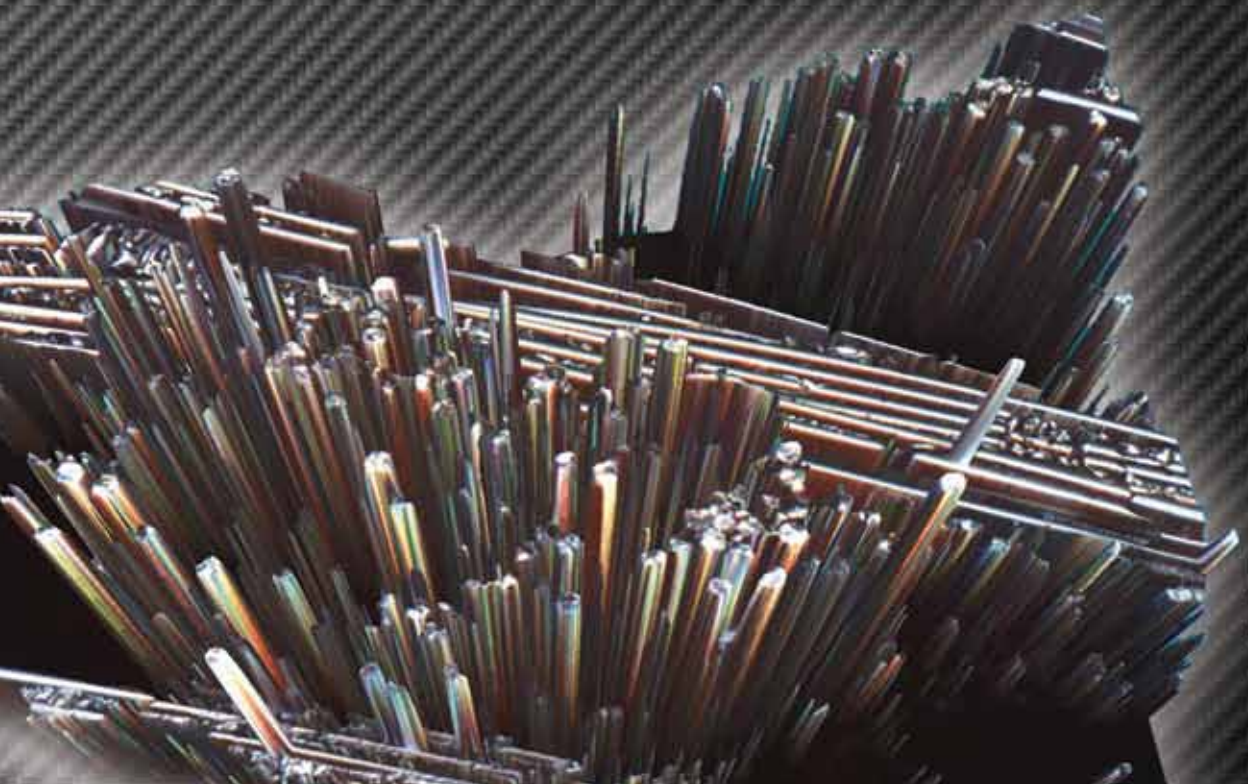
Composites and polymer engineering Laboratory

Developing the materials of tomorrow

in partnership with industry, government and academia



SOUTH DAKOTA
SCHOOL OF MINES
& TECHNOLOGY

Mission of the CAPE Lab

The CAPE Lab's Mission is

- to provide a stimulating and collaborative environment for innovative research and rigorous education in polymers, polymer matrix composites and related areas;
- to build strong, productive relationships with industrial, governmental and academic partners; and
- to create dedicated teams of research staff, faculty and students, focused on advancing knowledge in the polymer and composites field.

The Composites and Polymer Engineering (CAPE) Laboratory is a multidisciplinary research and education center at the South Dakota School of Mines and Technology (SDSMT), specializing in polymers and polymer matrix composites.

The CAPE Lab works with industrial, government and academic partners to explore and develop the next innovations in polymers and polymer composites, from research in materials science and processing technology to prototype demonstration and testing. To enable this spectrum of research activity, the laboratory possesses an exceptionally wide range of advanced processing, analytical and testing equipment, as well as advanced computational and simulation tools.

Collaboration is at the heart of the CAPE Lab's research philosophy. Our scientists and engineers work closely with various SDSMT departments, faculty members and students, and the lab is a hub of multidisciplinary interactions on campus. The lab has established close working relationships with government laboratories, and with several research groups and centers at other universities. It provides responsive research services to industry and develops productive research partnerships with industrial clients, customized to meet each company's commercial objectives, timelines and confidentiality requirements.

Partnership with the CAPE Lab can be on a one-to-one basis or as part of a consortium of organizations. Based on the goals, timeline and other input of sponsors, the CAPE Lab provides a program plan with clearly defined milestones and deliverables. In response to its clients' evolving needs, the lab is also open to redirecting the research focus of a project in light of new or unforeseen information.

In the execution of research projects, the CAPE Laboratory is able to draw on the expertise and experience of its own fulltime research scientists and engineers, the specialist knowledge of collaborating faculty members from various departments at the university and input from CAPE's group of graduate students.

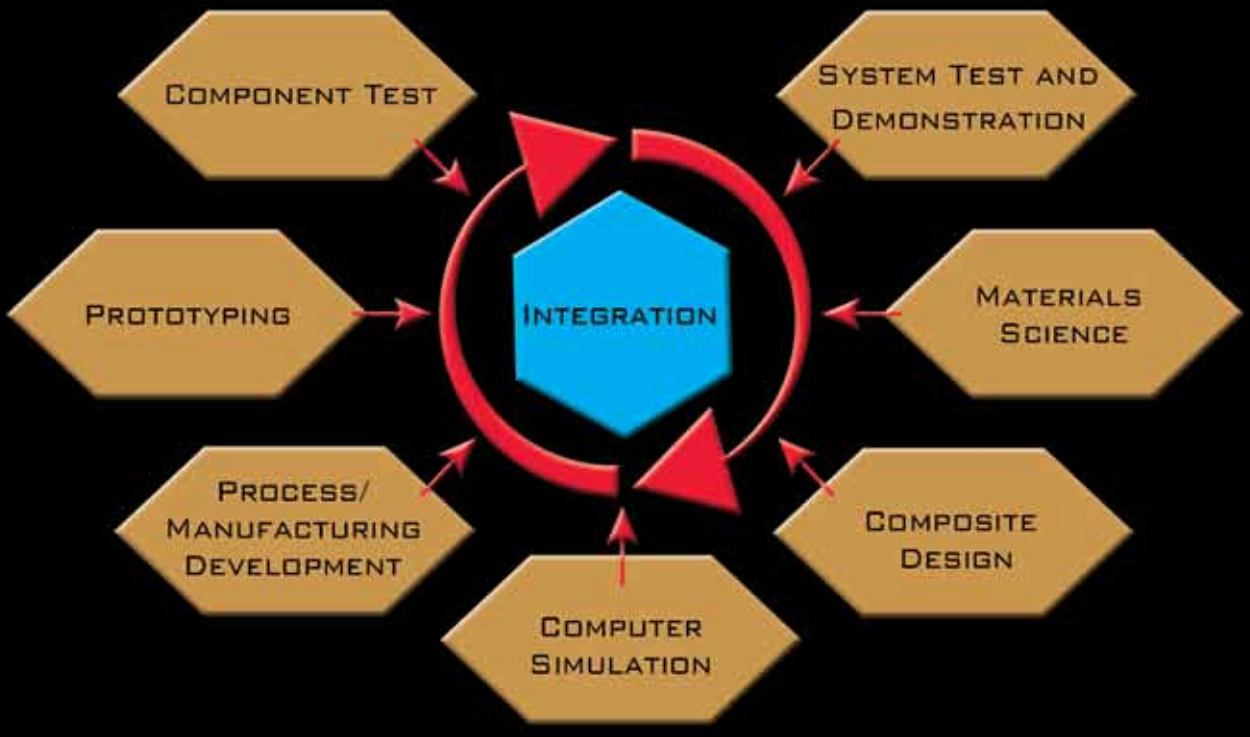
The CAPE Lab's capabilities include a fully integrated approach to research and development, encompassing:

- materials science and engineering
- composite and component design
- multiscale computer simulations
- process and manufacturing technologies
- prototyping and testing
- chemical, mechanical, and thermal characterization

RESEARCH AND DEVELOPMENT CAPABILITIES

An integrated approach to R&D ensures that development of industrially relevant technologies is based on recent advances in materials science and engineering made at CAPE Lab and elsewhere. In our most comprehensive programs, the CAPE Lab begins with a goal to prototype a material, component or product with specific properties, and then organizes parallel but highly interactive thrusts in materials science, process engineering, computer modeling, prototyping and testing, to realize the program objective. Typically, iterative procedures are established in which structures are designed, produced and tested, and then modified and optimized in light of testing results and model refinements.

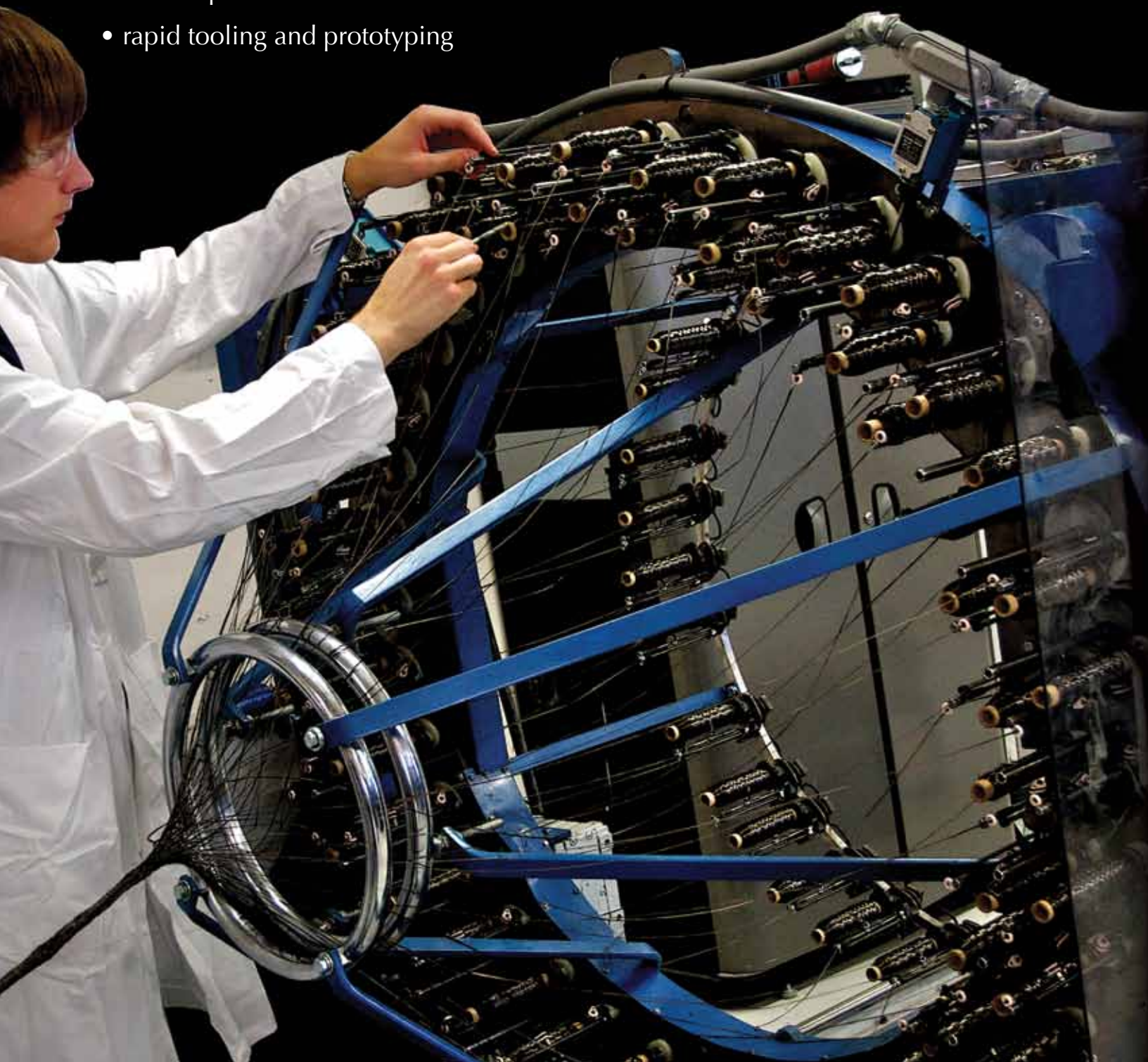
In addition to collaborating with our partners to build scientific understanding and to develop new products and processes, our scientists and engineers enjoy applying the knowledge they have built to solve practical problems for our industrial clients, sometimes on an urgent timeline.



Research Foci

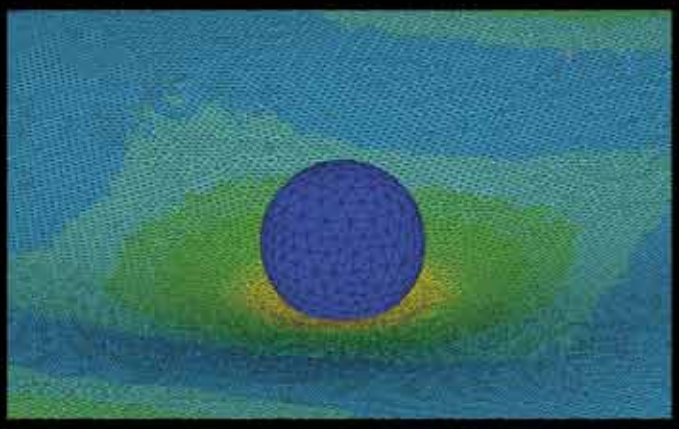
The CAPE Lab's current research foci include:

- polymers and composites for severe and extreme conditions
- composite materials with multiple sensing capability
- multi-functional composites and nanocomposites
- advanced processing of polymers and composites
- biocomposites
- rapid tooling and prototyping



Polymers and Composites for Severe and Extreme Conditions

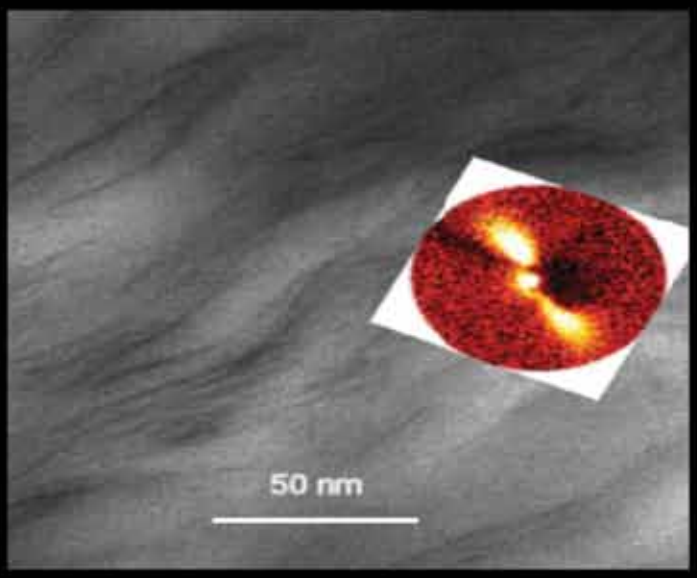
One of the CAPE Laboratory's current thrusts is the development of composite materials for severe and extreme conditions. For example, as part of a program with the Army Research Laboratory (ARL), the CAPE Lab is developing light-weight, functionally graded composite structures to enhance dissipation of impact and thermal energy from blast-waves, projectiles, flames, and so on. This work involves the creation of hybrid composite materials, comprising nanocomposites and fiber-reinforced composites with tailored properties. Key research areas related to this thrust include the synthesis and formation of novel nanoscale and multiscale structured materials, application of multiscale computer simulations as predictive tools and advanced processing methods to control and localize structure formation and properties.



Simulation of an impact event

Multi-Functional Composites

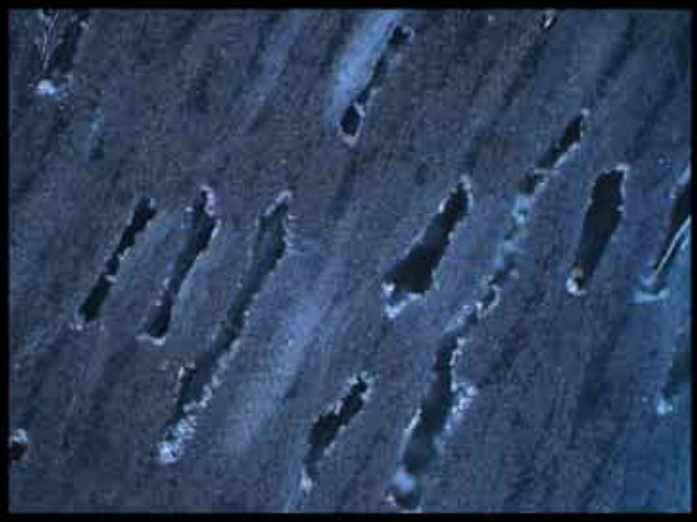
Multi-functional materials feature in the programs described above and are central to a number of areas of interest to the CAPE Laboratory. Integrated structures that can actively, and simultaneously, manage multiple advanced functions –(e.g., mechanical, electrical, optical, magnetic, thermal, biological) can potentially be realized through the addition of nanoparticle combinations at low loadings and/or through the design of layered composite and nanocomposite materials with functionally-graded properties. Investigations in this area involve polymer composite systems comprising fibers and particles with a range of chemical compositions, surface functionalities, length scales and geometries and employ both experimental studies and computational modeling methods.



TEM image and diffraction pattern of montmorillonite nanoparticles dispersed and oriented in a polymer matrix

Polymer and Composite Materials with Multiple Sensing Capability

The CAPE Laboratory is developing polymer materials and composites with embedded sensing, diagnostic and communications capability. One of the current application areas is in helmets and other protective gear for military and security personnel, rescue workers, firefighters, sports players, and so on. Integrated, miniaturized, multiple-sensing devices will provide the wearer, medical professional or command center with an array of critical information on hazardous environments, events and injuries met within the field.

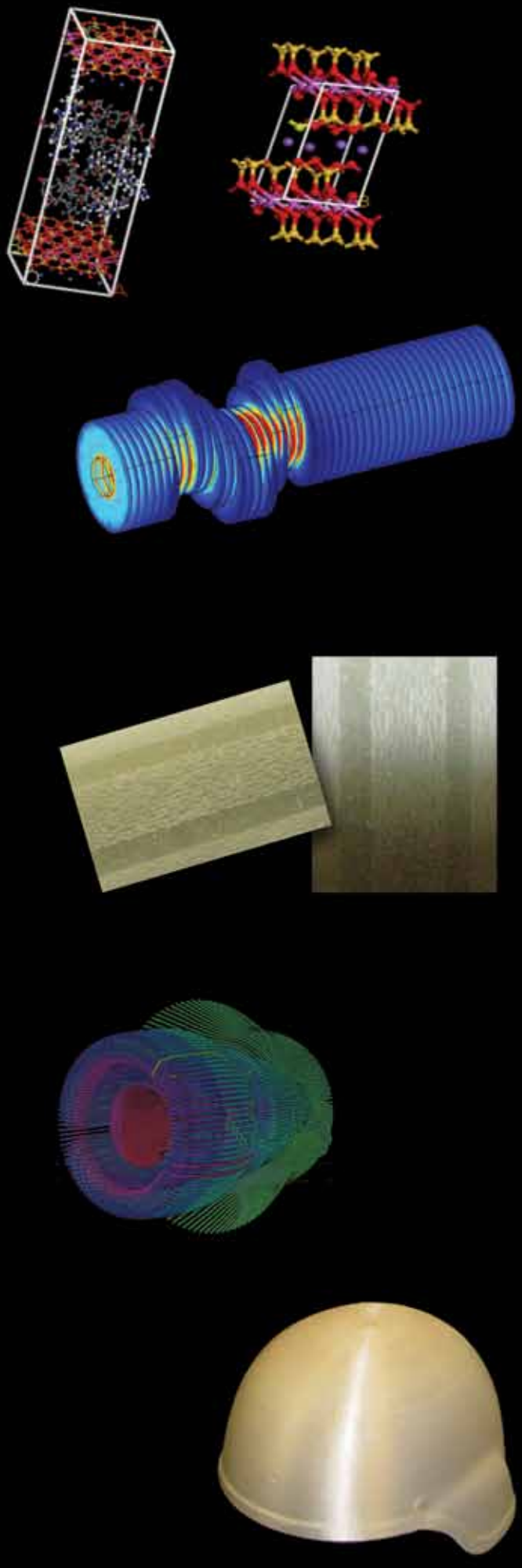


Damage morphology in a polymer composite

Advanced Processing of Thermoset and Thermoplastic Composites

The high fracture toughness of thermoplastic polymer composites is well recognized, and significant improvements in the strength and stiffness of these materials are allowing them to challenge the predominance of thermoset composites in a number of demanding markets – even aerospace. Further advantages of thermoplastic composites include the ease of re-shaping or remolding (e.g., stamp forming) and their relatively benign environmental impact. There are nevertheless numerous challenges in designing cost effective processes that optimize composite properties, and the CAPE Laboratory is investigating and developing novel thermoplastic composite technologies, especially high throughput, "continuous fiber" processes. The lab is also starting to explore novel compounding and mixing processes for the addition, dispersion and alignment of carbon nanotubes and other high aspect ratio nanoparticles in the polymer melt; and methods to efficiently produce hybrid thermoplastic-thermoset composites with tailored properties.

For both thermoset and thermoplastic polymer composites, the lab is investigating and developing processes to provide greater diversity and control of structure. One such method involves precision placement of nanoparticles and other additives in composite structures to impart selected properties (e.g., reinforcement, abrasion resistance, electrical conductivity, magnetism, chemical functionality) at localized regions of the composite part. This approach promises to provide enhanced composite functionality at reduced cost.



Research Foci

Biocomposites

The development of materials from biopolymers is emerging as an important contributor to minimization of energy consumption and waste generation, as well as providing new opportunities for the design and engineering of products with exceptional properties and applications from automobile components to bone replacement. The CAPE Laboratory is involved in the development of composites incorporating, or derived from, natural polymers that have the potential to replace petroleum-based composite materials in a number of commercially important markets. For example, the CAPE Lab is supporting and contributing to research selected by the Center for BioEnergy Research and Development (CBERD) on the utilization of solid lignin particles – co-products of the conversion of lignocellulosic biomass to ethanol – as property-enhancing composite additives.

Rapid Tooling and Prototyping

The CAPE Lab has the capability of moving efficiently from computer-aided design, to tool assembly, to prototype actualization, and our composite engineers continue to develop and refine these processes and system interfaces.

Processing and Prototyping Equipment

The CAPE Lab possesses advanced equipment and instrumentation in the following categories:

- polymer processing
- composites processing and fabrication
- rapid tool fabrication
- polymer and composite analysis and characterization
- mechanical testing
- computational modeling software

PROCESSING AND PROTOTYPING EQUIPMENT

The CAPE Laboratory is equipped with an outstanding array of polymer and composite processing and prototyping equipment, ranging from bench-scale units to industrial scale capabilities. Housed in a dedicated facility, with more than 10,000 square feet of laboratory space, the equipment includes:

Polymer Processing

Haake Polylab Single Screw Extruder
Coperion Twin-Screw Extruder
Cincinnati Milacron Injection Molder
K-Tron Gravimetric Feeders
Sheer Bay Bath and Pelletizer
Hitachi/Thermo RC6 Centrifuge
Powder King Pulverizer
Wabash 100 ton Press
Carver 30 ton Presses (2)

Composites Processing and Part Fabrication

Waeco Prepreg Machine
DRiFT Thermoplastic Prepreg Machine
JHM Resin Transfer Molding (RTM) Machine
VARTM Equipment
Wardwell Composite Braider
MAAC Model ASP Thermoforming Machine
Cobra Filament Winder
Puritan Industrial Stitcher
Farrell 2-Roll Mill
Taricco Industrial Autoclave
Wisconsin Walk-In Oven
Blue M Inert Atmosphere Oven
Muffle Furnaces (2)
Gerber CNC Cutting Table

Composite Tool Fabrication

Fadal VMC6030 CNC Mill
Tri-Tech 5-axis Mill Head
Haas CNC Lathe
Engis Tool Polishing Set
Tinius Olsen Model 104 IZOD Tester
Struers Automated Sample Polisher
Struers Automated Sample Saw

Rapid Prototyping and Reverse Engineering

Stratasys Fortus 400 FDM Prototype Machine
FARO V3 Laser CMM with Geomagic Software Suite

ANALYTICAL AND TESTING INSTRUMENTS

The CAPE Lab has the following instruments for characterization of polymers and composites:

MTS Load Frames (2) with Environmental Chambers

Tinius Olsen Model 104 IZOD Tester

Haake Polylab Rheometer

Brookfield Rheomix Rheometer

TA Instruments ARES G2 Rotational Rheometer

TA Instruments Q800 Dynamic Mechanical Analyzer

TA Instruments Q200 TM Differential Scanning Calorimeter

Carl Zeiss AxioImager M1m Motorized Microscope

Ultrasonic NDI Table

Krautkramer USN 58L Ultrasonic Flaw Detector

Laser Doppler Velocimeter (LDV)

QUV Accelerated Weathering Tester

The lab also has ready access to a range of other advanced analytical instruments across the SDSMT campus, including:

Atomic absorption spectroscopy

BET surface analyzer C, S, H, N and O elemental analyzer

Chromatography: Gas and Liquid, Gel and Ion

Field emission variable pressure hi-resolution ESEM

Inductively coupled argon plasma mass spectrometry

Interfacial force microscopy

Hysitron nano-indenter and MTS nano-indenter

Laser induced breakdown spectroscopy

Laser Raman spectroscopy

Mid- and Near- infrared spectroscopy

NMR spectroscopy

SEM with energy-dispersive X-ray analyzer

Scanning/Transmission electron microscopy

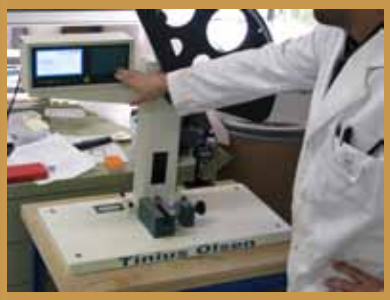
Scanning probe microscopy (AFM, IFM and STM)

Time correlated single photon counting fluorescence spectroscopy

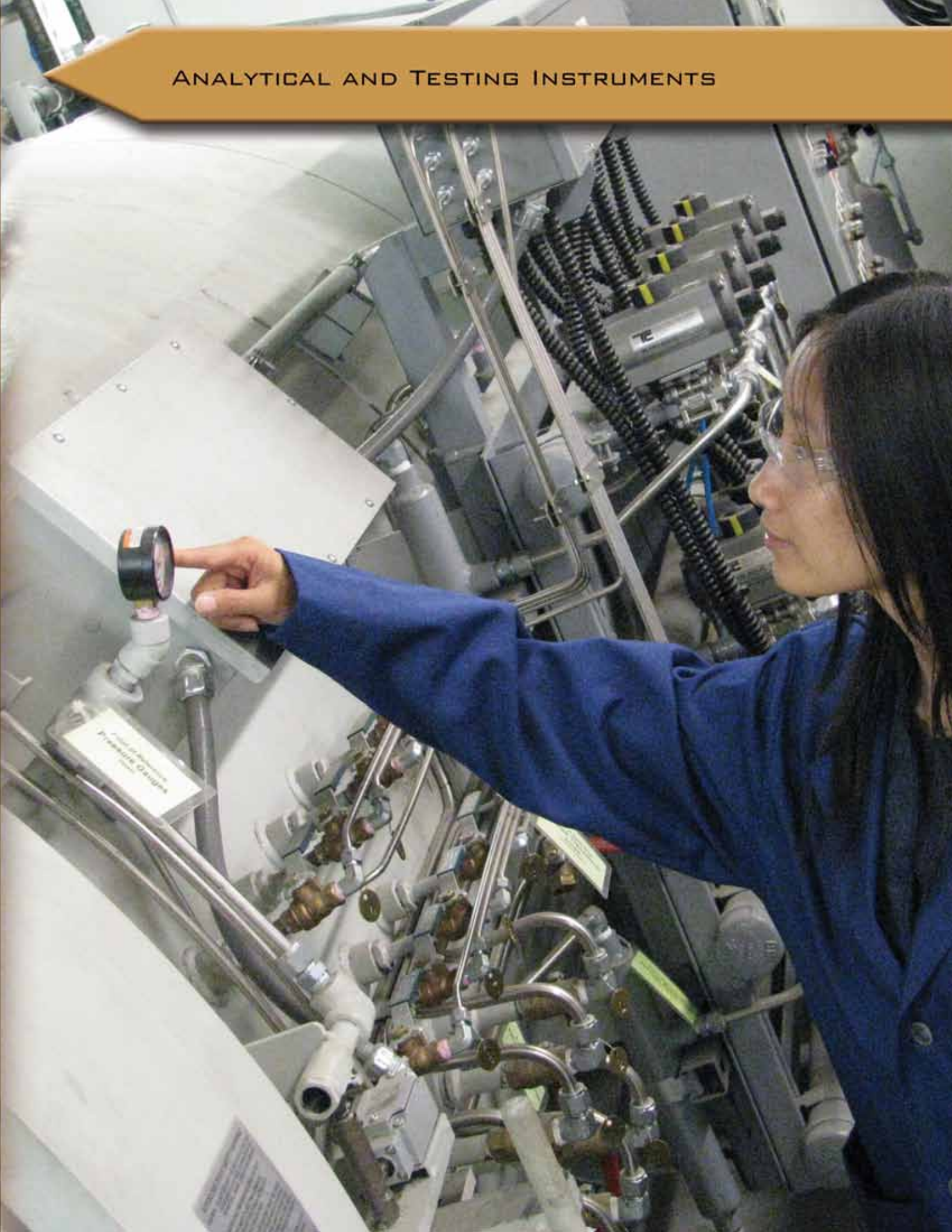
UV-Vis spectroscopy

Vibrational sum-frequency generation spectroscopy

X-Ray diffraction



Analytical and Testing Instruments



EDUCATIONAL ACTIVITIES

The CAPE Laboratory's educational mission is to play a key role in producing the next generation of polymer/composites engineers and scientists.

At the graduate level, CAPE Laboratory supports selected M.S. and Ph.D. students who work on thesis research in areas of interest to the laboratory.

At the undergraduate level, the CAPE Laboratory offers instruction and practical training in composites processing and characterization. This takes a number of forms, including: (1) a 1-credit lecture and laboratory course in composites manufacturing; (2) lab assistant training and employment of selected students; (3) support for senior student projects in the field of polymers and composites; and (4) support for design teams involved in national and international engineering competitions.

Undergraduate design teams supported by the CAPE Laboratory include:

Wind Turbine Development

Human-Powered Vehicle Competition

Supermileage Society of Automotive Engineers (SAE) Competition

Formula SAE Competition

Baja SAE Competition

Association for Unmanned Vehicle Systems International (AUVSI) International Aerial Robotics Competition

TEAM WITH THE CAPE LAB

Advances in the understanding of chemical and physical structure of polymers have led to the development of materials with exceptional properties. As a result of the ability to engineer polymer and composite structures to meet specific property requirements, these materials are utilized in a wide spectrum of demanding applications, including aerospace, medicine, renewable energy and construction. Today, the emergence of nanofibers, nanocomposites, polymer-ceramic hybrids, conductive polymers, electroactive polymers, biopolymers, biocomposites and other new polymer-based materials, is generating a further wave of innovation that will impact our everyday lives. We invite you to team with the CAPE Laboratory in researching and developing the exciting polymer and polymer-composite materials of tomorrow.

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