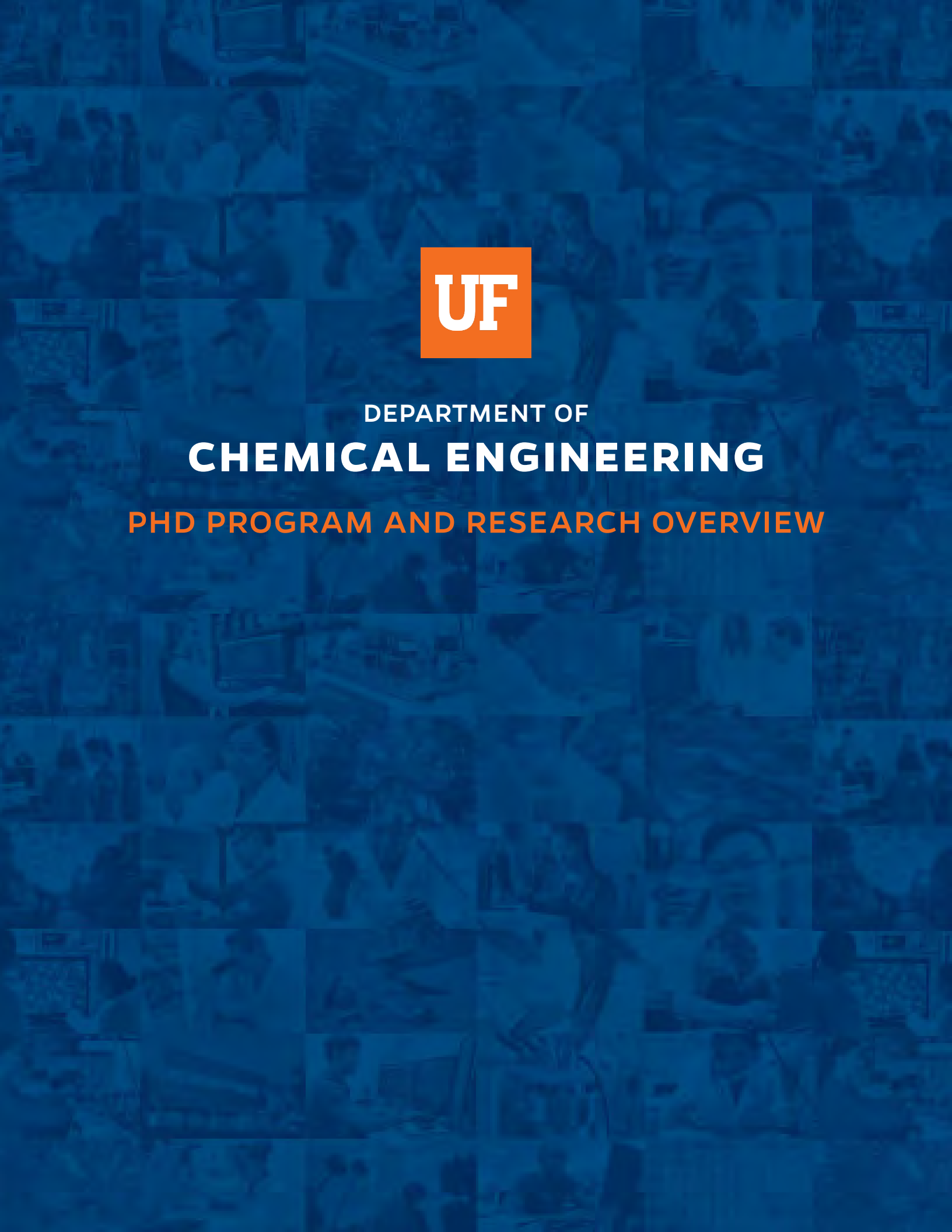


DEPARTMENT OF

CHEMICAL ENGINEERING

PHD PROGRAM AND RESEARCH OVERVIEW

CONTENTS

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 has 30 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 National Science Foundation (NSF), the National Institutes of Health (NIH), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), the Department of Defense (DOD), and nonprofit organizations, such as the American Chemical Society and the Gas Research Institute. Research within our department is also often supported through industry partnerships, providing a way for students to apply fundamental academic work to everything from basic science, commercial development and manufacturing, and advancements in healthcare and medicine. Graduate students in the Department of Chemical Engineering can pursue a Doctorate of Philosophy (Ph.D.), Master of Science (M.S., thesis or non-thesis), or Master of Engineering (M.E.) degree.

THE COLLEGE AND UNIVERSITY ENVIRONMENT

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.

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.

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.

GRADUATE LIFE

GRADUATE STUDENTS ARE SURROUNDED BY OPPORTUNITIES TO GROW AND DEVELOP AS ENGINEERS AND SCIENTISTS.

- State-of-the-art facilities with cutting edge research instrumentation.
- Access to leading experts across the Herbert Wertheim College of Engineering and the 15 other colleges across campus.
- Faculty mentors with awards for excellence in education and mentorship.
- Leading technology, including leading supercomputing technology for memory intensive computational efforts, data analysis, and database management.
- Ph.D. students are often supported through competitive awards and fellowships, including external awards such as the NSF's Graduate Research Fellowship and internal awards, such as our annual UF ChE Excellence Fund Departmental Awards for Research, Leadership, and Service to the profession.

GRADUATE STUDENTS ARE ENCOURAGED TO ENGAGE IN PROFESSIONAL DEVELOPMENT.

- First-class institutes and centers that foster entrepreneurship and interdisciplinary collaboration.
- Certificate programs to foster skills development and competency.
- Leadership opportunities in the chemical engineering graduate student association, GRACE (GRaduate Association of Chemical Engineers).
- Volunteering and community service opportunities.
- Coursework opportunities to learn and practice skills in teaching, managing, and educating others.

GRADUATE STUDENTS HAVE ACCESS TO AN ARRAY OF ACTIVITIES IN THE LOCAL COMMUNITY TO ENSURE STUDENTS MAINTAIN A VIBRANT LIFE DURING THEIR STUDIES.

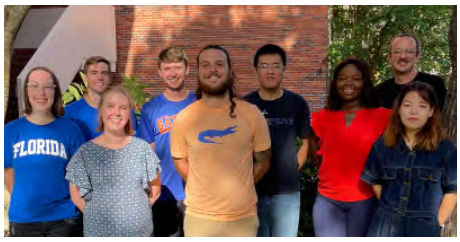
- Alachua County and north Florida are known for their beautiful springs, nature trails, and opportunities for kayaking, canoeing, paddle boarding, and bird watching.
- The Gainesville food scene has a variety of options from food trucks to fine dining, including over seven local breweries.
- UF Health Shands Hospital provides excellent healthcare for any issue a student or their family may encounter.
- Samuel P. Harn Museum of Art and the Phillips Center offer art installations, concerts, Broadway plays, and special events year-round.
- Gainesville has its own airport, with quick access to major airline hubs, including Atlanta, Charlotte, Dallas, and Miami.
- Proximity to large metropolitan areas including Orlando, Tampa, and Jacksonville.

Pictured: Ruth B. Kirby Gilchrist Blue Springs State Park and Downtown Gainesville

PH.D. STUDENTS ARE SUPPORTED AND ENCOURAGED TO GROW AND DEVELOP THROUGH A VARIETY OF DEPARTMENT AND COLLEGE SPONSORED ACTIVITIES AND EVENTS.

- All Ph.D. students making satisfactory progress receive guaranteed funding and incoming Fall 2023 Ph.D. students will receive an initial stipend of $32,000, tuition, and health insurance until the degree is awarded.
- Competitive department and university fellowships and travel awards are offered to support scientific communication and networking.
- We encourage student participation in activities designed to promote professional development, leadership, and outreach to our community.
- College and department sponsored activities for students to interact with industry leaders and academic mentors in preparation for a variety of careers.
- We are working to create a vibrant and diverse community to fulfill our students' intellectual and social needs while supporting their mental health and wellness.
- The department sponsors monthly events and activities, such as the "First Friday" social event.

GRADUATE ASSOCIATION OF CHEMICAL ENGINEERS (GRACE)



GRACE is a chemical engineering graduate student organization at UF that organizes programming focused on building a sense of community through events that focus on student well-being and professional development.

The annual **GRACE SYMPOSIUM** provides an opportunity for graduate students to share their recent scientific advancements with the community, including Ph.D. alumni.

WOMEN'S ADVANCEMENT AND MENTORING COMMITTEE (WAM)

The Women's Advancement and Mentoring Committee in the Department of Chemical Engineering was founded by Dr. Helena Hagelin-Weaver. Since 2018, this group has grown and its mission is to empower, advance, and advocate for women in Chemical Engineering. WAM programming focuses on activities that advance the professional development of women in chemical engineering in a supportive and community-focused

FIRST YEAR PH.D. STUDENT MENTORING PROGRAM

- Chemical engineering department-sponsored year long program for 1st year Ph.D. students that pairs new students with senior Ph.D. student mentors.
- Improve Ph.D. student study habits and create a collaborative learning environment.
- Encourage student social events and activities for students to make friends.
- Promote and model healthy habits for maintaining Ph.D. student mental health.
- Provide a near-peer mentor to reduce the propagation of "hidden curriculum" and ensure equal opportunities for student success.

DOCTORATE PROGRAM

WE PRIDE OURSELVES ON TRAINING OUR STUDENTS IN AN INCLUSIVE ENVIRONMENT THAT SUPPORTS THEIR SCIENTIFIC AND PROFESSIONAL DEVELOPMENT.

PH.D. DEGREE

The Ph.D. degree plan is primarily a research program. Graduate students enrolled in the Ph.D. program have the opportunity to work closely with our dynamic, internationally recognized faculty. 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 observe a strong commitment to excellence in research and education in both the classroom and the laboratory, through outreach events, leadership opportunities, and educational training.

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. Ph.D. students will also have opportunities to grow in their professional development through trainings and graduate certificates in Engineering Leadership, Engineering Innovation, and Engineering Education.

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 Transport Phenomena, Molecular Thermodynamics, Advanced Mathematics, 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 their doctoral dissertation and their 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 three to five years following a B.S. degree.

All Ph.D. students that maintain good academic standing and make satisfactory progress receive competitive stipends, full tuition, and medical insurance for the duration of their Ph.D.

"Gainesville is a home for me because of the diversity of people who live here and the friendly weather. At UF, I have met wonderful faculty members and students who are very supportive. There are lots of wellness activities available for healthy living."

Cynthia Ezeh
Ph.D. Candidate and
2023 Alec Courtelis Awardee

"From the moment I stepped on to UF's campus during Junior Preview, I knew that this place and the chemical engineering program was special. Everyone was welcoming and encouraging - I felt like pursuing a Ph.D. here would give me the opportunity to discover who I am as a scientist and a member of the global engineering community. And I haven't looked back since!"

Sam Martinusen
Ph.D. Candidate

"UF has so many opportunities for collaboration. Having the medical campus, dental school, and many research centers on campus means you can always find people with similar interests to help you explore your curiosities and research questions."

Marisa Pacheco
Ph.D. Candidate and
NSF Graduate Research Fellow

"If given the opportunity to go back in time and select another graduate school, I would still choose UF! Remember that your talent and the Florida sunshine will always be with you!"

Hanqin Zhao
Ph.D. Candidate

RESEARCH AREAS

ADVANCED MATERIALS, DEVICES, AND NANOTECHNOLOGY

Travis Anderson
Won Tae Choi
Helena Hagelin-Weaver
David Hibbitts
Piyush Jain
Yeongseon Jang
Peng Jiang
Joshua Moon
Mark Orazem
Fan Ren
Carlos Rinaldi-Ramos
Janani Sampath
Whitney Stoppel
Kirk Ziegler

BIOMOLECULAR ENGINEERING, CELLULAR ENGINEERING, AND SYNTHETIC BIOLOGY

Henry Chu
Carl Denard
Richard Dickinson
Piyush Jain
Yeongseon Jang
Mark Orazem
Fan Ren
Carlos Rinaldi-Ramos
Janani Sampath
Whitney Stoppel
Spyros Svoronos

COMPLEX AND MULTIPHASE FLOW DYNAMICS

Jason Butler
Henry Chu
Dmitry Kopelevich
Anthony Ladd
Ranga Narayanan

ENERGY, ENVIRONMENT, AND SUSTAINABILITY

Won Tae Choi
Henry Chu
Oscar Crisalle
Helena Hagelin-Weaver
David Hibbitts
Peng Jiang
Joshua Moon
Mark Orazem
Juan Restrepo-Flórez
Janani Sampath
Spryos Svoronos
Sergey Vasenkov
Jason Weaver
Kirk Ziegler

HETEROGENEOUS CATALYSIS AND SURFACE SCIENCE

Helena Hagelin-Weaver
David Hibbitts
Jason Weaver
Kirk Ziegler

MODELING, THEORY, AND SIMULATION

Henry Chu
David Hibbitts
Dmitry Kopelevich
Anthony Ladd
Ranga Narayanan
Mark Orazem
Juan Restrepo-Flórez
Janani Sampath
Spyros Svoronos

TRANSPORT, MOLECULAR THERMODYNAMICS, AND ELECTROCHEMICAL ENGINEERING

Jason Butler
Won Tae Choi
Henry Chu
Dmitry Kopelevich
Anthony Ladd
Joshua Moon
Ranga Narayanan
Mark Orazem
Juan Restrepo-Flórez
Carlos Rinaldi-Ramos
Sergey Vasenkov
Kirk Ziegler

TRAVIS J. ANDERSON, PROFESSOR

Ph.D., 2008, University of Florida **tjanderson@che.ufl.edu**
Until Fall 2024, Head of the Power Electronics and Advanced Materials Branch, U.S. Naval Research Laboratory

THE ANDERSON RESEARCH LAB ENCOMPASSES A STATE-OF-THE-ART SEMICONDUCTOR MATERIALS GROWTH, PROCESSING, AND TEST FACILITY TARGETED TOWARD ADDRESSING THE FABRICATION CHALLENGES ASSOCIATED WITH NEXT-GENERATION SEMICONDUCTORS.

Power conversion losses are pervasive in all areas of electricity consumption, including motion control, lighting, air conditioning, and computation technology. The fielding of high efficiency power switch technology using wide- and ultrawide-bandgap semiconductor devices in applications such as data centers, motor drives, solid-state lighting, hybrid/electric vehicle technology, wind turbines, and grid-scale power distribution has the potential to significantly mitigate climate change through the reduction of CO2 emissions associated with inefficient electricity consumption. Semiconductor device fabrication represents a key application of core Chemical Engineering knowledge and training. The many steps involved in even a simple transistor process sequence include materials growth and film deposition, doping and etching, photolithography, thermal management, and steady-state operation of a foundry. In my group, we perform fundamental research addressing all of these topics.

NEXT GENERATION MICROELECTRONIC DEVICES

Wide-bandgap semiconductors (SiC, ZnO, GaN) and Ultrawide-bandgap semiconductors (Ga2O3, AlGaN, AlN, BN, and diamond) are key emerging materials for next-generation microelectronic device applications due to the high breakdown field and high mobility, enabling high switching speed and low switching losses. At the system level, this translates to improved size, weight, power consumption, cooling requirements, and system cost (SWaP-C2). In addition, materials are capable of operation in extreme environments such as high temperature (>500C) and radiation environments. In my group, we will evaluate device reliability and failure mechanisms, apply TCAD modeling and machine learning algorithms to device design, study heat transfer and novel thermal management technologies, understand operation in extreme environments, develop advanced processes for 2.5D and 3D heterogeneous integration, and collaborate with the Materials Science and Engineering Department on research topics associated with material growth by metal organic chemical vapor deposition.

JASON E. BUTLER, PROFESSOR

Ph.D., 1998, University of Texas at Austin **butler@che.ufl.edu**

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. Two major thrusts and examples within these spaces 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 **wontae.choi@ufl.edu**
Postdoctoral Scholar, 2017-2018, Georgia Institute of Technology
Postdoctoral Scholar, 2018-2021, University of Texas at Austin

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) perturbating 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.

IN-SITU ANALYSIS OF ELECTROCHEMICAL REACTIONS

Electrochemical processes offer sustainable and environmentally benign routes for energy conversion and storage. Challenges in many electrochemical systems is to design materials (i.e., electrodes and electrolytes) for a specific electrochemical reaction with high selectivity and yield. Establishing rational design strategies of materials is often hindered by limited understanding of the electrochemical reactions at molecular level. We will focus on quantitatively delving dynamics and kinetics of electrochemical reactions by using in-situ electroanalytical techniques (i.e., scanning electrochemical microscopy). The in-situ investigation will be expanded to solve electrochemical problems in diverse research areas including electrocatalysts, battery, biology, and corrosion.

HENRY C. W. CHU, ASSISTANT PROFESSOR

Ph.D., 2017, Cornell University **h.chu@ufl.edu**
Postdoctoral Scholar, 2017-2020, Carnegie Mellon University

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 crisalle@che.ufl.edu

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 A. DENARD, ASSISTANT PROFESSOR

Ph.D., 2014, University of Illinois at Urbana-Champaign cdenard@ufl.edu
Postdoctoral Scholar, 2015-2019, University of Texas at Austin

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

UNDERSTANDING AND REPROGRAMMING THE SUBSTRATE SPECIFICITY OF POST-TRANSLATIONAL MODIFICATION 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. Furthermore, leveraging and reprogramming the specificity of protein-modifying enzymes enables the development of novel therapeutics, diagnostic, and biotechnological tools.

Using methods of protein engineering and synthetic biology, my lab seeks to redefine and redesign the substrate specificity of protein-modifying enzymes 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. **In a second area of research, we are developing ML-guided technologies to reprogram proteases via novel functional protein-protein interactions**. In this area, we are uncovering fundamental mechanisms that govern protease distal regulation and designing enzyme and substrate-selective protease modulators based on macromolecules and natural products.

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**. Specifically, we are investigating how these enzymes recognize their substrates, uncovering non-canonical substrates, and engineering new substrate specificities. One payoff to this research is the ability to generate highly functionalized therapeutic agents with multipronged and synergistic modes of action and to image protein and cellular targets in their physiological contexts.

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 **dickinso@ufl.edu**

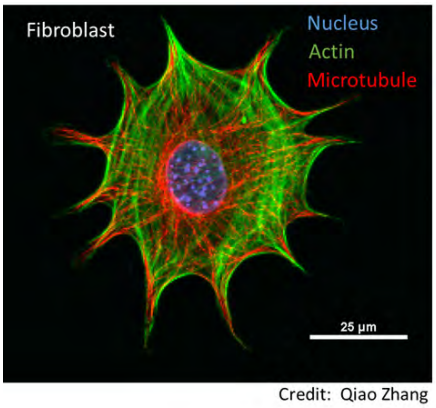
OUR RESEARCH IS IN THE AREA OF MOLECULAR/ CELLULAR bioengineering. We apply engineering principles to study the behavior of living cells or other small-scale biological systems. Using a combination of engineering modeling/analysis, quantitative experimentation, together with the tools of molecular cell 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.

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 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.

MECHANOBIOLOGY 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 and affect gene expression.



Credit: Qiao Zhang

HELENA HAGELIN-WEAVER, ASSOCIATE PROFESSOR AND DR. AND MRS. FREDERICK C. EDIE TERM PROFESSOR

Ph.D., 1999, Royal Institute of Stockholm, Sweden **hweaver@che.ufl.edu**

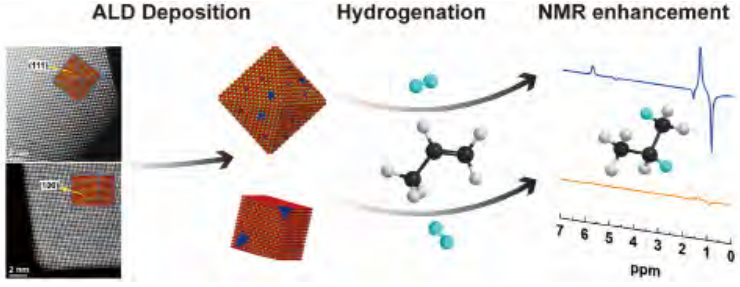
WE WORK ON HETEROGENEOUS CATALYST DEVELOPMENT in my laboratory and our ultimate goal is to obtain a fundamental understanding of these catalysts at the atomic level. Our approach is to synthesize well-defined heterogeneous catalysts using nanoparticle oxides with various shapes and sizes as supports 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.



DAVID HIBBITTS, ASSOCIATE PROFESSOR, ASSOCIATE CHAIR FOR GRADUATE STUDIES, AND MORENO RISING STAR PROFESSOR

Ph.D., 2012, University of Virginia **hibbitts@che.ufl.edu**
Postdoctoral Scholar, 2012-2015, University of California, Berkeley

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 CO_2-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

Ph.D., 2013, University of Missouri, Kansas City **jainp@ufl.edu**
Postdoctoral Scholar, 2014-2018, 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/Cas technology works by introducing two components inside cells, a Cas nuclease that acts like molecular scissors and a guide RNA that binds with Cas 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 hundreds of variants of CRISPR/Cas systems with applications in DNA and RNA manipulation. The biggest remaining challenges for CRISPR/Cas technology are safety, efficacy, and delivery. To address these pressing concerns, Jain lab is 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 discovered/engineered various CRISPR/Cas12 systems to turn them into fast cutters (Nat. Comms., 2020; Methods,2021; medRxiv, 2021). This helped us develop rapid and simple genomic tests for detecting SARS-CoV-2 virus (Comms. Med.-Nature-2022, eBioM-The Lancet, 2022) 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 chemically modify the guide RNA or 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 (Nat. Comms., 2020).

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 (Nanoscale, 2019).

YEONGSEON JANG, ASSISTANT PROFESSOR

Ph.D., 2013, Seoul National University **y.jang@ufl.edu**
Postdoctoral Scholar, 2014-2015, University of Pennsylvania
Postdoctoral Scholar, 2015-2018, Georgia Institute of Technology

MY RESEARCH GROUP SEEKS TO PROVIDE FUNDAMENTAL INSIGHTS AND PRACTICAL SOLUTIONS IN THE FIELD OF SUPRAMOLECULAR BIOMATERIALS. We aim to engineer structural and functional properties of supramolecular biomaterials for target applications including synthetic cells, micro-bioreactors, and antibacterial and drug release coatings. The vision of our lab is to utilize soft matter assembly, polymer engineering, and recombinant technology for the creation of advanced biomaterials. From a deep understanding of the interactions between soft matters, including polymers, proteins, and colloids, we develop supramolecular biomaterials that present target microscopic structure, mechanical properties, and functionality. Recombinant protein technology enables the creation of potential building blocks - functional fusion proteins controlled at molecular and supramolecular levels. The current focus of the Jang Lab is to design synthetic cell platforms based on the fusion protein-assembled vesicles, realize biomimetic functional surfaces for bactericidal properties, and understand cell-biomaterial Interactions.

PHASE STUDY OF GLOBULAR PROTEIN-FUSED DIBLOCK COPOLYMERS

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

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 synthetic 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 on the surfaces. We precisely control the 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.

PENG JIANG, PROFESSOR

Ph.D., 2001, Rice University **pjiang@che.ufl.edu**

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 AND UNDERGRADUATE PROGRAM COORDINATOR

Ph.D., 2002, University of Notre Dame **dkopelevich@che.ufl.edu**

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

Ph.D., 1978, University of Cambridge **ladd@che.ufl.edu**

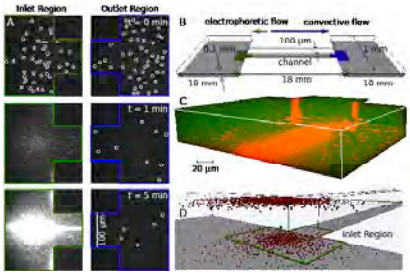
OUR RESEARCH FOCUSES ON DYNAMICS at scales that are small macroscopically (μm to mm), but are large compared to molecular sizes. The research combines statistical mechanics and fluid dynamics with advanced computing to elucidate the key physical processes that underlie laboratory observations and measurements.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

JOSHUA D. MOON, ASSISTANT PROFESSOR

Ph.D., 2019, The University of Texas at Austin **joshua.moon@ufl.edu**
Postdoctoral Scholar, 2019-2022, University of California, Santa Barbara

OUR RESEARCH FOCUSES ON DESIGNING ADVANCED POLYMER MATERIALS for clean energy, clean water, and environmental sustainability. We combine modular polymer synthesis with experimental tools that probe both molecular-scale and macroscopic transport in polymers with the goal of informing predictive design of the next generation of materials for membrane-driven separations.

A few areas of interest to our group are:

PREDICTING GAS SEPARATION MEMBRANE PERFORMANCE IN REALISTIC ENVIRONMENTS

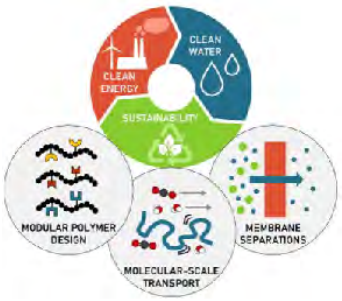
Polymer membranes offer a competitive option for energy-efficient carbon capture and hydrocarbon purification; however, many promising materials developed in the lab fail to perform as well in the field. We aim to bridge this gap by studying how the components in industrial gas and vapor mixtures affect polymer membrane properties at the molecular level and how these dynamic and thermodynamic properties can be leveraged to develop high-performance membranes for efficiently separating complex mixtures vital to the energy industry.

DESIGNING CUSTOM-TAILORED ADSORBENTS FOR REMOVING TOXIC COMPOUNDS FROM WATER

Persistent organic pollutants such as perfluoroalkyl substances (PFAS) are a major contaminant of concern for our drinking water resources. Our lab aims to leverage the versatility and modularity of "click" chemistry to design fit-for-purpose hydrogel membranes and adsorbents with functionality specifically tailored to capture and remove PFAS compounds from water. Adsorption kinetics and thermodynamics will provide a route to link molecular-level structure to PFAS separation performance.

DEVELOPING REPROCESSABLE POLYMER MATERIALS FOR MEMBRANES AND SUSTAINABLE PACKAGING

As the world edges toward a circular polymer economy, developing reusable materials is becoming increasingly important for mass transfer applications including membranes and food or electronics packaging. We will explore how dynamic chemistry, such as non-covalent interactions, can be used to develop new classes of reprocessable, self-healing materials with desirable barrier or separation properties that could offer more sustainable alternatives to commodity plastics.



RANGA NARAYANAN, DISTINGUISHED PROFESSOR, AND DISTINGUISHED TEACHER-SCHOLAR

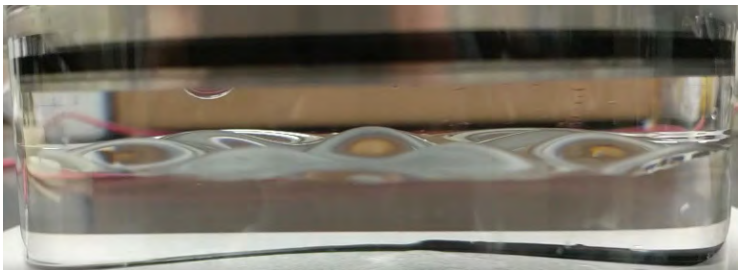
Ph.D., 1978, Illinois Institute of Technology **ranga@ufl.edu**

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

Ph.D., 1983, University of California, Berkeley meo@che.ufl.edu

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. In current work, we are developing models to predict corrosion of copper-clad cannisters Intended for storage of nuclear waste in underground repositories.

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, 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 modeling and experimental study of the impedance of enzyme-based sensors for biological systems, a modelling and experimental study of electrodes used for stimulation of neurons, 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.

FAN REN, DISTINGUISHED PROFESSOR

Ph.D., 1991, Brooklyn Polytechnic Institute of Technology ren@che.ufl.edu

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. AlGaN/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

b-phase of Gallium Oxide is a very promising monoclinic semiconductor with relevant applications for power electronics and also for solar blind photodetectors. β-Ga_2O_3 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 Ga_2O_3, 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.

JUAN MANUEL RESTREPO-FLÓREZ, ASSISTANT PROFESSOR

Ph.D., 2019, Georgia Institute of Technology **restrepoflorezj@ufl.edu**
Postdoctoral Scholar, 2019-2022, University of Wisconsin-Madison

In my group, we leverage our expertise in optimization and multhyphysics simulations to formulate mathematical models enabling the identification of new, sustainable, and innovative processes, and materials. We are motivated by the grand-challenges in sustainability: (1) the need to develop carbon-neutral processes to produce energy and chemicals, (2) the need to minimize waste generation, and (3) the urgency to find mitigation strategies to alleviate the damage already done. We focus our efforts into two research thrusts: (1) the design of tools and the formulation of models to support the synthesis, analysis, and optimization of sustainable energy systems and processes that use waste materials as feedstock, and (2) the development of methods for analyzing and enabling new separation technologies.

AT THE ENERGY SYSTEMS LEVEL, we are interested in the synthesis of biorefineries, their integration with electro/photo-catalytic processes that produce fuels and chemicals from CO2, and the incorporation of renewable energy sources into these processes.

AT THE WASTE MANAGEMENT LEVEL, we are concerned with designing and analyzing facilities to process/upgrade plastic waste.

Our efforts are devoted to addressing four questions instrumental for the deployment of these technologies: What pathways should we use to upgrade biomass or plastics into fuels and chemicals? How can we identify them considering economic and environmental criteria? How can we tailor them to obtain products with similar or better properties than those currently available? And how can we design their supply chains? To address these questions, we leverage the use of optimization tools (e.g., mixed-integer non-linear programming (MINLP), superstructure-based optimization, stochastic programming), life cycle analysis (LCA), and techno-economic analysis (TEA).

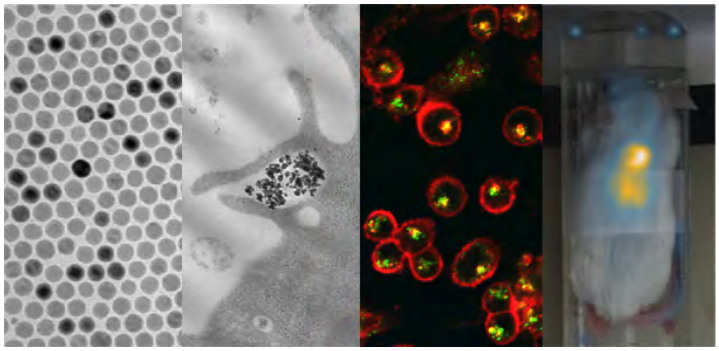
AT THE SEPARATIONS LEVEL, we focus on developing tools for the synthesis and analysis of membranes and adsorption processes and on the design of new materials for the precise control of mass diffusion. Designing energy-efficient separations is fundamental to mitigate the environmental impact of industrial processes. Both membranes and adsorption appear as energy-efficient alternatives. The understanding of these technologies from the material to the process scale enables their widespread implementation. In this field, my research addresses the following questions: How can we use multiphysics simulations to inform the design of adsorption and membrane processes? How can we automate the synthesis of membrane separation cascades? How can we exploit recent advances in diffusion theory to design new materials and devices? To tackle these questions, we will rely on tools such as multiphysics simulations, data-driven surrogate models, and superstructure-based optimization.

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

Ph.D., 2002, Massachusetts Institute of Technology **carlos.rinaldi@ufl.edu**

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 characterization, 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

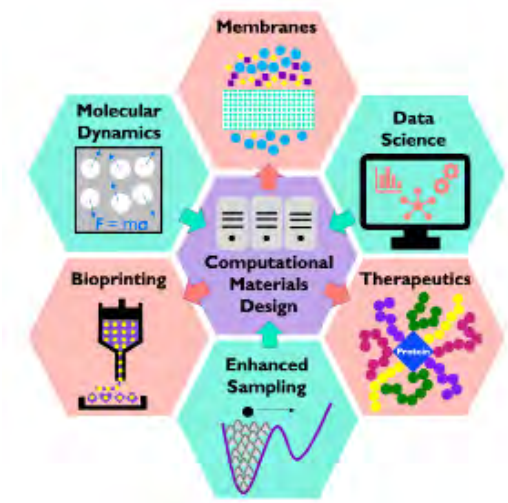
Ph.D., 2018, The Ohio State University **jsampath@ufl.edu**
Postdoctoral Scholar, 2018-2020, University of Washington

WE STUDY POLYMERS, PROTEINS, AND THEIR HYBRIDS TO DESIGN THE NEXT GENERATION OF SOFT MATERIALS using molecular dynamics simulations, high throughout 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 L. STOPPEL, WILLIAM P. AND TRACY CIRIOLI TERM ASSISTANT PROFESSOR AND PH.D. RECRUITMENT COORDINATOR

Ph.D., 2014, University of Massachusetts Amherst **whitney.stoppel@ufl.edu**
Postdoctoral Scholar, 2014-2018, Tufts University

The Stoppel Lab is focused on the design and optimization of natural biomaterials for a variety of applications in healthcare and medicine. We explore and then leverage biopolymers produced by other species, such as insects or plants, and work to understand and engineer complex structures and materials, using nature as our inspiration. We aim to link mechanical and structural properties to transport and kinetics within these materials, understanding and predicting bioactive molecule delivery. We utilize these materials to harness the power of the immune system in tissue regeneration to alter the way that these materials integrate following implantation or to develop 3D material platforms to investigate disease progression. Work in the Stoppel Lab is in collaboration with engineers, clinicians, and scientists. We value educating and training a diverse workforce and welcome anyone interested in applications of chemical engineering to advancing technologies for human health.

TAKING INSPIRATION FROM NATURE TO ENGINEER NEW MATERIALS

Insects in the Lepidopteran order produce silk fibroin proteins to form their cocoons, aid in food storage, and for transportation. Traditionally, silk-based healthcare materials come from cocoons of the domesticated silkworm (Bombyx mori), and we aim to expand use to other species. We use rheological and microscopy techniques to quantify mechanical and structure properties in new materials. We use genetic engineering techniques, such as CRISPR, to alter protein sequences. We explore environmental changes, such as those anticipated with climate change, on wild type silk protein sequence and structures. We take inspiration from these insects to engineer biomaterials to meet current and future challenges in healthcare and medicine.

MATERIAL DESIGN AND IN VITRO CHARACTERIZATION

Natural biopolymers such as silk fibroin, alginate, or decellularized extracellular matrix can be combined to form biomaterials. The biomaterial's composition has significant impact on cell 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.

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 neo-tissue formation.

SPYROS SVORONOS, HARRY AND BERTHA BERNSTEIN PROFESSOR AND ASSOCIATE CHAIR FOR UNDERGRADUATE STUDIES

Ph.D., 1981, University of Minnesota svoronos@che.ufl.edu

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. Phlips of the UF School of Forest Resources and Conservation.

SERGEY VASENKOV, PROFESSOR

Ph.D., 1994, Russian Academy of Science svasenkov@che.ufl.edu

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 PROPERTRIES

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, DOW CHEMICAL COMPANY FOUNDATION TERM 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 kinetic measurements combined with operando surface spectroscopy 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.

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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.

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