DEPARTMENT OF MACROMOLECULAR SCIENCE AND ENGINEERING

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Macromolecular science and engineering is the study of the synthesis, structure, processing, and properties of polymers. These giant molecules are the basis of synthetic materials including plastics, fibers, rubber, films, paints, membranes, and adhesives. Research is constantly expanding these applications through the development of new high performance polymers, e.g. for engineering composites, electronic, optical, and biomedical uses. In addition, most biological systems are composed of macromolecules—proteins (e.g. silk, wool, tendon), carbohydrates (e.g. cellulose) and nucleic acids (RNA and DNA) are polymers and are studied by the same methods that are applied to synthetic polymers.

Production of polymers and their components is central to the chemical industry, and statistics show that over 75 percent of all chemists and chemical engineers in industry are involved with some aspect of polymers. Despite this, formal education in this area is offered by only a few universities in this country, resulting in a continued strong demand for our graduates upon completion of their BS, MS, or PhD degrees.

Mission

To educate students who will excel and lead in the development of polymeric materials and the application of structure-property relationships. The department seeks to prepare students for either professional employment or advanced education, primarily in this or related science or engineering disciplines, but also in professional schools of business, law or medicine. Undergraduate students are offered opportunities for significant research experience, capitalizing on the strength of our graduate program.

Research

The research activities of the department span the entire scope of macromolecular science and polymer technology.

Synthesis

New types of macromolecules are being made in the department's synthesis laboratories. The emphasis is on creating polymers with novel functional properties such as photoconductivity, selective permeation, and biocompatibility, and in producing new materials which behave like classical polymers without being linked together by covalent bonds.

Physical Characterization

This is the broad area of polymer analysis, which seeks to relate the structure of the polymer at the molecular level to the bulk properties that determine its actual or potential applications. This includes characterization of polymers by infrared, Raman, and NMR and mass spectroscopy, thermal and rheological analysis, determination of structure and morphology by x-ray diffraction, electron microscopy, and atomic force microscopy, permeability and free volume, and investigation of molecular weights and conformation by light scattering.

Mechanical Behavior and Analysis

Polymeric materials are known for their unusual mechanical capabilities, usually exploited as components of structural systems. Analysis includes the study of viscoelastic behavior, yielding and fracture phenomena and a variety of novel irreversible deformation processes.

Processing

A major concern of industry is the efficient and large scale production of polymer materials for commercial applications. Research in this area is focusing on reactive processing, multi-layer processing and polymer mixing, i.e., compounding and blends. The integration of sensors and processing equipment, and methods for examining changes in structure and composition during processing steps are growing areas of inquiry. Both laboratory and simulation research are brought to bear on these critical issues.

Materials Development and Design

Often, newly conceived products require the development of polymeric materials with certain specific properties or design characteristics. Materials can be tailor-made by designing synthesis and processing conditions to yield the best performance under specified conditions. Examples might be the design of photoluminescent and semi-conducting polymers for use in optoelectronic devices, polymers that are stable at high temperatures for fire-retardant construction materials, high temperature polymer electrolytes for use in advanced fuel cells, low density thermal insulating polymer composite materials, advanced polymeric optical devices, and biocompatible polymers for use in prosthetic implants, reconstructive medicine and drug-delivery vehicles.

Biopolymers

Living systems are composed primarily of macromolecules, and research is in progress on several projects of medical relevance. The department has a long-standing interest in the hierarchical structure and properties of the components of connective tissues (e.g., skin, cartilage, and bone). The department is also engaged in the development of new biocompatible polymers for applications in human health.

Faculty

Gary Wnek, PhD
(University of Massachusetts, Amherst)
The Joseph F. Toot, Jr. Professor and Chair
Polymeric biomaterials for drug delivery and regenerative medicine; nano- and micro-fiber fabrication; bio-mimicking approaches for polymer flammability mitigation; polymer packaging systems design; polyelectrolyte gels and elastomers; physiologically-mimicking macromolecular constructs with attention to primitive motile and irritable systems

Eric Baer, DEng
(Johns Hopkins University)
Director, Centered for Layered Polymeric Systems (CLiPS) and Herbert Henry Dow Professor of Science and Engineering
Multilayered and ultrathin polymer films and devices. Irreversible microdeformation mechanisms; pressure effects on morphology and mechanical properties; relationships between hierarchical structure and mechanical function; mechanical properties of soft connective tissue; polymer composites and blends; polymerization and crystallization on crystalline surfaces; viscoelastic properties of polymer melts; damage and fracture analysis of polymers and their composites. Structure-property relationships in biological systems

Michael Hore, PhD
(University of Pennsylvania)
Associate Professor
Polymer physics; neutron scattering; polymer nanocomposites; grafted polymers and brushes; theory and modeling; self-consistent field theory; structure-property relationships; reconfigurable materials.

Hatsuo Ishida, PhD
(Case Western Reserve University)
Professor
Processing of polymers and composite materials; structural analysis of surfaces and interfaces; molecular spectroscopy of synthetic polymers

João Maia, PhD
(University of Wales Aberystwyth, U.K.)
Associate Professor
Polymer rheology: extensional rheology and rheometry; micro- and nano-rheology; bio-rheology: food rheology and processing; rheology for macromolecular technology: development and optimization of polymer blends and composites; viscoelasticity of micro- and nano-layered polymer films; on- and in-line monitoring of extrusion-based processes; micro-processing; environmental rheology and processing

Ica Manas-Zloczower, DSc
(Israel Institute of Technology)
Professor
Structure and micromechanics of fine particle clusters; interfacial engineering strategies for advanced materials processing; dispersive mixing mechanisms and modeling; design and mixing optimization studies for polymer processing equipment through flow simulations

Svetlana Morozova
(University of Massachusetts, Amherst)
Assistant Professor
Polymer dynamics

Valentin Rodionov, PhD
(Scripps Res. Institute)
Assistant Professor
Organic polymer chemistry; synthesis of novel macromolecular structures and architectures; catalysis

Lei Zhu, PhD
(University of Akron)
Professor
Nanoscale structure and morphology of crystalline/liquid crystalline polymers and block copolymers; ferroelectric and dielectric polymers for electric energy storage; polymer/inorganic hybrid nanocomposites; biodegradable polymers for diagnostic and drug delivery

Secondary Faculty

James M. Anderson, PhD
(Oregon State University, M.D.)
Professor of Macromolecular Science, Pathology, and Biomedical Engineering
Biocompatibility, inflammation, foreign body reaction to medical devices, prostheses, and biomaterials

Donald Feke, PhD
(Princeton University)
Professor of Chemical Engineering and Macromolecular Science
Fine-particle processing, colloidal phenomena, dispersive mixing, and acoustic separation methods

Roger French, PhD
(Massachusetts Institute of Technology)
F. Alex Nason Professor of Materials Science
Optical materials and elements, optical properties and electronic structure of materials, and electrodynamic van der Waals-London dispersion interactions

John Protasiewicz, PhD
(Cornell University)
Professor of Chemistry
Inorganic, organic, main group, materials, polymer, catalysis, organometallic chemistry, and X-ray crystallography

Charles Rosenblatt, PhD
(Harvard University)
Professor of Physics
Experimental condensed matter physics and liquid crystal physics

Kenneth Singer, PhD
(University of Pennsylvania)
Professor of Physics
Modern optics and condensed matter experiment and nonlinear optics

Philip Taylor, PhD
(Cambridge University, England)
Perkins Professor of Physics
Phase transitions and equations of state for crystalline polymers; piezoelectricity and pyroelectricity

Horst von Recum, PhD
(University of Utah, Salt Lake City)
Assistant Professor of Biomedical Engineering
Novel platforms for the delivery of molecules and cells and the use of novel stimuli-responsive polymers for use in gene and drug delivery

Adjunct Faculty

Thomas Chapin, PhD
(University of Connecticut)
Vice President, UL Laboratories
Polymer Flammability

Lashanda Korley, PhD
(Massachusetts Institute of Technology)
Distinguished Professor, Materials Science & Engineering and Chemical & Biomolecular Engineering, University of Delaware
Hierarchical peptide polymer hybrids; new fiber manufacturing strategies for functional material development; responsive composites; interplay of covalent and non-covalent interactions

Jon Pokorski, PhD
(Northwestern University)
Associate Professor, Nanoengineering, University of California San Diego
Biomaterials for delivery of therapeutic proteins; protein-polymer conjugates; drug-delivery; biopolymer catalysts; self-assembling peptides; affinity-based delivery of therapeutics; layered polymeric delivery systems

Stuart Rowan, PhD
(University of Glasgow)
Professor, The Institute for Molecular Professor for Molecular Engineering, Innovation and Enterprise, University of Chicago
Supramolecular chemistry; synthesis of metallosupramolecular and stimuli-responsive polymers; isolation and utilization of cellulose nanocrystals in biomimetic and porous systems; reversible covalent chemistry

Christoph Weder, DrScNat
(ETH Zurich Switzerland)
Professor of Polymer Chemistry and Materials and Director, Adolphe Merkle Institute of the University of Fribourg, Switzerland
Design, synthesis and investigation of structure-property relationships of novel functional polymers: polymers with unusual optic and/or electronic properties; (semi)conducting conjugated polymers; stimuli-responsive polymers; biomimetic materials, polymer nanocomposites, supramolecular chemistry

CWRU/Brazil Dual PhD Degree Adjunct Professors

Rosario Elida Suman Bretas, PhD
(Federal University of Sao Carlos)
Professor
Department of Materials Engineering

Veronica Maria de Araujo Calado, PhD
(Federal University of Rio de Janeiro)
Professor

Sebastiao Vicente Canevarolo Junior, PhD
(Federal University of Sao Carlos)
Professor
Center for Exact and Technology, Dept of Materials Engineering

Leonardo Bresciani Canto, PhD
(Federal University of Sao Carlos)
Professor
Department of Materials Engineering

Marcio da Silveira Carvalho, PhD
(Pontifical Catholic University of Rio de Janeiro)
Professor
Department of Mechanical Engineering

Osvaldo de Lazaro Casagrande Junior, PhD
(Federal University of Rio Grande do Sul)
Professor
Department of Organic Chemistry

Jose Roberto Moraes d'Almeida, PhD
(Federal University of Rio de Janeiro)
Professor
Department of Chemical Engineering

Griselda Barrera Galland, PhD
(Federal University of Rio Grande do Sul)
Professor
Institute of Chemistry

Aurora Perez Gramatges, PhD
(Pontifical Catholic University of Rio de Janeiro)
Professor
Department of Chemistry

Elizabete Fernandes Lucas, PhD
(Federal University of Rio de Janeiro)
Professor
Institute of Macromolecules

Raquel Santos Mauler, PhD
(Federal University of Rio Grande do Sul)
Professor
Department of Organic Chemistry

Paulo de Souza Mendes, PhD
(Pontifical Catholic University of Rio de Janeiro)
Professor
Department of Mechanical Engineering

Monica Feijo Naccache, PhD
(Pontifical Catholic University of Rio de Janeiro)
Professor
Department of Mechanical Engineering

Sidnei Paciornik, PhD
(Pontifical Catholic University of Rio de Janeiro)
Professor
Department of Materials Engineering

Luiz Antonio Pessan, PhD
(Federal University of Sao Carlos)
Professor
Department of Materials Engineering

Cesar Liberato Petzhold, PhD
(Federal University of Rio Grande do Sul)
Professor
Institute of Chemistry

Joao Henrique Zimnoc Dos Santos, PhD
(Federal University of Rio Grande do Sul)
Professor
Institute of Chemistry

Paulo Henrique Schneider, PhD
(Federal University of Rio Grande do Sul)
Professor
Institute of Chemistry

Henri Stephan Schrekker, PhD
(Federal University of Rio Grande do Sul)
Professor
Institute of Chemistry

Argimiro Resende Secchi, PhD
(Federal University of Rio de Janeiro)
Professor
COPPE-Chemical Engineering Program

Bluma Guenther Soares, PhD
(Federal University of Rio Grande do Sul)
Professor
Institute of Chemistry

Marcio Nele De Souza, PhD
(Federal University of Rio de Janeiro)
Professor
Department of Chemical Engineering

Frederico Wanderley Tavares, PhD
(Federal University of Rio de Janeiro)
Professor
School of Chemistry and Program of Chemical Engineering of COPPE

Roney Leon Thompson, PhD
(Federal University of Rio de Janeiro)
Professor
Department of Mechanical Engineering

Emeritus Faculty

John Blackwell, PhD
(University of Leeds, England)
Leonard Case Jr. Professor
Determination of the solid state structure and morphology of polymers. X-ray analysis of the structure of thermotropic copolyesters, copolyimides, polyurethanes, polysaccharides; supramolecular assemblies, fluoropolymers; molecular modeling of semi-crystalline and liquid crystalline polymers; rheological properties of polysaccharides and glycoproteins

Alexander M. Jamieson, DPhil
(Oxford University, England)
Professor
Quasielastic laser light scattering; relaxation and transport of macromolecules in solution and bulk; structure-function relationships of biological macromolecules

David A. Schiraldi, Ph.D.
(University of Oregon)
Peter A. Asseff, Professor of Organic Chemistry Emeritus
Composites, including Aerogel composites, structure-property relationships, transport phenomena and packaging materials, condensation polymers, bio-based polymer synthesis, polymer flammability and sustainable FR agents, polymer blends and complex polymer systems.

Programs

- Macromolecular Science, MS
- Macromolecular Science, PhD
- Polymer Science and Engineering, BSE
- Polymer Science and Engineering, Minor

Dual Degrees

- Undergraduate Programs toward Graduate or Professional Degrees

Facilities

The Kent Hale Smith Science and Engineering Building houses the Department of Macromolecular Science. The building was built in 1993, and specifically designed to meet the specific needs of polymer research. The facility consists of five floors, plus a basement. The laboratories for chemical synthesis are located principally on the top floor, the molecular and materials characterization laboratories on the middle floors, and the major engineering equipment on the ground floor, while the NMR, MALDI-TOF, and TA-Instruments. Thermal Characterization instrumentation are located in the basement. Modern, computer-interfaced classrooms are installed on the ground floor. Additional instrumentation available includes Small and Wide-Angle X-ray diffractometers; scanning electron microscopy; a complete range of molecular spectroscopic equipment including FTIR, laser Raman, and high resolution solution and solid-state NMR (including imaging), as well as Raman and FTIR microscopes; and dynamic light scattering spectroscopy. There are also facilities for polymer characterization (molecular weight distribution), optical microscopy, solution and bulk rheology, scanning calorimetry, and for testing and evaluating the mechanical properties of materials. A newly built-out processing lab provides the complete suite of Thermo-Fisher batch, single- and twin-screw mixing and extrusion equipment, as well as that manufacturer's state of the art rheometers. The C. Richard Newpher polymer processing laboratory includes a high temperature Rheometrics RMS-800 dynamic mechanical spectrometer, a Bomem DA-3 FTIR with FT-Raman capabilities, a compression molding machine, a Brabender plasticorder, a high speed Instron testing machine, and a vibrating sample magnetometer. The Charles E. Reed '34 Laboratory is concerned with the mechanical analysis of polymeric materials. The major testing is done by Instron Universal testing instruments including an Instron model 1123 with numerous accessories such as an environmental chamber for high or low temperature experiments. Additional mechanical testing of fibers, films and injection-molded (Boy model 22-S) are provided by MTS universal testers which are used for both research and undergraduate teaching laboratory classes. The NSF Center for Layered Polymeric Systems (CLiPS) has its central facility within the department, with three cutting-edge multilayer extrusion systems as its centerpiece. CLiPS also operates a Bruckner KARO IV biaxial stretching unit, which allows controlled biaxial stretching of polymer films, and an Atomic Force Microscope which probes the morphological and mechanical properties of materials at the nanoscale. The Molecular Modeling Center provides access to various software packages for the rheological and molecular modeling of polymers.