain and/or plane-stress conditions. Relationships between structure (atomistic structure and microstructure) and mechanical behavior of crystalline and glassy materials, including metals, intermetallics, semiconductors, ceramics, and composites. State-of-the-art facilities are available for testing mechanical properties over a range of strain rates, test temperatures, stress states, and size scales under monotonic and cyclic loading and under stress–corrosion conditions.

Materials Processing

Phase-transformation- and thermo-mechanical processing of alloys, including solution-, precipitation-, recovery-and-recrystallization- and stress-relief heat-treatments, also for intentional generation of residual-stresses. *Deformation processing* of materials. Surface engineering, crystal growth, sputter-, vapor- and laser-ablation synthesis of films. Melting and casting of metal alloys into sand/ceramic molds, injection into metallic molds, and by rapid solidification to form crystalline or (metallic-) glass ribbons. Ceramic- and metal powder synthesis. Consolidation processing by cold-pressing and sintering, electric-field-assisted compaction, or hot-pressing. Composite materials by forming of layered materials, electroplated metals, diffusion-bonding, brazing, and welding. Electrochemical- and thermo-chemical conversion processing, e.g. oxide-film growth by anodizing or thermochemical conversion. Synthesis of micro-to-nano-porous metal/oxide structures, e.g. for battery and capacitor electrodes or for catalyst support.

Environmental Effects

Durability and lifetime extension of structural, energy-conversion-, and energy-storage materials, including materials for solar energy conversion. Corrosion, oxidation, stress-corrosion, low- and high-cycle fatigue, adhesion, decohesion, friction, and wear. Surface modification and coatings, adhesion, bonding, and dis-bonding of dissimilar materials, reliability of electronics, photonics, and sensors.

Surfaces and Interfaces

Material surfaces in vacuum, ambient-, and chemical environments, grain- and phase boundaries, hetero-interfaces (interfaces between different metals, ceramics, carbon/graphite, polymers, and combinations thereof).

Electronic, Magnetic, and Optical Materials

Materials for energy conversion technologies, such as photovoltaics, organic and inorganic light-emitting diodes and displays, fuel cells, electrolytic capacitors, solid-state Li-ion batteries, and building-envelope materials. Processing, properties, and characterization of magnetic, ferroelectric, and piezoelectric materials.

Microcharacterization of Materials

Facilities for high-resolution imaging, spatially resolved chemical analysis and spectrometry, and diffractometry. Conventional, analytical, and high-resolution transmission electron microscopy, scanning electron microscopy, focused ion beam techniques, scanning probe microscopy, light-optical microscopy, optical and electron spectroscopies, surface analysis, and X-ray diffractometry.

Materials Data Science

Rapid qualification of alloys, data science applications in polymers and coatings. Distributed computing, informatics, statistical analytics, exploratory data analysis, statistical modeling, and prediction. Hadoop, cloud computing, and computationally intensive research are supported through the operation of a scalable high-performance computing (HPC) system.

Faculty

Frank Ernst, Dr. rer. nat. habil.
(University of Göttingen)
Leonard Case Jr. Professor of Engineering
https://goo.gl/OWsF9K
Microstructure and microcharacterization, alloy surface engineering, defects in crystalline materials, interface- and stress-related phenomena.

Laura S. Bruckman, PhD
(University of South Carolina)
Associate Professor
Materials data science, lifetime and degradation science, study protocol development, spatiotemporal data integration

Jennifer W. Carter, PhD
(The Ohio State University)
Associate Professor
Processing–structure–property relationships of crystalline and amorphous materials. Multi-scale material characterization methods for correlating local microstructural features with mechanical and environmental responses.

Roger H. French, PhD
(Massachusetts Institute of Technology)
Kyocera Professor
Optical properties and electronic structure of polymers, ceramics, optical and biomolecular materials. These determine the vdW interactions which drive wetting of interfaces and mesoscale assembly biomolecular and inorganic systems including CNTs, proteins and DNA. Energy research focused on lifetime and degradation science. Including developing CRADLE, a Hadoop/Hbase/Spark-based distributed computing environment, for data science and analytics of complex systems such as photovoltaics and outdoor exposed materials. This allows multi-factor real-world performance to be integrated with lab-based datasets to identify mechanisms and pathways activated over lifetime using statistical and machine learning.

Hyeji Im, PhD
(Korea Advanced Institute of Science and Technology)
Assistant Professor
Development and manufacturing of structural materials, extreme environment materials, metal additive manufacturing, sustainable alloy design and processing, materials characterization and metallurgical phenomena, and nano-microstructure control.

Neamul Khansur
(UNSW Sydney, Australia)
Assistant Professor
Processing-structure-properties relationships in multi-functional materials. Powder aerosol deposition for fabricating protective and functional ceramic coatings. In situ X-ray and neutron diffraction characterization methods for non-linear dielectric ceramics

John J. Lewandowski, PhD
(Carnegie Mellon University)
Arthur P. Armington Professor of Engineering
Mechanical behavior of materials. Fracture and fatigue. Micromechanisms of deformation and fracture. Composite materials. Bulk metallic glasses and composites. Refractory metals. Toughening of brittle materials. High-pressure deformation and fracture studies. Hydrostatic extrusion.

James D. McGuffin-Cawley, PhD
(Case Western Reserve University)
Arthur S. Holden Professor of Engineering
Powder processing of ceramics. Manufacturing and materials. Additive manufacturing and rapid prototyping. Aggregation phenomena. Defects, diffusion, and solid state reactions. Materials for optical devices.

Alp Sehirlioglu, PhD
(University of Illinois at Urbana Champaign)
Associate Professor
Energy conversion materials, including piezoelectrics and thermoelectrics. Bulk and film electro-ceramics. Epitaxial oxide films.

Gerhard E. Welsch, PhD
(Case Western Reserve University)
Professor
High-temperature materials. Materials for capacitive energy storage. Metals, metal sponges, oxides. Mechanical and electrical properties. Synthesis.

Matthew A. Willard, PhD
(Carnegie Mellon University)
Associate Professor
Magnetic materials: properties, microstructure evolution, phase formation, and processing conditions. Rapid solidification processing. Soft magnetic materials. Permanent magnet materials. Magnetic shape memory alloys, magnetocaloric effects, magnetic nanoparticles, and multiferroics.

Research Faculty

Erika Barcelos, PhD
(Case Western Reserve University)
Research Assistant Professor

Janet L. Gbur, PhD
(Case Western Reserve University)
Research Assistant Professor
Fatigue and fracture of medical materials, mechanical behavior of superelastic Nitinol; development of microscale medical devices for rehabilitation; and flexible circuit fabrication using aerosol jet printing.

Hoda Amani Hamedani, PhD
(Georgia Institute of Technology)
Research Assistant Professor
Nanomaterials synthesis and characterization for electrochemical energy harvesting, conversion (solar cells, fuel cells). Nanostructured platforms for biomedical applications including flexible bioelectronics and implantable microdevices, localized drug delivery, neural interfacing, sensing and in vivo power generation.

Pawan Tripathi, PhD
(Indian Institute of Technology)
Research Assistant Professor
Materials Data Science, Advanced Manufacturing, Synchrotron Data Analysis, Image Processing, Deep Learning, Artificial Intelligence, Uncertainty Quantification, Atomistic Simulation

Jeffrey Yarus, PhD
(University of South Carolina)
Research Professor
Applications of data science and statistics in materials science, materials engineering, and geology.

Secondary Faculty

Clemens Burda, PhD
Professor
Chemistry

Sunniva Collins, PhD
Associate Professor
Mechanical Engineering

Liming Dai, PhD
Kent Hale Smith Professor
Macromolecular Science and Engineering

Walter Lambrecht, PhD
Professor
Physics

Clare Rimnac, PhD
Professor
Mechanical Engineering

Mohan Sankaran, PhD
Goodrich Professor of Engineering Innovation
Chemical Engineering

Russell Wang, DDS
Associate Professor
Dentistry

Xiong (Bill) Yu, PhD, PE
Professor
Civil Engineering

Adjunct Faculty

Jennifer Braid, PhD
(Colorado School of Mines)
Adjunct Professor
Developing data science and computer vision techniques for PV module and system research

Arnon Chait, PhD
(The Ohio State University)
Adjunct Professor
NASA Lewis Research Center

Mark DeGuire, PhD
(Massachusetts Institute of Technology)
Adjunct Associate Professor

George Fisher, PhD
Adjunct Professor
Ion Vacuum Technologies Corporation

N.J. Henry Holroyd, PhD
(Newcastle University)
Adjunct Professor
Luxfer Gas Cylinders

Jeffrey J. Hoyt, PhD
(University of California, Berkeley)
Adjunct Professor
McMaster University

Jennie S. Hwang, PhD
(Case Western Reserve University)
Adjunct Professor
H-Technologies Group

Peter Lagerlof, PhD
(Case Western Reserve University)
Adjunct Associate Professor

Ina Martin, PhD
(Colorado State University)
Adjunct Assistant Professor
Case Western Reserve University

Farrel Martin, PhD
Adjunct Professor
United States Naval Research Laboratory

David Matthiesen, PhD
(Massachusetts Institute of Technology)
Adjunct Associate Professor

Terence Mitchell, PhD
(University of Cambridge)
Adjunct Professor
Los Alamos National Laboratory

Erik Mueller, PhD
(University of Florida)
Adjunct Assistant Professor

Badri Narayanan, PhD
(The Ohio State University)
Adjunct Assistant Professor
Lincoln Electric

Joe H. Payer, PhD
Adjunct Professor
University of Akron

Timothy Peshek, PhD
(Case Western Reserve University)
Adjunct Assistant Professor
NASA Glenn Research Center

Rudolph Podgornik, PhD
(University of Ljubljana)
Adjunct Professor
University of Ljubljana

Gary Ruff, PhD
(Case Western Reserve University)
Adjunct Professor
Ruff Associates

Ali Sayir, PhD
(Case Western Reserve University)
Adjunct Professor
Air Force Office of Scientific Research

Mohsen Seifi, PhD
(Case Western Reserve University)
Adjunct Assistant Professor
ASTM International

Emeritus Faculty

William A. "Bud" Baeslack III, PhD
(Rensselaer Polytechnic Institute)
Professor Emeritus
Welding, joining of materials, and titanium and aluminum metallurgy

Mark De Guire, PhD
(Massachusetts Institute of Technology)
Associate Professor Emeritus
Synthesis and properties of ceramics in bulk and thin-film form, including fuel cell materials, gas sensors, coatings for biomedical applications, photovoltaics, and ferrites. Testing and microstructural characterization of materials for alternative energy applications. High-temperature phase equilibria. Defect chemistry.

Arthur H. Heuer
Professor Emeritus

Peter Lagerlof, PhD
(Case Western Reserve University)
Associate Professor Emeritus
Mechanical properties of ceramics and metals. Low-temperature deformation twinning. Light-induced plasticity of semiconductors. Methodology of transmission electron microscopy and diffractometry.

David Matthiesen, PhD
(Massachusetts Institute of Technology)
Associate Professor Emeritus
Nitride-based ferromagnetic materials. Applied atomistic simulation of materials. Materials for use in wind turbines. Wind resource measurements onshore and offshore. Materials interactions with ice. Bulk crystal growth processing. Process engineering in manufacturing. Heat, mass, and momentum transport.

Pirouz Pirouz
Professor Emeritus

Programs

- Applied Data Science, Graduate Certificate
- Applied Data Science, Minor
- Materials Science and Engineering, BSE
- Materials Science and Engineering, Minor
- Materials Science and Engineering, MS
- Materials Science and Engineering, PhD

Dual Degrees

- Programs Toward Graduate or Professional Degrees

Related Majors in Other Departments

- Data Science and Analytics, BS (administered by the Department of Computer and Data Sciences)

Facilities

Advanced Manufacturing and Mechanical Reliability Center (AMMRC)

White Building 115, 211, 216, 222, 300, 338

Deformation Processing Laboratory: White Building 115
Nitonol Commercialization Accelerator: White Building 300, 338
Mechanical Testing Laboratories: White Building 211, 216, 222

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The AMMRC (Advanced Manufacturing and Mechanical Reliability Center) permits the determination of mechanical behavior of materials over loading rates ranging from static to impact, with the capability of testing under a variety of stress states under either monotonic or cyclic conditions. A variety of furnaces and environmental chambers are available to enable testing at temperatures ranging from -196 °C to 1800 °C. The facility is operated under the direction of a faculty member and under the guidance of a full-time engineer. The facility contains one of the few laboratories in the world for high-pressure deformation and processing, enabling experimentation under a variety of stress states and temperatures. This state-of-the-art facility includes the following equipment:

- **High-Pressure Deformation Apparatus:** This unit enables tension or compression testing to be conducted under conditions of high hydrostatic pressure and consists of a pressure vessel and diagnostics for measurement of load and displacement on deforming specimens, as well as instantaneous pressure in the vessel. Pressures up to 1.0 GPa loads up to 10 kN, and displacements of up to 25 mm are possible. This oil-based apparatus can be operated at temperatures up to 300 °C.
- **Hydrostatic-Extrusion Apparatus:** Hydrostatic extrusion (e.g. pressure-to-air, pressure-to-pressure) can be conducted at temperatures up to 300 °C on manually operated equipment interfaced with a computer data acquisition package. Pressures up to 2.0 GPa are possible, with reduction ratios up to 6 to 1, while various diagnostics provide real time monitoring of extrusion pressure and ram displacement.
- **Advanced Forging-Simulation Rig:** A multi-actuator MTS machine based on 1.5 MN, four post frame, enables sub-scale forging simulations over industrially relevant strain rates. A 490 kN forging actuator is powered by five nitrogen accumulators enabling loading rates up to 3.0 m/s on large specimens. A 980 kN indexing actuator

provides precise deformation sequences for either single, or multiple, deformation sequences. Data acquisition at rates sufficient for analysis is available. Testing with heated dies is possible.

- **Advanced Metal-Forming Rig:** A four-post frame with separate control of punch actuator speed and blank hold down pressure enables determination of forming limit diagrams. Dynamic control of blank hold down pressure is possible, with maximum punch actuator speeds of 30.0 cm/s. A variety of die sets are available.
- **Servo-hydraulic Machines:** Four MTS Model 810 computer-controlled machines with load capacities of 13 kN, 90 kN, 220 kN, and 220 kN, permit tension, compression, and fatigue studies to be conducted under load-, strain-, or stroke control. Fatigue crack growth may be monitored via a DC potential drop technique as well as via KRAK gauges applied to the specimen surfaces. Fatigue studies may be conducted at frequencies up to 30 Hz. In addition, an Instron Model 1331 90 kN Servo-hydraulic machine is available for both quasi-state and cyclic testing.
- **Universal Testing Machines:** Three INSTRON screw-driven machines, including two INSTRON Model 1125 units permit tension, compression, and torsion testing.
- **Electromechanical Testing Machine:** A computer-controlled INSTRON Model 1361 can be operated under load-, strain-, or stroke control. Stroke rates as slow as 0.3 nm/s are possible.
- **Fatigue Testing Machines:** Three Sonntag fatigue machines and two R. R. Moore rotating-bending fatigue machines are available for producing fatigue-life (S–N) data. The Sonntag machines may be operated at frequencies up to 60 Hz.
- **Creep Testing Machines:** Three constant load frames with temperature capabilities up to 800 °C permit creep testing, while recently modified creep frames permit thermal cycling experiments as well as slow cyclic creep experiments.
- **Impact Testing Machines:** Two Charpy impact machines with capacities ranging from 20 ft-lbs to 240 ft-lbs are available. Accessories include a Dynatup instrumentation package interfaced with an IBM PC, which enables recording of load vs. time traces on bend specimens as well as on tension specimens tested under impact conditions.
- **Instrumented Microhardness Tester:** A Nikon Model QM High-Temperature Microhardness Tester permits indentation studies on specimens tested at temperatures ranging from -196 °C to 1200 °C under vacuum and inert gas atmospheres. This unit is complemented by a Zwick Model 3212 Microhardness Tester as well as a variety of Rockwell Hardness and Brinell Hardness Testing Machines.

Swagelok Center for Surface Analysis of Materials

Glennan Building 101

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Jeffrey Pigott, 216-368-6012, jxp652@case.edu
Website: https://engineering.case.edu/centers/scsam/

SCSAM, the Swagelok Center for Surface Analysis of Materials, is a multi-user facility providing cutting-edge major instrumentation for microcharacterization of materials. SCSAM is administered by the CSE (Case School of Engineering) and is central to much of the research carried out by CSE's seven departments. The facility is also extensively used by the CAS (College of Arts and Sciences) Departments of Physics, Chemistry, Biology, and Earth, Environmental, and Planetary Sciences, as well as many departments within the School of Medicine and the School of Dental Medicine. Typically, more than 200 users, mostly academic, utilize the facility per year.

SCSAM's instruments encompass a wide and complementary range of characterization techniques, which provide a comprehensive resource for high-resolution imaging, diffractometry, and spatially-resolved compositional analysis.

Current capabilities for high-resolution imaging include: an AFM (atomic force microscope) which can optionally be operated with an imaging nanoindenter scan head or a stand-alone automated nanoindenter; a Keyence optical microscope providing the next-generation of optical microscopy with a large depth-of-field and advanced measurement capabilities for inspection and failure analysis.; two scanning electron microscopes, one equipped for FIB (focused ion beam) micromachining, and both equipped with XEDS (X-ray energy-dispersive spectrometry), TSEM (transmission scanning electron microscopy), and EBSD (electron backscatter diffraction) detectors.

For XRD (X-ray diffractometry), SCSAM provides two diffractometers with 1D and 2D detectors to allow for phase identification, phase fraction determination, crystal structure refinements, as well as stress and strain measurements of crystalline solids.

SCSAM's surface analysis suite of instruments includes an instrument for ToF-SIMS (time-of-flight secondary-ion mass spectrometry), a SAM (scanning Auger microprobe) for spatially resolved AES (Auger electron spectroscopy), and an instrument for XPS (X-ray photoelectron spectroscopy, also known as ESCA, electron spectrometry for chemical analysis), that accomplishes high spatial resolution by operating with a focused X-ray beam.

SCSAM's instruments are housed in a centralized area allowing users convenient access to state-of-the-art tools for their research.

Magnetometry Laboratory

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The Magnetometry Laboratory has facilities used to investigate the magnetic properties of materials. This laboratory has the following instruments:

- **Lake Shore Cryotronics Model 7410 Vibrating Sample Magnetometer** This instrument serves for measurement of hysteresis loops (at constant temperature) and thermomagnetic measurements (at constant magnetic field). The maximum applied field at room temperature (without furnace in place) is 3.1 T. For high temperature measurements, the maximum applied field is 2.5 T over the temperature range from room temperature to 1000 °C.
- **Home-Built Magnetostriction Measurement System** This system has been designed and built to measure the shape change of magnetic materials under applied magnetic fields. Better than 1 ppm sensitivity is possible by this strain gauge technique. An applied field of ≈0.2 T is used to saturate samples.

SDLE Research Center

White Building 538

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The SDLE Research Center was established in 2011 as a Wright Project Center with funding from Ohio Third Frontier. Initially it was dedicated to advancing the fields of lifetime and degradation science using data science. The research center activities have expanded to include research focused on the durability and degradation of environmentally exposed, long-lived materials and technologies such as photovoltaics (PV), coatings, energy efficient lighting, and building envelope applications, as well as broad-based collaborations in materials data science in reliability and degradation, carbon capture and storage, geothermal energy applications.

Today the SDLE Research Center is advancing the development of Materials Data Science for use in Materials Reliability, Materials Science and broader application areas.

The SDLE Research Center, also includes the SDLE Core Facility, which is a CWRU User Facility, which provides both reliability and Materials Data Science tools and capabilities available to the CWRU community, other academic researchers and industrial and national laboratory researchers.

A data science approach is needed to handle large-scale data on materials, components, systems, modules, commercial power plants, and the grid. These approaches involve data ingestion into nonrelational data warehouses and data-driven modeling with a foundation in the underlying physics and chemistry of degradation and lifetime performance. Assembling FAIR (Findable, Accessible, Interoperable, Reusable) data and other data, developing and sharing codes and tools, and reporting research results along a materials value chain is a key component of the Center. The SDLE Research Center facilitates complex data-driven modeling, including geostatistical, geospatiotemporal modeling, graph network modeling, and degradation network models. The data analytics platform (CRADLE), an integrated distributed and high performance computing cluster, was developed in the center to facilitate large data storage and analysis with ease of access to team members enabling fleets of high performance computing jobs for improved data analytics.

The SDLE Center has developed a method to enable large-scale distributed analysis of commercial fleet scale photovoltaic (PV) power plants for both performance loss rate (PLR) determination and power forecasting. This study includes a set of timeseries datasets for 100,000 PV plant inverters and determines the data quality of these plants in relation to prediction of PLR. Additionally, a multi-year benchmarking and review of the impact of data quality and filtering, power prediction algorithms, and PLR determination methods has defined the challenges in PLR determination. The data quality, data gaps, and filtering of timeseries data of commercial fleets of PV plants restrict which algorithms analyses can use and can bias results and reduce their accuracy. Data quality and data gaps can be improved with spatio-temporal graph neural network (st-GNN) models of PV power plant data including satellite weather data and autoencoders for data imputation of missing data. FAIR data principles are used to make FAIR data and models in order to improve transferability of data and models.

The SDLE Center has a focus on materials data science in relation to long-lived materials. This work determines the degradation mechanisms in material systems, which can be mitigated to optimize lifetime performance of materials, components, and devices. Understanding these key degradation mechanisms in relation to the stress and stress level is fundamental to lifetime and degradation science (L&DS). By encompassing the knowledge from the experimental insights of the degradation of materials, the lifetime of materials can be predicted under multiple different stress conditions. Thus far traditional materials reliability has been flawed with costly failures in applications such as polyamide backsheet failure in photovoltaic (PV) modules. The Center has developed an epidemiological approach to understanding materials degradation which provides more scientific value by giving information on the standard deviation within a population. Additionally, by combining standard and modified accelerated exposures with real-world exposures, degradation can be more accurately predicted on a variety of different grades of materials or component structure. Then data-driven or network modeling provides insights into the impact of stress conditions on degradation and performance. Real-world degradation gives the information on the complex and synergistic nature of materials degradation compared to single or even combinational accelerated stressors. The unique environment that a material exists in the real world or in-use conditions is varied due to specific microstressors as well as the impact of climate change on climate zones.

Geostatistical geospatiotemporal modeling is an active area of research within SDLE which is a quantitative method for mapping phenomena that are inherently tied to geographic and/or temporal space. The method provides for estimating at unsampled locations and for simulating multiple equally probable realizations to assess the space of uncertainty in the subsurface, surface, or near surface environment. Applications include environmental, mineral resources, geothermal, hydrology, agriculture, climate, forestry, soil, air, and more.

The SDLE Research Center's Core Facility has capabilities and equipment including:

- Outdoor solar exposures: SunFarm with 14 dual-axis solar trackers with multi-sun concentrators, and power degradation monitoring
- Solar simulators for 1-1000X solar exposures
- Multi-factor environmental test chambers with temperature, humidity, freeze/thaw, and cycling
- A full suite of optical, interfacial, thermo-mechanical, and electrical evaluation tools for materials, components, and systems
- CRADLE: 800 Terabytes of nonrelational data warehouses based on Cloudera's distribution of Apache's Hadoop, Hbase, and Spark
- High Performance Compute Cluster for data science and analytics

The Center for Materials Data Science for Reliability and Degradation (MDS-Rely)

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The Center for Materials Data Science for Reliability and Degradation (MDS-Rely) is a National Science Foundation (NSF) Industry-University Cooperative Research Center (IUCRC) which CWRU leads in partnership with the University of Pittsburgh. Center Members from both industry and government join the Center as Members and directly fund center research. MDS-Rely seeks to apply data science-informed research to better understand the reliability and lifetime of essential materials, while creating code packages, models, and other materials-agnostic deliverables that are jointly owned by Member organizations.

Through a series of competencies, research thrusts, and materials value chains, MDS-Rely focuses on transferable research outputs while training a data-enabled workforce of students and graduates that enjoy strong, collaborative relationships with our Member organizations. Through a diverse research portfolio, MDS-Rely provides insight into the following areas:

1. Competencies: Standards & Reliability Protocols; Materials Data Science; Reliability, Performance, & Degradation Solutions
2. Research Thrusts: Weathering & Performance; Subtractive & Additive Manufacturing; Energy Technologies.
3. Materials Value Chains: Polymers, Elastomers, & Coatings; Metals & Alloys; Semiconductors & Optoelectronics; and an evolving focus on circular economy, sustainability, & climate.

MDS-Rely works in close partnership with the SDLE Research Center. Interested parties should reach out to Jonathan Steirer, Managing Director, at jonathan.steirer@case.edu or Roger French, Center Director, at roger.french@case.edu