

The logo consists of the letters 'UF' in a white, bold, sans-serif font, centered within a solid orange square. The background of the entire page is a blue-tinted collage of various images showing students and researchers in laboratory and classroom settings. The top and bottom edges of the page feature decorative borders with a pattern of small white dots on a blue background.

UF

DEPARTMENT OF
CHEMICAL ENGINEERING

GRADUATE PROGRAMS

MESSAGE FROM THE CHAIR



Carlos M. Rinaldi-Ramos, Ph.D.
DEPARTMENT CHAIR AND
DEAN'S LEADERSHIP PROFESSOR

WE ARE DELIGHTED TO PROVIDE YOU WITH INFORMATION ABOUT

our department and its exciting graduate programs. The University of Florida has over 100 years of history and tradition in excellence in chemical engineering research and education, and is among the largest and highest ranked chemical engineering programs in the southeastern region.

Our faculty are leaders in research and education. They include Distinguished Professors, Fellows of professional societies, and recipients of national and international awards. Our students are passionate about finding solutions to societal problems through the application of chemical engineering principles. Our staff are committed to supporting faculty and students alike. Together, we strive to create an environment supportive of scholarly work that is also welcoming to diverse backgrounds and thinking.

Our research and educational activities extend beyond the department, as many of our faculty collaborate with peers in other disciplines and either lead or are active members of multidisciplinary centers. We are located within a short walk to the Nanoscale Research Facility, UF College of Medicine, the Emerging Pathogens Institute, the UF Cancer & Genetics Research Complex, and the UF Clinical & Translation Science Institute, which facilitate fruitful interdisciplinary collaborations.

While the University of Florida provides a wonderful academic environment, the quality of life in the city of Gainesville and the surrounding community is second to none. Serving as the cultural, educational, and commerce center of beautiful North Central Florida, Gainesville is only an hour from both the Atlantic Ocean and the Gulf of Mexico and less than two hours from Jacksonville, Orlando, and Tampa.

Thank you for your interest, we invite you to apply today.

- Carlos M. Rinaldi-Ramos, Department Chair





DEPARTMENT OF
CHEMICAL ENGINEERING
INFORMATION



HERBERT WERTHEIM
COLLEGE OF ENGINEERING



THE UNIVERSITY OF FLORIDA



PROGRAMS OF STUDY



RESEARCH AREAS/FACULTY



GRADUATE LIFE



ABOUT GAINESVILLE

THE DEPARTMENT

THE DEPARTMENT OF CHEMICAL ENGINEERING AT THE UNIVERSITY OF FLORIDA PROVIDES A WONDERFUL ACADEMIC ENVIRONMENT FOR GRADUATE SCHOOL, INCLUDING EXCEPTIONAL FACULTY, RESOURCES, AND A PICTURESQUE CAMPUS.

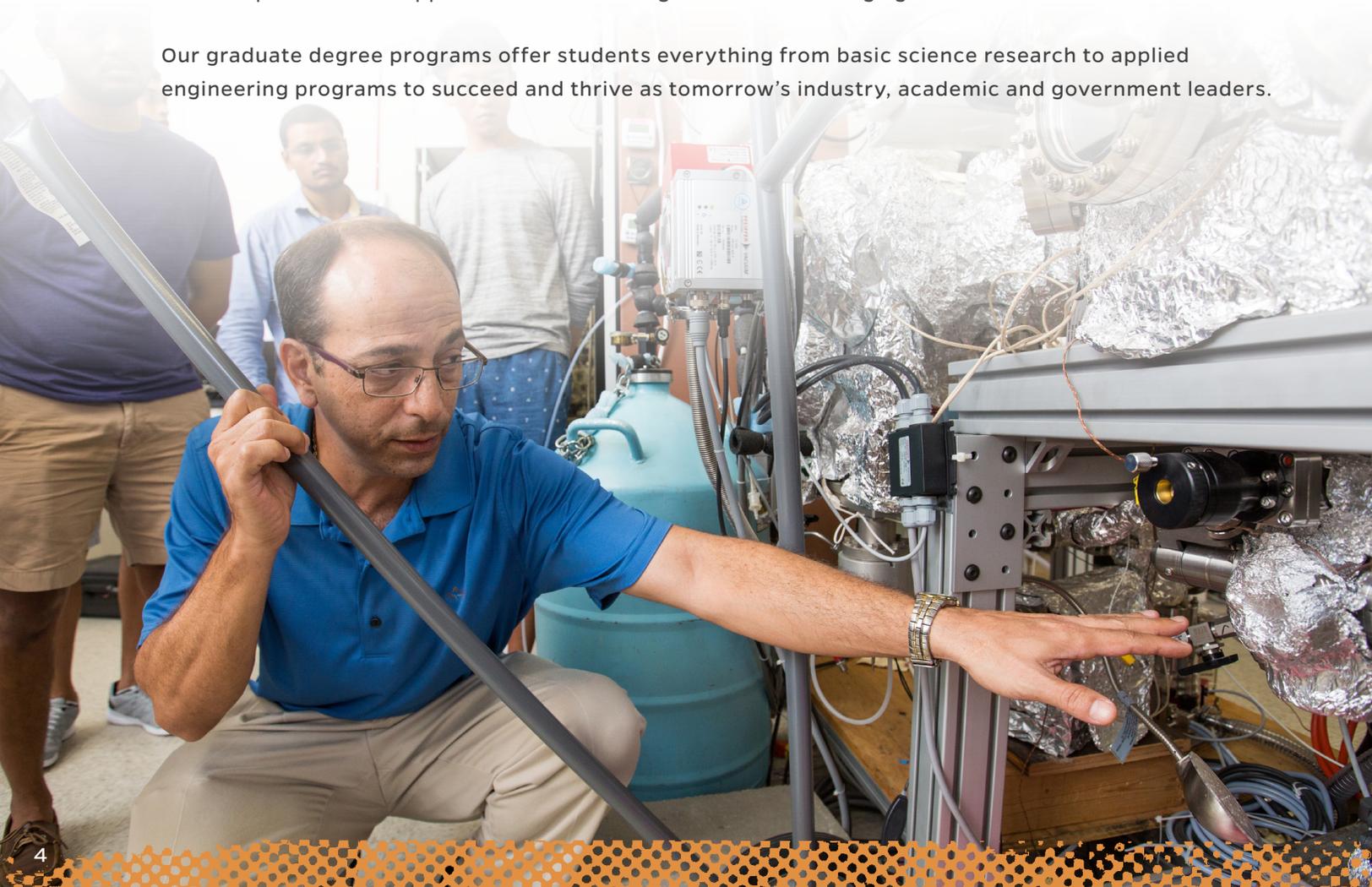
The Department of Chemical Engineering has 29 faculty members engaged in graduate research and teaching. Their interests span a wide range of topics including bioengineering, nanotechnology, complex fluids, catalysis, advanced materials processing, and surface and interfacial phenomena. This diversity of interests is reflected in the types of graduate courses available at both the department and the college, allowing our students excellent opportunities to obtain a broad background in chemical engineering.

Many faculty are leading members or directors of special university centers, such as the Florida Energy Systems Consortium, the Institute for Cell & Tissue Science and Engineering, the Nanoscale Institute for Medical Engineering Technology, the Particle Engineering Research Center, the UF Health Cancer Center, and the National High Magnetic Field Laboratory.

Support for our programs comes from federal agencies such as NSF, NIH, NASA, DOE, DOD, and non-profit organizations, such as the American Chemical Society and the Gas Research Institute.

The department emphasizes fundamental academic work that traditionally provides the basis for commercial development and manufacturing. The relevance of our research studies is demonstrated by industrial funds from a large number of chemical, aerospace, defense and semiconductor companies that also complement the support we receive from government funding agencies.

Our graduate degree programs offer students everything from basic science research to applied engineering programs to succeed and thrive as tomorrow's industry, academic and government leaders.



SUPPORTING YOU ALONG THE WAY



All Ph.D. students making satisfactory progress receive **guaranteed funding**, including \$30,000+ stipend, tuition and health insurance, from first semester until degree awarded



Competitive university fellowships and opportunities for professional development and outreach



College and department sponsored activities for students to interact with industry leaders and academic mentors in preparation for a variety of careers



Award-winning faculty recognized for their role in Ph.D. mentoring



Vibrant and diverse community to fulfill your intellectual and social needs and support your mental health

100+

**GRADUATE STUDENTS
FROM DIVERSE
BACKGROUNDS AND
CULTURES**

OVER

4,150

CHE ALUMNI

#5

**UF RANKED NUMBER 5
AMONG PUBLIC
UNIVERSITIES**

U.S. NEWS & WORLD REPORT 2022

OUTSTANDING RESEARCH FACILITIES

Ph.D. students have the opportunity to become experts in operation of and data collection with state-of-the-art instrumentation at UF's Research Service Centers



#26

**BEST CHEMICAL
ENGINEERING GRADUATE
PROGRAM OVERALL**

U.S. NEWS & WORLD REPORT 2022

The HiPerGator supercomputer at the University of Florida enables Ph.D. students to simulate transport, molecular dynamics, and reactions in an array of systems, including catalyst interfaces and polymeric materials

35%

**OF FACULTY AWARDED
PROFESSORSHIPS**



**CENTRALLY LOCATED NEAR
THE COLLEGE OF MEDICINE
AND WORLD-CLASS
RESEARCH CENTERS**

ENGAGED STUDENT ORGANIZATIONS

- Peer mentoring program for Ph.D. students
- Social and cultural events
- Community outreach
- Annual student research symposium

29

**RESEARCH AND TEACHING
FACULTY AND GROWING**

11

**NEW FACULTY
SINCE FALL 2018**

**MORE THAN A CHEMICAL ENGINEERING DEPARTMENT,
WE'RE EMBEDDED IN THE DYNAMIC
HERBERT WERTHEIM COLLEGE OF ENGINEERING.**

**OUR DEPARTMENT IS HOUSED IN OUR FOUR-STORY,
51,000-SQUARE-FOOT BUILDING,
MUCH OF WHICH IS DEVOTED TO RESEARCH.**

415,000+

**UF ALUMNI RESIDING IN EVERY STATE
AND IN MORE THAN 150 COUNTRIES**

OUR GRADUATES ARE EMPLOYED BY (PARTIAL LIST):

ACADEMIC

Kansas State University
Korea Institute of Science and
Technology (S. Korea)
Massachusetts Institute of Technology
Oregon State University
University of Alabama
University of South Florida
University of Tulsa
University of Virginia
Vanderbilt University
Virginia Polytechnic Institute
and State University

INDUSTRIAL

Albemarle
AMD
Applied Materials
ASM International
Corning
ExxonMobil
Honeywell
Intel
Keysight
LG Chem
Mainstream Engineering
Medtronics

Samsung
Shell
Shire Pharmaceuticals
Sun Chemical
Taiwan Semiconductor

NATIONAL LABS

Army Research Laboratory
Idaho National Laboratory
NASA
National High Magnetic Field Laboratory
Naval Research Laboratory
Wright-Patterson Air Force Base

THE COLLEGE

THE HERBERT WERTHEIM COLLEGE OF ENGINEERING HOUSES ONE OF THE LARGEST AND MOST DYNAMIC ENGINEERING PROGRAMS IN THE NATION.

- Curriculum offered across 10 departments, 15 degree programs, and more than 20 centers and institutes produces leaders and problem-solvers who take a multidisciplinary approach to innovative and human-centered solutions.
- Engineering is the second largest college, and one of the top three research units at UF.
- The college produces inventions at twice the national average – and startups at three times the national average – for every research dollar spent.
- A significant amount of interdisciplinary research is conducted through centers, such as the Florida Institute for Cybersecurity Research, the Florida Institute for Sustainable Energy, the Nanoscience Institute for Medical and Engineering Technology, the Institute for Cell Engineering and Regenerative Medicine and the Institute for Computational Engineering.
- Students, faculty and alumni are hailed as New Engineers who aim to transform the way we live, work and play.



"I like the diversity that is present at UF. In classes, riding the bus, walking on campus and the department, anywhere."
-Victor Rivera-Llabres, Ph.D. Student

THE HERBERT WERTHEIM LABORATORY FOR ENGINEERING EXCELLENCE is the college's flagship building with an 84,000 square foot state-of-the-art research and educational environment.



THE UNIVERSITY



"UF went above and beyond to make me feel valued and wanted, and had the community which has now given me a home."

-Julie F. Jameson, Ph.D. Candidate



"Gainesville has many nature trails and springs to explore. The proximity to the beaches is also great."

-Aniruddha Kulkarni, Ph.D. Student

WITH OVER 55,000 STUDENTS, THE UNIVERSITY OF FLORIDA IS THE FIFTH LARGEST UNIVERSITY IN THE UNITED STATES.

- UF is ranked number 5 among the nation's top public research universities and is one of only 17 public, land-grant universities that belong to the Association of American Universities.
- The Graduate School coordinates more than 200 graduate programs.
- Over 100 interdisciplinary research centers, bureaus and institutes on campus.
- As a land-grant university identified by the Morrill Act of 1862, UF has a special focus on engineering, as well as agriculture, with a mandate to deliver the practical benefits of university research throughout the state.
- In addition to the 2,000-acre main Gainesville campus, UF has research centers, extension operations, clinics and other facilities and affiliates in every Florida county.



GRADUATE STUDENTS IN THE DEPARTMENT OF CHEMICAL ENGINEERING CAN PURSUE A DOCTORATE OF PHILOSOPHY, MASTER OF SCIENCE (THESIS OR NON-THESIS), AND A MASTER OF ENGINEERING DEGREE.

DOCTORATE OF PHILOSOPHY DEGREE

The Ph.D. degree plan is primarily a research program. Graduate students enrolled in the Ph.D. program will have the opportunity to work closely with our dynamic, internationally-recognized faculty. Many Ph.D. students will have the opportunity to work on innovative research problems through interdisciplinary collaborations in the colleges of engineering, liberal arts and sciences, and medicine, which are all co-located on the Gainesville campus. Ph.D. students will observe a strong commitment to excellence in research and education in both the classroom and the laboratory.

The granting of the degree is based on general proficiency and distinctive achievements of the Ph.D. candidate in their research field. Ph.D. students are expected to demonstrate the ability to conduct independent investigation of research problems and attain mastery of a field of knowledge. Ph.D. students will also have opportunities to gain valuable teaching and communication experience by assisting instructors in the classroom and supervising undergraduate and other graduate researchers in the laboratory.

Briefly, the requirements for the Ph.D. degree are:

1. Completion of at least 90 credits (minimum of 24 credits of coursework) beyond the B.S. degree while maintaining an overall and major GPA of 3.0 or higher. Specific coursework requirements include completion of Continuum Basis, Molecular Basis, Mathematical Basis, and Chemical Engineering Kinetics.
2. Successful completion of a written research proposal and oral qualifying examination based on the candidate's research plan to achieve the objectives for his/her doctoral dissertation and his/her general knowledge of chemical engineering fundamentals.
3. Successful completion of a written doctoral dissertation and final oral examination based on the candidate's original research.

Final acceptance into the Ph.D. program requires successful completion of both the research proposal and the oral qualifying examination. Although the time to complete all Ph.D. degree requirements is dependent on the specific research program and student motivation, the minimum requirements for the Ph.D. program are typically met in 3 – 5 years following a B.S. degree.

All Ph.D. students that maintain good academic standing receive competitive stipends, tuition waivers, and medical insurance.

MASTER OF SCIENCE DEGREE

The Master of Science program provides an opportunity to develop an in-depth knowledge of chemical engineering fundamentals. M.S. students are encouraged to emphasize their coursework on a specific specialization area within chemical engineering. M.S. students are also strongly encouraged to take advantage of courses that focus on valuable management experience in chemical engineering settings. Many students also acquire applied and fundamental skills through departmental research or industrial internships.

All new M.S. students are admitted to the Non-Thesis option at the time of admission. M.S. students enrolled in the Thesis option are required to add a research component to the degree plan. Those M.S. students that desire to improve their research skills may convert to the Thesis option upon approval of their research advisor and the Associate Chair for Graduate Studies.

M.S. students typically complete the degree requirements within 12 to 24 months. Briefly, the formal requirements for the M.S. degree are:

1. Completion of at least 30 credits of coursework beyond the B.S. degree, including Continuum Basis, Mathematical Basis, Chemical Engineering Kinetics, and Advanced Chemical and Biological Processing Laboratory.
2. Successful completion of a written thesis or report on a research project, internship, or a contemporary chemical engineering topic.
3. Successful completion of final oral examination based on the student's innovative and original research (Thesis Option).

M.S. students who demonstrate exceptional understanding of chemical engineering fundamentals and outstanding progress in research achievements may advance to the Ph.D. program when there are available opportunities.

MASTER OF ENGINEERING DEGREE

The Master of Engineering program is designed for students that already hold a Bachelor of Science degree in biology, chemistry, physics, mathematics, or another branch of engineering. The program provides an opportunity for M.E. students to develop an in-depth knowledge of chemical engineering fundamentals through both undergraduate and graduate coursework. M.E. students need to complete core classes associated with an undergraduate degree in chemical engineering before enrolling in most graduate-level courses. Many students also acquire basic experience in research or industrial practice through a short internship.



RESEARCH AREAS

Advanced Materials, Devices, and Nanotechnology

CORE FACULTY

Won Tae Choi	p. 11	Yeongseon Jang	p. 16	Janani Sampath	p. 20
Helena Hagelin-Weaver	p. 13	Peng Jiang	p. 16	Whitney Stoppel	p. 20
Charles Hages	p. 14	Mark Orazem	p. 18	Kirk Ziegler	p. 22
David Hibbitts	p. 15	Fan Ren	p. 19		
Piyush Jain	p. 15	Carlos Rinaldi-Ramos	p. 19		

Biomolecular Engineering, Cellular Engineering, and Synthetic Biology

CORE FACULTY

Henry Chu	p. 12	Yeongseon Jang	p. 16	Janani Sampath	p. 20
Carl Denard	p. 13	Mark Orazem	p. 18	Whitney Stoppel	p. 20
Richard Dickinson	p. 13	Fan Ren	p. 19	Spyros Svoronos	p. 21
Piyush Jain	p. 15	Carlos Rinaldi-Ramos	p. 19		

Complex and Multiphase Flow Dynamics

CORE FACULTY

Jason Butler	p. 11	Dmitry Kopelevich	p. 17	Ranga Narayanan	p. 18
Henry Chu	p. 11	Tony Ladd	p. 17		

Energy, Environment, and Sustainability

CORE FACULTY

Won Tae Choi	p. 11	David Hibbitts	p. 15	Sergey Vasenkov	p. 21
Henry Chu	p. 12	Peng Jiang	p. 16	Jason Weaver	p. 22
Oscar Crisalle	p. 12	Mark Orazem	p. 18	Kirk Ziegler	p. 22
Helena Hagelin-Weaver	p. 14	Janani Sampath	p. 19		
Charles Hages	p. 14	Spyros Svoronos	p. 21		

Heterogeneous Catalysis and Surface Science

CORE FACULTY

Helena Hagelin-Weaver	p. 14	Jason Weaver	p. 22
David Hibbitts	p. 15	Kirk Ziegler	p. 22

Modeling, Theory, and Simulation

CORE FACULTY

Henry Chu	p. 12	Tony Ladd	p. 17	Janani Sampath	p. 20
David Hibbitts	p. 15	Ranga Narayanan	p. 18	Spyros Svoronos	p. 21
Dmitry Kopelevich	p. 17	Mark Orazem	p. 18		

Transport, Molecular Thermodynamics, and Electrochemical Engineering

CORE FACULTY

Jason Butler	p. 11	Dmitry Kopelevich	p. 17	Carlos Rinaldi-Ramos	p. 19
Won Tae Choi	p. 11	Tony Ladd	p. 17	Sergey Vasenkov	p. 21
Henry Chu	p. 12	Ranga Narayanan	p. 18	Kirk Ziegler	p. 22
Charles Hages	p. 14	Mark Orazem	p. 18		



JASON E. BUTLER, PROFESSOR

Ph.D., 1998, University of Texas at Austin

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MY RESEARCH GROUP GENERATES INSIGHTS AND SOLUTIONS

to problems regarding the transport of complex fluids using experimental, computational, and theoretical methods. Complex fluids, which encompass suspensions

of particulates, emulsions, polymer solutions, and more, serve important roles in a wide range of industries as well as emerging technologies. Efficient control and processing of these fluids requires predictive capabilities that, in most cases, are lacking, as they often demonstrate nonlinear dynamics that create unexpected and intriguing observations.

Some specific examples from our work are described:

MACROMOLECULAR TRANSPORT IN MICROFLUIDICS

Microfluidic, or lab-on-chip, technologies have the potential to significantly improve medical diagnostic capabilities and accelerate advances in biological and biochemical research. Realizing this promise requires the ability to model and manipulate macromolecular motion within these small devices. As one effort, we have been examining transport dynamics of DNA, a

polyelectrolyte, through electrodeless channels. The work has demonstrated new and unexpected methods that can be harnessed to control the cross-stream distribution of DNA using a combination of pressure gradients and electric fields. We are validating our model of this phenomenon through rigorous comparison of experimental results and simulations while simultaneously investigating technological applications such as the extraction of DNA from biological samples.

SUSPENSION RHEOLOGY AND DYNAMICS

Suspensions of particles in viscous fluids are found in everyday materials such as concrete, in industrial advanced technological applications, and even in natural processes. Consequently, advances in evaluation in the transport properties and predictive capabilities for the dynamics will have a widely distributed impact through improved ability to rationally design processes. Some recent work in our group is focused on assessing the precise origin of irreversibilities in non-colloidal suspensions of spheres; these irreversibilities can cause, as one example, suspensions to demix during rheological testing and create inaccurate estimates of viscosities. Much of our work examines suspensions of rod-like particles, where coupling of the orientational dynamics with the flow field and center-of-mass motion creates truly complex results.



WON TAE CHOI, ASSISTANT PROFESSOR

Ph.D., 2017, Georgia Institute of Technology

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THE CHOI LAB RESEARCH IS AIMED AT RATIONAL DESIGN AND ENGINEERING OF NEXT-GENERATION ELECTROCHEMICAL SYSTEMS FOR HUMAN CONVENIENCE AND ENERGY APPLICATIONS.

WE SEEK TO ADDRESS key questions related to electrochemical systems

by leveraging electrochemistry, materials chemistry, and device engineering. Our interests include (1) synthesis of new materials for electrochemical devices, (2) combining electroanalytical chemistry, spectroscopy, and synchrotron characterizations to understand thermodynamics and kinetics of charge transfer processes, (3) perturbing chemistry and physics of materials to develop structure-property relationships, and (4) developing architectures for efficient energy storage and conversion devices and next-generation electronics.

CHARGE TRANSPORT OF CONJUGATED POLYMERS

Significant attention has been paid to utilize conjugated polymers in a liquid environment for potential applications such as sensors, bioelectronics, energy conversion/storage devices (battery, supercapacitors, and solar fuel productions), and neuromorphic computing. The charge transport is a keystone to determine the performance of polymer-based electrochemical

or photoelectrochemical devices, which is largely affected by physicochemical properties of polymers and interfacial phenomena at polymer/liquid junctions. We will focus on 1) unveiling structure-property relationship by the combination of electroanalysis, spectroscopy, and synchrotron characterizations, 2) design and synthesis of new materials suitable for electrochemical and/or photoelectrochemical processes, and 3) developing next generation energy and/or electronic devices.

ELECTROCHEMISTRY OF REDOX ACTIVE COLLOIDS

Redox flow batteries are rechargeable batteries that energy is stored in electrolyte solutions that are pumped through each electrode of flow cells separated by a membrane. Their unique cell architecture brings about large energy storage capacity by increasing the tank volume. Research has been focused on metal salts-based redox flow batteries, but commercialization of such redox flow batteries is hindered by shortcomings including toxicity and scarcity of metal salts and high cost (500 USD per square meter) of ion exchange membrane. We will focus on 1) design and synthesis of redox active colloids, 2) investigating electrochemical activities using advanced electrochemical analysis techniques (i.e., scanning electrochemical microscopy), and 3) developing next-generation materials for safe and affordable redox flow battery technology.



HENRY C. W. CHU, ASSISTANT PROFESSOR

Ph.D., 2017, Cornell University

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THE THEME OF OUR RESEARCH IS HETEROGENEOUS SOFT MATTER TRANSPORT AND DESIGN, covering topics such as complex fluid dynamics, colloid and interface science, electrokinetics, and rheology.

Our research develops predictive multi-scale computational tools (e.g. particle/fluid dynamics simulations) and fundamental theory (e.g. asymptotic/scaling analyses) to address emerging NAE Grand Challenges for Engineering in these research areas, emphasizing on close collaboration with experimental groups to translate knowledge into applications. Examples of applications include enhanced oil recovery, CO2 sequestration, smart materials assembly, sustained drug delivery, engineered functional surfaces, 3D printing, adaptive micro-robots, and microfluidic energy harvesting. Our current research focuses on the following three critical areas:

IONIC GRADIENT-INDUCED TRANSPORT OF COLLOIDS

For charged colloidal particles in an electrolyte solution, the concentration gradient of the electrolyte causes motion of the particles known as diffusiophoresis. We have predicted novel transport phenomena where colloids could be spatially arrested or spread orders of magnitude faster than regular diffusion. We

are expanding our mathematical model for a wider spectrum of particles, electrolytes, and system configurations.

SURFACE TENSION DRIVEN FLOW OVER ACTIVE POROELASTIC MEDIA

Deposition of surfactants onto a liquid surface creates a surface tension gradient, inducing a subsurface “Marangoni” flow. We have developed a computational model to quantify the molecular transport, interfacial dynamics, and multiphase flows. Our ongoing effort is to predict Marangoni flows over microstructured surfaces, particularly flexible and self-propelling poroelastic media.

DESIGNING ADAPTIVE COLLOIDAL TRANSPORT IN HETEROGENEOUS MEDIA

Complex fluids comprise sub-micron size colloids (solid particles, liquid drops, gas bubbles) suspended in a solvent. We have developed a statistical mechanics framework to relate the micromechanics of individual colloid to the macroscopic flow response of the complex fluid. We are advancing the framework to design colloids which could adapt to their surrounding physically and chemically heterogeneous media to achieve specific tasks.

For details of available projects and information of our group, see www.chugroup.site



OSCAR CRISALLE, PROFESSOR

Ph.D., 1990, University of California, Santa Barbara

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OUR RESEARCH FOCUSES ON THE ANALYSIS AND DESIGN of advanced multivariable control systems. Our approach is to establish new theoretical foundations and validate advances through computer simulation studies and

experimental implementations. The applications include energy production systems and fuel cells, the manufacture of integrated microelectronic and photovoltaic devices, control of autonomous vehicles, and the development of on-line measurement instrumentation, among other fields of interest.

CONTROL SCIENCE

We design controllers that deliver high performance in spite of the presence of modeling uncertainty. Ongoing research seeks the synthesis of robust multivariable controllers such as predictive-control, variable-structure control, and frequency-domain techniques, including our formulation of the *Nyquist Robust Stability Margin* as a robustness metric.

VIRTUAL SENSORS

Often critical process variables needed for diagnostics and control cannot be measured because of the inability to place a physical sensor inside constrained geometries. Our group designs software sensors that estimate the value of inaccessible measurements using mathematical models and data from other locations. The technology involves Kalman and Luenberger observers, as well as integral observers that can preserve accuracy even under conditions of data uncertainty.

FUEL CELLS

We are developing direct methanol fuel cells designed to serve as long lasting power supplies for small electrical appliances. Our group conducts first-principles fuel cell modeling work to serve as the basis for designing real-time control manipulations. The objective is to optimize operations and ensure high quality performance. The effort seeks to contribute new green and renewable energy production technologies that can effectively address our society’s growing need for a sustainable energy infrastructure.



CARL DENARD, ASSISTANT PROFESSOR

Ph.D., 2014, University of Illinois at Urbana-Champaign

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My research is in the area of molecular and cellular bioengineering. We apply our expertise in cellular and protein engineering to develop novel strategies to diagnose, target and fight disease.

protein-modifying enzymes in order to repurpose them as novel therapeutic and diagnostic modalities. In one area of focus, we are evolving the specificity of **proteases to target misfolded and aberrant proteins involved in neurodegenerative, autoimmune diseases and cancer**. We hypothesize that catalytic degradation of disease-related proteins can help fight diseases in ways that can be complementary to and mechanistically distinct from current therapeutic approaches.

“DESIGNER” PROTEIN-MODIFYING ENZYMES FOR BIOMEDICINE, BIOTECHNOLOGY AND SYNTHETIC BIOLOGY

Enzymes that catalyze site-specific protein modifications play vital roles in regulating cellular processes. Understanding their substrate specificity not only provides insight into their physiological mechanisms but also enables their selective targeting to remediate disease states. In addition, leveraging the specificity of protein-modifying enzymes enables the development of novel therapeutics, biomedical and biotechnological tools. However, there is a need to expand the limited substrate scope and low catalytic activity of protein-modifying enzymes to fully realize their potential in these domains.

Using methods of protein engineering and synthetic biology, my lab seeks to redefine and redesign the substrate specificity of

In a related area of research, we aim to **evolve enzymes for the site-specific labeling of proteins, cells and biomaterials to improve their therapeutic efficacy and disease targeting**. We envision to generate highly-functionalized therapeutic agents with multipronged and synergistic modes of action.

A complementary research focus is to take advantage of site-specific protein modifications to build circuit-level logic functions that reprogram cellular behavior along rapid time scales. Highly programmable, responsive and predictable synthetic protein circuits will augment genetic engineering by introducing novel design principles that facilitate cellular engineering. In addition to applications in biosensing, successes in this area are central to developing on-demand delivery of catalytic actuators to disease sites.



RICHARD DICKINSON, PROFESSOR

Ph.D., 1992, University of Minnesota

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OUR RESEARCH IS IN THE AREA OF MOLECULAR/CELLULAR bioengineering.

We apply engineering principles to study the behavior of living cells or other small-scale biological systems. Using a combination of engineering

modeling/analysis, quantitative experimentation, together with the tools of molecular cell biology, we seek to better understand the relationship between cell function and the physical and molecular properties of cells and their environment. Our projects are typically in collaboration with experts in microscopy and cell biology.

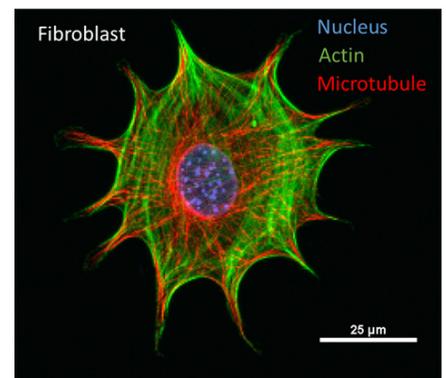
the nucleus and allows the cell to locate its center. Another area of interest is to understand the dynamics and mechanical properties of muscle-like actin filament bundles called stress fibers in non-muscle cells.

FORCE GENERATION OF THE NUCLEUS

Cell behavior depends strongly on the chemical and mechanical properties of its environment. For example, stem cells cultured on compliant materials will differentiate to cells of the tissue type that has similar rigidity. Mechanical cues change gene expression in a process called “mechanotransduction”, which often involves transmission of force from the outside to the cell to the nucleus. One current focus is to understand how these forces are transmitted to generate stresses on the nuclear surface that result in shape changes and positioning of the nucleus.

FORCE GENERATION BY INTRACELLULAR BIOPOLYMERS

Living cells have a cytoskeleton comprised of semi-flexible filaments (actin microfilaments, microtubules, and intermediate filaments), which determine the cell’s mechanical properties and, through their interactions with molecular motors, are responsible for cell movements and intracellular force generation. In one area of focus, we study the reaction/diffusion processes involved with filament assembly that lead to cellular protrusions during cell crawling and propel intracellular pathogens such as *Listeria monocytogenes*. We are also investigating how the molecular motor protein complex dynein generating force on microtubules moves



Credit: Qiao Zhang



HELENA HAGELIN-WEAVER, ASSOCIATE PROFESSOR AND GRADUATE RECRUITMENT COORDINATOR

Ph.D., 1999, Royal Institute of Stockholm, Sweden

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WE WORK ON HETEROGENEOUS CATALYST DEVELOPMENT in my laboratory and our ultimate goal is to obtain a fundamental understanding of these catalysts at the atomic level. Our approach is to synthesize well-defined

heterogeneous catalysts using nanoparticle oxides with various shapes and sizes as supports and carefully control the deposition of active metal onto these supports using atomic layer deposition (ALD), or other more conventional catalyst synthesis methods, such as precipitation-deposition or incipient wetness impregnation. Since different shapes of nanoparticle oxides expose different surface facets, the use of these materials allows us to investigate how the active metal-support interactions vary with surface facets, and how this ultimately affects the catalytic activities and selectivities.

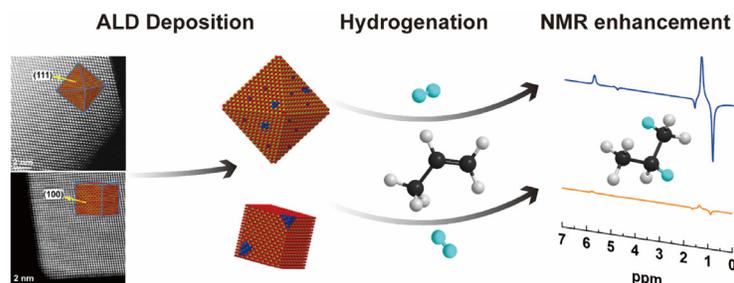
OUR RESEARCH INVOLVES CAREFUL CHARACTERIZATION

OF the synthesized heterogeneous catalysts using a number of analytical techniques to determine important catalyst properties. We routinely perform surface area measurements, chemisorption of selected molecules to probe specific sites, temperature programmed reduction and oxidation (TPR and TPO) experiments to determine reduction-oxidation (redox) properties, X-ray diffraction

(XRD) measurements to determine crystal structures and crystallite sizes, X-ray photoelectron spectroscopy (XPS) to determine electronic structure and surface chemical composition, high-resolution transmission electron microscopy (TEM) to determine particle sizes and shapes, and use the information to determine structure-activity relationships.

WE FOCUS MAINLY ON ENVIRONMENTALLY FRIENDLY, ENERGY-RELATED REACTIONS

Our projects include catalyst development for selective oxidation and hydrogenation reactions. Examples include low temperature activation of methane and conversion to higher value chemicals, selective hydrogenations for parahydrogen-induced polarization nuclear magnetic resonance applications, and algae to liquid fuels conversion.



CHARLES HAGES, ASSISTANT PROFESSOR

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DEVELOPING NEXT-GENERATION SEMICONDUCTORS for energy research is the primary focus of our group. Fundamental device physics and unique processing routes are combined to

design new materials and device architectures, with particular focus on developing high-performance, low-cost electronics from low-energy, high-throughput processing techniques and earth-abundant resources. Using holistic material research techniques – including material simulation, synthesis, device fabrication, and optoelectronic characterization – enhanced understanding and rapid feedback between processing parameters and fundamental device properties is achieved to accelerate the material development process.

NEW MATERIAL DISCOVERY in our lab starts with screening for desired material properties from first-principles theoretical calculations. Next, solution-based techniques are used to synthesize nanomaterial films and low-dimensional electronic materials. Subsequently, controlled recrystallization techniques can be applied to form thin-films. Lastly, state-of-the-art electronic devices are fabricated. The use of nanomaterials in this process

allows for unique device architectures, novel control over material optoelectronic properties, as well as highly-tunable recrystallization routes. Furthermore, such solution-based techniques are well suited for high-throughput research and the fabrication of next-generation technology such as light-weight, low-cost flexible electronics.

ADVANCED OPTOELECTRONIC CHARACTERIZATION at all stages of the material development process is a key aspect of material development in our lab. Such characterization provides rapid feedback for the accurate screening of relevant optoelectronic properties and optimal synthesis parameters in early-stage materials. We specialize in the characterization of non-ideal semiconductors – common to such early-stage materials – as well as novel all-optical measurement techniques to extract relevant material and device properties at very early stages of development. Our work combines a unique blend of engineering, chemistry, materials science, and physics resulting in highly-collaborative research at the forefront of modern chemical engineering.



DAVID HIBBITTS, ASSOCIATE PROFESSOR AND MORENO RISING STAR PROFESSOR

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DEVELOP ATOMIC-LEVEL UNDERSTANDING OF HETEROGENEOUS CATALYSTS using experiments and density functional theory (DFT) calculations to develop

structure-function relationships critical to the development of new catalysts and chemical processes. Experiments are used to determine reaction kinetics with lab-scale reactors, trace chemical pathways with isotopes, and observe reaction intermediates with spectroscopy. DFT calculations estimate activation barriers and reaction energies for reaction pathways and allow one to directly model the effects of catalyst composition, morphology, and reaction conditions. We combine experiments and DFT calculations to provide a comprehensive understanding of reactions at catalyst surfaces and train well-rounded students who understand practical and fundamental issues in heterogeneous catalysis.

DRIVE ENERGY- AND CARBON-EFFICIENT TRANSFORMATIONS of traditional and renewable chemical and fuel feedstocks. Catalysis is a critical part of our world, playing a huge role in the production of energy and chemicals from traditional fossil fuel resources. Catalysis, furthermore, will be critical to develop new processes based on renewable energy and chemical resources such as

solar and wind power as well as biomass-based chemicals. This transformation from fossil- to renewables-based energy, fuels, and chemicals is critical to curb climate change caused by increasing CO₂-emissions. Our research focuses on reactions that convert methane and biomass-derived compounds into value-added fuels and chemicals; furthermore, we research novel catalysts to reduce polluting emissions in car exhausts.

DESIGN A COMPUTATIONAL CATALYSIS INTERFACE that combines command-line and graphical-user interfaces to facilitate theoretical studies of chemical reactions. "Standard" DFT calculations can be difficult, expensive, and time consuming; however, our group has developed the Computational Catalysis Interface (CCI) which makes DFT studies much easier to perform. CCI provides user-friendly set up of DFT calculations through natural language commands allowing novices to immediately generate meaningful data. Calculations are automatically split into multiple steps to decrease the amount of time they require and therefore their cost. Calculations are easily monitored, can trigger subsequent calculations, and can be used as templates to initiate hundreds of additional calculations enabling high-throughput studies with minimal user interaction.



PIYUSH JAIN, ASSISTANT PROFESSOR AND SHAH RISING STAR PROFESSOR

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Postdoc, 2018, Massachusetts Institute of technology

MY RESEARCH GROUP IS GENERATING INSIGHTS AND SOLUTIONS TO

problems with genome engineering, specifically CRISPR/Cas systems. Over the past few years, the slow-progressing field of

genome engineering has been transformed by the breakthrough of Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) with astronomical applications in science, medicine, agriculture, biotechnology, and biomanufacturing. Originally derived from the bacterial immune system, the CRISPR/Cas9 technology works by introducing two components inside cells, a Cas9 nuclease that acts like molecular scissors and a guide RNA (sgRNA) that binds with Cas9 and directs the complex to the target DNA to create double-stranded cuts in the DNA. Due to its ease of use, it is becoming a standard tool for genome engineering and the toolbox is exponentially increasing with other variants of CRISPR/Cas systems with applications in DNA and RNA manipulation. The biggest challenges for CRISPR/Cas technology that are affecting the bridge between *in vitro* and *in vivo* applications are safety, efficacy, and delivery. To address these pressing concerns, the Jain lab is focused on developing a multi-scale biomolecular engineering platform using nucleic acids chemistry, protein engineering, and nanoengineering.

Specific examples include:

RAPID CRISPR-BASED TESTS FOR DETECTING CORONAVIRUS

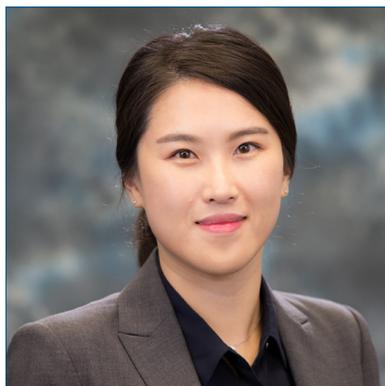
Jain lab recently engineered CRISPR/Cas systems to turn them into fast cutters. This helped us develop a rapid paper-based test for detecting SARS-CoV-2 virus as well as other pathogens and diseases.

UNDERSTANDING AND IMPROVING SPECIFICITY OF CRISPR/CAS SYSTEMS

CRISPR/Cas systems can tolerate several mutations in the DNA resulting into undesirable off-target cleavage. What if we change the length and chemistry of the guide RNA or modify the Cas? Using nucleic acids design and protein engineering, we employ an array of bioanalytical techniques with immediate applications for the detection and treatment of genetic disorders.

TARGETED DELIVERY OF CRISPR/CAS SYSTEMS

Despite the vast literature highlighting the delivery issues with CRISPR/Cas systems, it remains a major concern. The answer lies in developing safe and effective non-viral delivery methods. We aim to design multifunctional targeted nanoparticle systems that can protect CRISPR/Cas from degradation and target specific tissues *in vivo* with immediate applications for detection and treatment of cancer.



YEONGSEON JANG, ASSISTANT PROFESSOR

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MY RESEARCH GROUP AIMS TO PROVIDE FUNDAMENTAL INSIGHTS AND PRACTICAL SOLUTIONS IN THE FIELD OF SUPRAMOLECULAR BIOMATERIALS.

We are aiming at engineering structural and functional

properties of supramolecular biomaterials for target applications including synthetic cells, smart capsules, micro-reactors, antibacterial, and drug release coatings. The vision of our lab is to utilize soft matter assembly and recombinant technology for the creation of advanced biomaterials. From the deep understanding of the interactions between soft matters, including polymers, proteins, and colloids, we develop supramolecular biomaterials to present target microscopic structure, mechanical properties, and functionality. We also apply recombinant protein technology to rationally design functional building blocks. The supramolecular biomaterials developed in my research group include multicompartment vesicles, porous thin films, multilayer coatings, and a variety of self-assembled structures in solutions or at surfaces.

MULTICOMPARTMENT PROTEIN VESICLES FOR PROTOCELL DEVELOPMENT

We create multicompartment vesicles made from functional

globular fusion proteins with controlled geometry by tuning their self-assembly or using microfluidics. Cell sized-protein vesicles carry multiple biological cargoes such as therapeutic proteins and genes for de novo protein synthesis, which enables the rational design of hierarchically ordered protein vesicles to mimic essential cellular functions.

FUNCTIONAL NANOTHIN FILMS FOR CELL FATE CONTROL

We develop functional thin films and coatings to control cell fate at the surfaces. We precisely control surface structure, chemistry, and mechanical properties of polymeric thin films to achieve target functionality to tailor cellular adhesion, proliferation, and death. The functional thin films have a variety of biomedical applications, such as stem cell co-culture platforms, antibacterial coatings, and drug release patches.

PHASE STUDY OF GLOBULAR PROTEIN-FUSED DIBLOCK COPOLYMERS

We provide the fundamental understanding of the self-assembly of globular proteins fused with diblock copolymers that exhibit complex interactions. We study the phase transition/separation behavior of the globular fusion proteins in solution and at interface/surface under diverse physical and chemical stimuli, mainly using scattering and microscopic techniques. This study enables us to create a new supramolecular nanostructure with functional globular proteins, providing the potential uses for sensing.



PENG JIANG, PROFESSOR

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WE ARE BROADLY INTERESTED IN

DEVELOPING new chemical, physical, engineering, and biological applications related to self-assembled nanostructured materials.

Our current research is focused on the following

four topics:

SELF-ASSEMBLED PHOTONIC & PLASMONIC CRYSTALS

Photonic crystals and plasmonic crystals offer unprecedented opportunities for the realization of all-optical integrated circuits and high-speed optical computation. Our group is developing a number of scalable colloidal self-assembly technologies to control, manipulate, and amplify light on the sub-wavelength scale. We are also involved in the fabrication, characterization, and modeling of a large variety of functional nanooptical and plasmonic devices enabled by the bottom-up approaches.

BIOMIMETIC BROADBAND ANTIREFLECTION COATINGS

By mimicking the nanostructured antireflection layer on the cornea of a moth and the water-shedding coating on the wings of a cicada, we are developing self-cleaning broadband antireflection coatings for a wide spectrum of applications ranging from highly efficient solar cells and light emitting diodes to high-sensitivity spectroscopy for space exploration. Once again, we are interested

in scalable nanomanufacturing technologies that can be inexpensively applied to large areas.

NOVEL STIMULI-RESPONSIVE SHAPE MEMORY POLYMERS

By integrating scientific principles drawn from two disparate fields—the fast-growing photonic crystal and shape memory polymer (SMP) technologies, we have developed a new type of shape memory polymer (SMP) that enables unusual “cold” programming and instantaneous shape recovery triggered by applying a large variety of unconventional stimuli (e.g., static pressure, vapors, and shear stress) at ambient conditions.

These new stimuli-responsive SMPs differ greatly from currently available SMPs as they enable orders of magnitude faster response and room-temperature operations for the entire shape memory cycle. We are now exploring the broad applications of these smart materials in detecting Weapons of Mass Destruction (WMD) materials and aerospace morphing structures.

SMART WINDOW COATINGS FOR ENERGY-EFFICIENT BUILDINGS

Windows are typically regarded as a less energy efficient building component, and they contribute about 30 percent of overall building heating and cooling loads. We are developing a transformative dynamic window technology that enables dynamic and independent control of visible and near infrared light and eliminates expensive transparent conductors in the final devices. The innovative dynamic windows are inspired by the mature heat pipe and photonic crystal technologies, which have been widely used in controlling the flow of heat and light, respectively.



DMITRY KOPELEVICH, ASSOCIATE PROFESSOR

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OUR RESEARCH FOCUSES ON THEORETICAL & COMPUTATIONAL

investigation of transport phenomena and non-equilibrium processes in nano- and microscale systems. We apply various simulation methods, such as

molecular and Brownian dynamics, as well as theoretical tools to various systems whose understanding is of significant scientific and technological importance.

SELF-ASSEMBLED SURFACTANT SYSTEMS

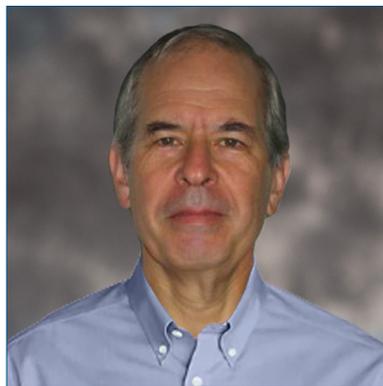
Surfactants (or amphiphiles) are molecules that contain both hydrophobic and hydrophilic segments. In aqueous solutions, surfactants spontaneously self-assemble into a variety of microstructures that find use in numerous applications, including drug delivery vehicles and templates for advanced nanostructured materials. In addition to their industrial uses, self-assembled structures of amphiphilic molecules, such as lipid bilayers, are building blocks for various biological systems. In all of these systems, the dynamics of self-assembly and transitions between different self-assembled structures plays an important role. Our goal is to understand molecular mechanisms of these transitions. In particular, we investigate mechanisms of formation and break-up of micelles and dynamics of lipid membranes.

DNA TRANSPORT IN MICROFLUIDIC DEVICES

Microfluidic devices enable efficient and inexpensive analysis and processing of macromolecules in various biomedical applications. Transport and separation of polyelectrolyte molecules, such as DNA, in these devices is often facilitated by application of an electric field. In this project we, in collaboration with Prof. Butler, aim to understand effects of electric fields and other factors on the molecular transport. In particular, we focus on development of an accurate model for electrohydrodynamic interactions in polyelectrolytes.

NON-BROWNIAN SUSPENSIONS

Particle suspensions in liquids have a wide array of applications, ranging from pharmaceutical to oil industries. When suspended particles are sufficiently large, thermal Brownian forces acting on them are negligible. Nevertheless, the particles are observed to undergo diffusive motion, which is qualitatively similar to the Brownian motion. In this project we, in collaboration with Prof. Butler, apply tools of statistical mechanics to investigate fundamental mechanisms of diffusion in such non-Brownian suspensions. In particular, we aim to explain some counterintuitive experimental observations, for example, that increasing particle roughness leads to decrease of their diffusivity.



ANTHONY LADD, PROFESSOR

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OUR RESEARCH FOCUSES ON DYNAMICS at scales that are small macroscopically (μm to mm), but are large compared to molecular sizes. The research combines statistical mechanics and fluid dynamics with advanced computing to elucidate the key physical processes

that underlie laboratory observations and measurements. Current applications include:

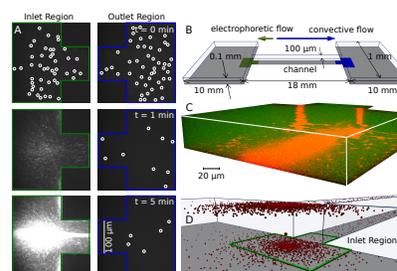
REACTIVE TRANSPORT IN POROUS MEDIA

Flow and transport in porous media are usually modeled at the Darcy scale, where the system is described locally by average properties, such as porosity, permeability, dispersion coefficients, and reactive surface area. Although this allows large volumes to be simulated efficiently, there are serious difficulties in developing suitable models for the properties of the individual elements. Pore-scale modeling overcomes many of the limitations of Darcy-scale models, replacing unknown functions with well-defined parameters. Nevertheless, it is not yet clear that a single set of parameters – fluid viscosity, ion diffusion coefficients, and surface reaction rates – can consistently describe the dissolution of samples with different pore structures. The goal of our DOE sponsored project is

to investigate the dissolution of idealized samples both numerically and experimentally to prove (or disprove) the correctness of the underlying equations.

MIGRATION OF DNA IN COMBINED FLOW AND ELECTRIC FIELDS

This project (in collaboration with Dr. Jason Butler) aims to investigate both the fundamental physics and potential biotechnological applications of the effect of a combination of hydrodynamic shear and electric field. From a fundamental point of view, the interest is to better understand the novel mechanism by which a charged polymer (like DNA) can be manipulated in directions perpendicular to the field lines. In a simple microfluidic device this can cause a rapid accumulation and trapping of the DNA, with implications for both biosensing and DNA extraction applications.



A. Epifluorescent images at the device inlet (green) and outlet (blue).
B. Schematic of the device showing the direction of flow (blue) and electrophoresis (green); the diagram is not entirely to scale.
C. A confocal scan showing the three-dimensional

distribution of DNA within a 40 micron slab located on the lower wall of the inlet. DNA (orange) is concentrated on the wall of the device.
D. A perspective sketch of the inlet region, indicating the distribution of trapped DNA.



RANGA NARAYANAN, DISTINGUISHED PROFESSOR, AND DISTINGUISHED TEACHER-SCHOLAR

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TRANSPORT OF HEAT, MASS, AND MOMENTUM ARE OFTEN accompanied by spatial and temporal pattern formation.

Understanding the cause of pattern formation is pivotal

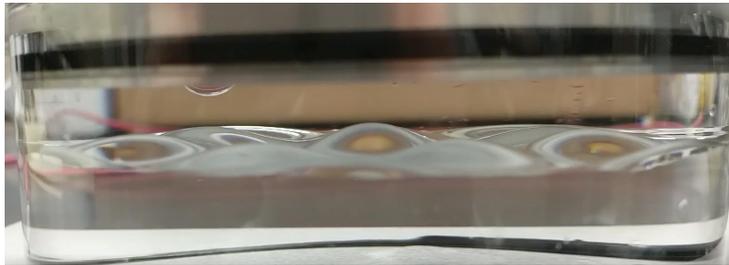
as this research has application to the processing of materials on earth and under microgravity conditions. Such processes include additive manufacturing of metals, bulk crystal growth of semiconductors, thin film growth during evaporation, and electroplating.

IN THE AREA OF INSTABILITIES, IT IS THE GOAL of the present research to examine the physics of the spontaneous generation

of spatial patterns in processes that involve flow resonance, solidification, electrodeposition, and free-surface convection. The pattern formation is associated with instabilities of a parent state as a control parameter is changed. Other processes of interest that involve instabilities are shearing flows with viscous dissipation of heat and oscillatory flows where flow reversal is the cause of non-rectilinear patterns.

THE MATHEMATICAL METHODS USED IN OUR RESEARCH are related to bifurcation theory, non-linear energy methods, and perturbation techniques.

THE EXPERIMENTAL METHODS involve electrostatic levitation and forcing, electrochemical deposition and flow sensing by infrared imaging and shadowgraphy.



Interfacial wave formation between layers of water (bottom) and silicone oil (top) when the fluids are subjected to an oscillatory electric field.



MARK ORAZEM, DISTINGUISHED PROFESSOR

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ELECTROCHEMICAL ENGINEERING

The research performed in this group represents applications of electrochemical engineering to systems of practical importance. In recent work, electrokinetic

phenomena were exploited to enhance continuous separation of water from dilute suspensions of clay associated with phosphate mining operations. The technology developed in this project is intended to greatly reduce the environmental impact of mining operations. Our group recently patented a sensor, based on indirect impedance measurements, that can detect corrosion of post-tensioned tendons in segmentally constructed bridges.

ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY

Electrochemical impedance spectroscopy is an experimental technique in which sinusoidal modulation of an input signal is used to obtain the transfer function for an electrochemical system. In its usual application, the modulated input is potential, the measured response is current, and the transfer function is represented as an impedance. The impedance is obtained at different modulation

frequencies, thus invoking the term spectroscopy. Through use of system-specific models, the impedance response can be interpreted in terms of kinetic and transport parameters. Through an international collaboration with scientists and engineers from France, Italy, and the United States, work is underway to improve the understanding of how impedance can be interpreted to gain insight into the physics and chemistry of such diverse systems as batteries, fuel cells, corroding metals, and human skin.

Current projects include a modelling and experimental study of the impedance of enzyme-based sensors for biological systems and fundamental studies designed to enhance interpretation of impedance spectra. For example, in collaboration with French and Italian colleagues, our group developed a novel method to extract physically meaningful information from impedance data affected by frequency dispersion, a problem that had been unresolved since it was identified in the 1940s. Our power-law model, first published in 2010, has proven useful for oxides on metals, for human skin, and for water uptake in coatings. It is now implemented in industry to assess the quality of raw materials for electrochemical fabrication lines. Our new understanding of the influence of electrode geometry on impedance response gives developers of impedance-based sensors guidelines for electrode size and shape.



FAN REN, DISTINGUISHED PROFESSOR

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HEALTH SENSORS

We aim to develop a highly sensitive and low-cost heart attack sensor technology, which can be implemented in a wireless-capable, real-time and handheld sensor

for personal and medical usages. Acute myocardial infraction (AMI) causes one of the highest mortality rates worldwide. The existing methods employed by first responders, hospitals and clinics are time consuming and require trained personnel to perform tests. The challenge is to develop a real-time, accurate, handheld and low cost heart attack sensor for both personal and medical applications. AlGaIn/GaN high electron mobility transistor (HEMT) based wide-energy bandgap semiconductor sensors amplify tiny changes of the surface charges from 10^5 to 10^6 times larger (50-60 dB higher) than those results from simple conductive or resistive measurements for the conventional conductive or resistive based sensors.

WIDE ENERGY-BANDGAP DEVICES

β -phase of Gallium Oxide is a very promising monoclinic semiconductor with relevant applications for power electronics and also for solar blind photodetectors. β -Ga₂O₃ based devices are predicted to have a Baliga figure-of-merit at least 4 times

higher than either SiC or GaN, as reflected in the higher breakdown field and lower on-state resistance. Several types of transistors, including MOSFETs and MESFETs, as well as power Schottky diodes and solar blind UV detectors have also been reported. Our group holds the records of highest forward current as well as highest reverse breakdown voltage. We are studying the effects of total dose proton, electron, gamma ray and neutron fluxes on Ga₂O₃, which has exceptionally high breakdown fields and great promise for high power, high temperature electronics.

CERAMIC COATINGS

Ceramic prostheses are important components of restorative dentistry because of their unrivalled aesthetics and biocompatibility. However, ceramic veneers are susceptible to chipping failures intraorally, compromising the integrity of the prostheses. The resulting roughened surfaces can lead to increased plaque accumulation and the replacement of these prostheses. The long-term goal of this research is to develop fracture-resistant and chemically stable (durable) dental ceramics for prostheses by applying protective coatings. The overall objective is to critically evaluate the corrosion resistance and the strength of these dental ceramic coatings as a function of a simulated environment with constant changes in pH and intermittent abrasion.



CARLOS M. RINALDI-RAMOS, DEPARTMENT CHAIR AND DEAN'S LEADERSHIP PROFESSOR

Ph.D., 2002, Massachusetts Institute of Technology

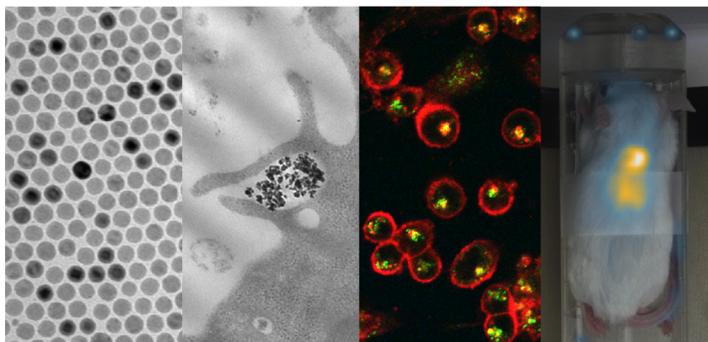
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MY GROUP STUDIES THE BEHAVIOR AND BIOMEDICAL APPLICATIONS OF MAGNETIC NANOPARTICLES. We combine expertise in synthesis and surface modification of magnetic nanoparticles, physical, chemical, and magnetic char-

acterization, and modelling to understand the colloidal behavior of magnetic nanoparticles, their interaction with biological entities, and to advance their biomedical applications. We are actively investigating novel methods of synthesizing nanoparticles with tailored magnetic properties, evaluating nanoparticle stability and mobility in biological environments, and advancing applications of magnetic nanoparticles in cancer therapy and magnetic particle imaging.

Magnetic particle imaging (MPI) is a new biomedical imaging modality that enables unambiguous, tomographic, and quantitative evaluation of the distribution of magnetic nanoparticles in living subjects. We engineer biocompatible nanoparticle tracers for MPI that offer unprecedented resolution and sensitivity and can be used to track immune cells or image the distribution of biomarkers in pre-clinical

models of cancer. We also engineer the surface of tracers to label cells of the innate and adaptive immune system for sensitive and quantitative tracking of their biodistribution. We collaborate with clinicians and other scientists to evaluate the application of MPI for tracking adoptive cell transfer immunotherapies. Students in my group become experts in nanoparticle synthesis, characterization, and evaluation for biomedical applications through highly collaborative, interdisciplinary research projects.





JANANI SAMPATH, ASSISTANT PROFESSOR

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WE STUDY POLYMERS, PROTEINS, AND THEIR HYBRIDS TO DESIGN THE NEXT GENERATION OF SOFT MATERIALS

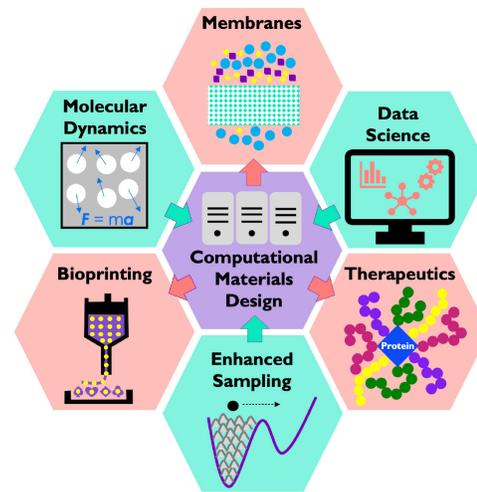
using molecular dynamics simulations, high throughput computations, and enhanced

sampling methods. To sustain materials discovery in the future given the limited resources at our disposal, predictive engineering techniques must be employed to allow for efficient design and optimization of materials. Specific applications that interest us are:

1) Engineering polymer membranes for gas separation and water purification: Polymer membranes are widely used for separations due to their energy efficiency and relative ease of production. Using precisely controlled models of polymer membranes, we will describe the effect of membrane chemistries, polymer crosslinking, free volume density, and feed conditions on the membrane's separation ability.

2) Developing Bio-ink for 3D Printing: Materials used for 3D bioprinting are known as 'bio-ink', and primarily consist of a mixture of polymers and proteins. A clear understanding of the ordering of polymer-protein conjugates in solution will lead to greater structural control of the final 3D printed object, and we will provide general design guidelines for material selection of bio-inks.

3) Designing Polymer-Protein Conjugates for Therapeutics: Polymer-protein conjugates display a host of advantageous properties, as they combine the functionality and structure of proteins, along with the stability and processability of polymers. Using simulations, we will characterize polymer chain conformation when it is conjugated to therapeutically relevant proteins like insulin, to understand polymer length scales over which protein functionality is preserved, for a range of polymer chemistries.



WHITNEY STOPPEL, ASSISTANT PROFESSOR

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Our research team is focused on the design and optimization of natural biomaterials for a variety of clinical applications. Experimental research explores the mechanical and transport properties of elastic and viscoelastic materials, aiming to

determine a predictive set of material characteristics that have a known function in the body. We aim to harness the power of the immune system in tissue regeneration to alter the way that these materials integrate following implantation, providing a new strategy for optimizing materials for clinical applications.

MATERIAL DESIGN AND IN VITRO CHARACTERIZATION

Natural materials and polymer composites derived from biopolymers such as silk fibroin, alginate, or decellularized extracellular matrix can be combined to form a variety of material shapes, architectures, and mechanical properties. In turn, the format for the biomaterial can have a significant impact on cellular function and biological processes. We determine specific material properties and compositions that consistently alter or direct cell function through time-dependent analysis of cell-material interactions. These materials have applications in soft

tissue repair and as in vitro platforms for understanding disease progression.

QUANTIFYING BIOMATERIAL PERFORMANCE IN VIVO

Understanding complex interactions between the immune system, local stromal cell populations, and implanted biomaterials necessitates spatiotemporal analysis of biomaterial degradation and histogenesis. We quantify how biomaterial composition and structure alter the rate of degradation and the composition and strength of new tissue that replaces the material. On-going efforts aim to understand how secondary diseases, ancestry, biological sex, and age influence the kinetics of degradation and tissue formation.

Work in the Stoppel Lab is in collaboration with engineers, clinicians, and scientists across UF. The Stoppel Lab values educating and training a diverse workforce and welcomes any student interested in applications of chemical engineering to advancing technologies for human health.



SPYROS SVORONOS, HARRY AND BERTHA BERNSTEIN PROFESSOR AND UNDERGRADUATE PROGRAM COORDINATOR

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BIOFUEL PRODUCTION FROM SALINE CYANOBACTERIA

Although microalgae provide excellent means of capturing sunlight and atmospheric carbon dioxide, impediments to their widespread utilization are the inability to grow algae in a sustainable manner without large inputs of freshwater and nutrients—and to economically separate valuable products. Our research aims to establish a path for the economic production of a biofuel (methane) and an extracellular bioproduct. It utilizes a remarkable cyanobacterium that eliminates the need for

fresh water inputs or external addition of nitrogenous nutrients and avoids expensive purification methods for product recovery. The project is in collaboration with Professor Pratap Pullammanappallil of the UF Agricultural and Biological Engineering Department and Professor Edward J. Phelps of the UF School of Forest Resources and Conservation.



SERGEY VASENKOV, PROFESSOR

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MY RESEARCH PROGRAM FOCUSES ON DEVELOPING FUNDAMENTAL UNDERSTANDING OF

TRANSPORT of molecules and ions in membranes, sorbents, catalysts and related materials on a broad range of microscopic length scales between around 100

nm and tens of microns. Such materials usually exhibit complex and, in some cases, even hierarchical structure that results in different transport properties on different microscopic length scales. Understanding the complexity of microscale transport in these materials on a fundamental level is required for optimizing their performance in separations and catalysis. For such studies, we develop and apply nuclear magnetic resonance (NMR) techniques that benefit from combining advantages of high magnetic field and high magnetic field gradients.

MICROSCOPIC GAS TRANSPORT IN GAS-SEPARATION MEMBRANES AND CATALYSTS

An application of a unique diffusion NMR technique, pulsed field gradient (PFG) NMR at high magnetic field and large magnetic field gradients resulted in the first direct measurements of microscale transport of gas molecules in mixed matrix membranes (MMMs)

and carbon molecular sieve (CMS) membranes as well as in aerogel and nanoporous gold catalysts. In particular, for MMMs, which are formed by dispersing fillers, such as metal-organic frameworks (MOFs) in polymeric matrices, it was possible to resolve diffusion inside MOF particles from diffusion in the polymer phase between the particles. My group has proposed and validated experimentally an analytical expression for the long-range diffusivity in MMMs.

TRANSPORT-STRUCTURE RELATIONSHIP IN MEMBRANES WITH IONIC PROPERTIES

Polymer membranes with ionic properties such as the commercially available Nafion® are among the most promising materials in a wide variety of applications including fuel cells, water desalination, chemical sensing, and selective capture of chemical warfare agents (CWA). Molecular and ion diffusion plays an important role in these applications. My group applies advanced NMR techniques to quantify intramembrane transport of liquid sorbates on all relevant microscopic length scales leading to fundamental understanding of transport-structure relationship in this class of materials.



JASON WEAVER, PROFESSOR

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OUR RESEARCH FOCUSES ON ADVANCING THE MOLECULAR-LEVEL

understanding of surface chemical reactions that are important in applications of heterogeneous catalysis. My students and I investigate chemical reactions on solid surfaces using a wide array

of analysis methods based on ultrahigh vacuum (UHV) surface chemistry and physics, including methods that provide information about surface reaction kinetics, adsorbed intermediates, atomic scale surface structure and the chemical states of adsorbed molecules and atoms of the solid. We make rigorous comparisons between our experimental data and predictions of molecular simulations, and find that this approach is a powerful way to identify elementary steps in surface reaction networks. We also investigate the catalytic behavior of well-defined surfaces using in situ synchrotron-based techniques to enable comparisons between the results of our model UHV studies and the behavior of working catalysts.

GROWTH AND SURFACE CHEMISTRY OF OXIDE THIN FILMS

We are investigating the growth and chemical properties of oxide thin films that develop on the surfaces of late transition metals during oxidation catalysis. This work is motivated by findings that metal oxide layers form on metallic catalysts in oxygen-rich environments, and that such oxide layers can play a decisive role in determining catalytic performance. In our research, we

produce oxide thin films for characterization in UHV by oxidizing metallic surfaces using atomic oxygen beams or through controlled exposure to O₂ in an isolated reaction cell. This approach allows us to investigate oxide films under well-controlled conditions, and gain insights about the growth and surface chemical properties of oxides that are central to several catalytic applications, such as the catalytic combustion of natural gas, exhaust gas remediation in automobiles and selective oxidation processes. Key topics of focus include the oxidation mechanisms of late transition-metal surfaces and the chemistry of small molecules on metal oxide surfaces, particularly the oxidation of light alkanes. Our work continues to advance the molecular-level understanding of catalytic reaction mechanisms on late transition-metal oxides.

CATALYSIS ON MULTIFUNCTIONAL SURFACES

We are also studying chemistry on dilute alloys, mixed-metal oxides and metal-oxide nanostructures. These types of materials feature different types of surface sites and domains separated by interfacial regions at which the constituents make atomic contact. Such multifunctional surfaces can exhibit unique catalytic properties as a result of cooperativity among the coexisting surface domains as well as distinct chemical properties of the interfacial regions and isolated sites. Our main goals are to determine how coexisting sites and domains influence catalytic reaction processes and develop structure-reactivity relationships that may be used to design multifunctional surfaces that promote selective catalysis. We are particularly interested in understanding how to modify these surfaces to achieve high selectivity and activity for converting light alkanes to value-added products such as olefins and organic oxygenates.



KIRK J. ZIEGLER, ASSOCIATE CHAIR FOR GRADUATE STUDIES

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NEARLY ALL NANOMATERIAL APPLICATIONS REQUIRE

an interface with other materials, including, for example, polymers in composites, electrodes in devices, pharmaceuticals in drug delivery, body fluids and cells in bioimaging and biosensors, or analytes in

chemical sensors. Our group focuses on developing a fundamental understanding of interfaces in nanoscale systems, which can have far-reaching implications to various fields of nanotechnology. The goal is to manipulate interfaces to dictate the nanostructures that are fabricated and to control reactions and transport at the surface of the nanostructures. Once these interfaces can be controlled and manipulated, it is possible to fabricate nanomaterials with novel functionality, improving their integration and performance in several applications.

MANIPULATING INTERFACES

The ultimate objective is to create new functionality by manipulating the interface. The manipulation of nanoscale interfaces can alter the wettability, interaction of nanomaterials with matrices, and their stability to environmental effects. We

aim to control these interfaces to alter the dispersion and sensing properties of the nanoparticles. These factors also limit the organization and dimensions of nanostructures that are fabricated. For example, we have exploited the natural sensing capabilities of single walled carbon nanotubes (SWCNTs) to help us characterize the localized environment surrounding them. The ability to characterize the surface of SWCNTs has enabled the development of processes to alter the surfactant structure surrounding the nanotube, providing more stable suspensions, better fluorescence intensities, selective adsorption onto surfaces, and reduced toxicity.

CONTROLLING REACTIONS AND TRANSPORT AT SURFACES

Nanotechnology offers significant promise to improving the performance of solar cells, batteries, and supercapacitors because of the large surface area and unique properties of nanomaterials. However, designing these devices requires exceptional control of the chemical and electronic processes that occur at interfaces. Since many of the atoms in nanostructures exist on the surface, their reaction and transport properties depend strongly on the interface. Our group develops processes that control reactions and transport at the surface to synthesize porous materials suitable for gas phase separations. These nanomaterial interfaces can also be used to help control biological function or accessibility, enhance the collection of photons, improve charge transport, yield better heat transfer, and generate more plasma.

STEPS TO APPLY

NEW STUDENTS FOR ALL GRADUATE PROGRAMS ARE ADMITTED ONLY IN THE FALL SEMESTER. THE DEADLINE FOR APPLICATIONS TO THE PH.D. AND M.S. PROGRAMS ARE DECEMBER 5. LATE APPLICATIONS MAY BE ACCEPTED IF OPPORTUNITIES ARE AVAILABLE.

Apply online at <https://admissions.ufl.edu> and submit UF's non-refundable application fee of \$30.

Usually the department requires GRE scores for both US applicants and international applicants. Due to issues with standardized testing resulting from the COVID-19 pandemic, GRE scores are not required for admission to our programs between now and Fall 2022.

Arrange to have official transcripts sent to the UF Office of Admissions from each postsecondary institution attended. International applicants must submit official copies in their native language and in English.



GRADUATE LIFE

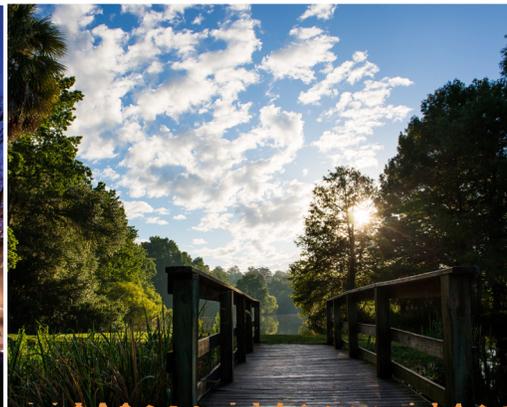
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