Graduate Study *at*

RICE

GRADUATE STUDY IN CHEMICAL AND BIOMOLECULAR ENGINEERING

Rice University

WWW.RICE.EDU/CHBE

For admission in 2018

FROM MOLECULES TO SYSTEMS

The recent revolutionary advances in nanoscale science and molecular biology open exciting new avenues for developing new materials, biological products, and medical therapeutics. At the same time, economic and social forces are driving a transition toward more sustainable and environmentally friendly production methods. Chemical engineers are uniquely qualified to play leading roles in these revolutions. For more than a century, we have been very successful in developing and refining the tools necessary for translating molecular-level discoveries into new and cost-effective products. To meet the challenges of the new century, however, we must integrate molecular biology and nanoscale science into the scientific foundation of our discipline. This expanded knowledge base will enable us to engineer new products by scaling up processes from the molecular to the system level.

To achieve these goals, Rice's Department of Chemical and Biomolecular Engineering is continually working to develop and enrich an integrated research and educational program aimed at:

- conducting world-class research in the areas of advanced materials and complex fluids, biosystems engineering and energy and environmental systems;
- educating outstanding undergraduate and graduate chemical engineers to rise to leadership roles in academia, industry, law, business, medicine and government; and
- promoting interdisciplinary collaborations and forming bridges linking Rice innovations to applications in the chemical, energy, biotechnology and materials industries.

The targeted research areas provide many opportunities for interdisciplinary research that emphasizes a combination of theoretical, computational and experimental approaches. This culture of collaboration is an integral part of our departmental tradition. Starting with its involvement in the emerging petrochemical industry in the 1920s and continuing with its pioneering work on artificial heart devices in the 1960s, our department has a long history of successfully tackling multidisciplinary problems and expanding the reach of chemical engineering to new areas.

Over the past two decades, Rice has established several institutes and centers to promote interdisciplinary research on nanotechnology, biological sciences and engineering, information technology, and energy and environmental engineering. Our faculty members play key roles in the Smalley Institute for Nanoscale Science and Technology, the Energy and Environmental Systems Institute, the Institute of Biosciences and Bioengineering and the Ken Kennedy Institute for Computer Technology.

Please visit our website at chbe.rice.edu for more information.

THE PROGRAMS

The Department of Chemical and Biomolecular Engineering at Rice offers a program of graduate study leading to a Doctor of Philosophy (Ph.D.) degree. A non-thesis professional master's degree (M.Ch.E.), involving course work only is also offered. The first year thesis degree program is flexible and allows entering students the time to develop a sound base in advanced areas of chemical and biomolecular engineering and to fully investigate the research interests of the faculty. A large portion of the formal course work leading to the Ph.D. degree is completed during the first year. Ph.D. students entering Rice with a bachelor's degree must take at least 24 semester hours of advanced courses. Courses are offered in thermodynamics, transport phenomena, mathematics and reaction engineering are required and provide excellent preparation for research and the qualifying examinations. Additional course selections are based on a student's individual preferences and previous educational background.

Entering graduate students attend a seminar series in which members of the faculty discuss their research programs. After attending these seminars, the students discuss possible Ph.D. thesis projects with individual faculty members and submit their top three choices of research projects to the graduate studies committee. The final decision on research topic assignments is made during a departmental faculty meeting. Most Ph.D. students complete their degrees in four to five years.

FACULTY/CURRENT RESEARCH

One of the most important criteria in choosing a graduate school is the availability of one or more faculty members within a department who can provide stimulating guidance in developing the student's independent research abilities. Members of the Rice chemical and biomolecular engineering faculty and their specialized research interests are described below. Joint faculty whose primary appointment is bioengineering will accept graduate students through that department. Additional information can be found on the department's website at chbe.rice.edu.

Sibani Lisa Biswal. Associate Professor, Chemical and Biomolecular Engineering. Materials Science and Nano Engineering. B.S. (1999) California Institute of Technology, M.S. (2001) and Ph.D. (2004) Stanford University. Intermolecular forces lead to unique structures in self-assembling systems and play a major role in many biochemical processes, such as drug–receptor binding. Professor Biswal's area of research involves exploiting these forces to develop novel materials, with a primary focus on understanding and controlling their physical and chemical properties. One problem of interest is how confined colloidal fluids can change their structure and mechanical properties under the action of controlled external forces. Unlike molecular self-assembled systems, which are at equilibrium, the systems we study are dynamic and become ordered when energy is dissipated. Dr. Biswal's group is developing nano- and microfluidic systems to change the scale of confinement, thereby changing the rules for self-assembly. The second area of interest is interfacing biological molecules with inorganic substrates. These hybrid biomaterials allow us to convert molecular and biological signals into mechanical and electronic information. These areas of research are based on understanding and designing interactions among nanoparticles, biomolecules and surfaces with the hopes of achieving new types of functionality.

Walter G. Chapman. William W. Akers Professor, Chemical and Biomolecular Engineering, Associate Dean for Energy Research. B.S. (1983) Clemson University, Ph.D. (1988) Cornell University.
Professor Chapman's group develops models to predict the thermodynamic properties and interfacial structure of complex fluids used in plastics, paints, coatings and films. His group also develops novel approaches to measure and model systems like natural gas hydrates and asphaltenes of interest to the energy industry. Research tools such as molecular simulation, computer visualization, statistical mechanics, high-pressure measurements and NMR are used to discover how macroscopic bulk and interfacial properties and molecular structure depend on molecular forces. Professor Chapman's present research program focuses on polymer solutions and blends, protein solutions, associating fluids, electrolyte solutions, asphaltenes and gas hydrates. Recent advances made by Professor Chapman's research group have found wide application in industry. For example, the group's models (e.g., the Statistical Associating Fluid Theory to model bulk phase behavior) and high pressure phase equilibria data are extensively used by Chevron, Dow, Shell, BASF and other energy, chemical, and process simulation companies.

Xue Sherry Gao. Assistant Professor, Chemical and Biomolecular Engineering. B.S. (2005) and MS (2007) Tianjin University, and Ph.D. (2013) University of California at Los Angeles.
Dr. Gao's research program lies at the interface of chemical biology and biomolecular engineering with primary focus on small- and macromolecule discovery and their applications to human health, agriculture, and energy. Natural products from microorganisms of diverse origins have played an extremely important role historically in drug discovery. Recent advances in human microbiome research have expanded our understanding of interactions between microbes and hosts related to human health. This unique microbial community also provides a golden opportunity for the discovery of new therapeutics. One of her main research areas is microbiome-based natural product discovery and engineering, and moreover, to develop enzymes involved in the natural product biosynthesis as powerful biocatalysts for difficult chemical reactions in the pharmaceutical and biotechnology industries. The recently discovered microbial ribonucleoprotein, CRISPR/Cas9, in complex with a single guide RNA, has been extensively applied to mediate genome—editing both in vitro and in vivo. Human genetic diseases were previously recognized to be untreatable until recent advances in genome-editing research, which have been revolutionizing medicine for treating human genetic diseases. Another main research interest of her group is to discover and develop advanced genome-editing agents and delivery systems and apply these genome-editing tools as next-generation therapeutics to clinical treatment of human genetic diseases.

George J. Hirasaki. Research Professor, Chemical and Biomolecular Engineering. B.S. (1963) Lamar University, Ph.D. (1967) Rice University. Professor Hirasaki's research in fluid transport through porous media ranges from the nanoscopic-scale intermolecular forces governing wettability to the megascopic-scale numerical reservoir simulators for fieldwide modeling. A recurring theme throughout this research is the dominance of interfaces in the determination of fluid transport processes. Measurement and estimation of the transport properties of bulk fluids and fluids in rocks are made with NMR spectroscopy. This has direct application to NMR well logging in the oil and gas industry. The wettability of petroleum systems is investigated with techniques ranging from AFM to numerical simulation. Surfactant and foam are used in oil recovery and aquifer remediation for mobility control and fluid diversion. Experiments and numerical simulations are used to quantify the interaction of formation heterogeneity with foam transport. Professor Hirasaki is a member of the National Academy of Engineering. He joined Rice's faculty in 1993 after a 26-year career with Shell Development Company.

Frederick C. MacKintosh. Abercrombie Professor, Chemical and Biomolecular Engineering, Professor Chemistry and Physics and Astronomy. Ph.D. (1989) Princeton University.
Professor MacKintosh's research focuses on the fundamental material properties of biological and soft matter networks. His key achievements include; the development of commonly used models of elasticity and dynamics of biopolymer gels, combined experimental and theoretical advances in micro rheology and non-equilibrium, motor-activated gels and active diffusion in cells, as well as the identification of affine to non-affine transitions and critical behavior of fiber networks.

Aditya D. Mohite, Associate Professor Chemical and Biomolecular Engineering and Materials Sciences and NanoEngineering. Ph.D. (2007) University of Louisville. Professor Mohite is an expert in semiconductor device physics and optoelectronic devices. His research philosophy is to develop out-of-the-box scientific and engineering solutions to solving long-standing bottlenecks in the integration of materials into practical devices. His research interest involves understanding and controlling charge transport and photo-physical processes in materials (nanoscale and bulk) and to integrate these materials into proof-of-concept high-efficiency optoelectronic and energy devices such as solar cells, light emitting diodes, lasers, photo-electrochemical cells (for H2 generation or CO2 reduction), photodetectors, flexible electronics, radiation detectors and sensors. He is an expert in the application of correlated interface sensitive techniques such as photocurrent, time-resolved PL, electro-absorption, capacitance, impedance spectroscopy, etc., to investigate the charge and energy transfer processes in materials.
Mohite is an internationally recognized expert in understanding the structure and optoelectronic properties of materials for the next-generation of optoelectronic devices. He has published his work journals as Science, Nature, Nature Materials, Nature Communications and Advanced Materials. (https://scholar.google.com/citations?user=J0XQ6I8AAAAJ&hl=en&oi=ao)
The Resnick Institute at Caltech awarded Mohite its Resonate Award, given for achievements in renewable energy and sustainability-focused science and technology.
Besides science, Mohite played professional cricket in India at the national and international levels.

Matteo Pasquali. Professor, Chemical and Biomolecular Engineering, Materials Science and Nano Engineering. Laurea (1992) Universita di Bologna, Italy; Ph.D. (1999) University of Minnesota. Professor Pasquali directs the research group cf2 (complex flows of complex fluids). The group's research revolves around understanding the interaction of flow and liquid micro- and nano-structure in complex fluids, with a focus on the processing of multifunctional materials, particularly those based on Carbon Nanotubes (CNTs), with applications to energy transmission and harvesting, biomedicine, petroleum, and defense. The cf2 group has made fundamental and applied advances on the manufactur-ing of CNT and graphene fibers, thin films and coatings, the behavior of liquid crystalline phases of CNTs and graphene, the dynamics of individual CNTs in fluids and confined environments, the interaction of CNTs with electromagnetic fields, the effect of flow on flexible and semiflexible molecules, the mechanics of blood cells in blood pumps, the rheology of attractive emulsions, and the application of finite elements, large-scale parallel computing, and thermodynamics projections in modeling flows of complex fluids occurring in microfluidics, coating, ink-jet printing, medical devices, and material processing. Current research efforts include understanding and improving the manufacturing and performance of CNT fibers, the effect of CNT length on the manufacturing and properties of CNT fibers and films, the liquid phase behavior of graphene and graphene oxide, the formation of three-dimensional solid structures of CNTs and graphene by fluid phase processing methods, the motion and detection of CNTs in porous media (with application to oil recovery), the dynamics of viscoelastic filaments in the presence of wetting and dewetting forces, and various applications of CNT fibers to field emission, data cables, and power transmission. Prof. Pasquali ealier research interests include theoretical and experimental studies of free surface flows of polymer solutions and the dynamics of semiflexible polymers. The cf2 group research includes collaborations with international groups in France (CNRS and Université Bordeaux), the Netherlands (Teijin Aramids and Vrije Universiteit Amsterdam), Germany (RWTH Aachen and Georg-August-Universität Göttingen), Italy (Università of Roma), Israel (Technion), Brazil (PUC Rio), and Australia (Monash University), as well as US collaborations with the Air Force Research Laboratory, the National Institute of Standards & Technology, University of Massachusetts at Amherst, University of Colorado at Boulder, and the University of Minnesota . The cf2 group is funded by government agencies (including Department of Defense, National Science Foundation, National Institutes of Health, and National Institute of Standards & Technology), foundations (Welch Foundation), and companies and industry consortia (Advanced Energy Consortium, Teijin Aramids, Lockheed-Martin, Saudi Aramco). For more information, see the website of Professor Pasquali's research group at pasquali.rice.edu.).

Marc A. Robert. Professor, Chemical and Biomolecular Engineering. Dipl. (1975) Swiss Federal Institute of Technology, Zurich; Ph.D. (1980) Swiss Federal Institute of Technology, Lausanne.
Professor Robert's research is concerned with theoretical, experimental and computer simulation studies of the thermodynamic, structural and transport properties of matter, in simple and complex systems. Of particular current interest are colloid-polymers systems, including proteins and DNA, magnetic carbon nanotubes, nanoclusters of magnetic elements or molecules and disordered systems. Professor Robert collaborates with Professor A. Panagiotopoulos and R. Car (Princeton University). In studies of the electrical and elastic properties of disordered systems, such as composites and polymers, Professor Robert and Dr. Payandeh are analyzing microscopic models of conductivity, superconductivity and elasticity as the materials become increasingly disordered; they also study symmetry breaking in quantum field theory.

Laura Segatori. Associate Professor, Chemical and Biomolecular Engineering and Bioengineering. B.S. (2000) University of Bologna, Italy; Ph.D. (2005) University of Texas at Austin.
Professor Segatori's research interest focuses on cellular protein folding particularly in association with the development of human diseases. Proteins must fold into the correct three-dimensional conformation in order to attain their biological function. The balance between formation and maintenance of proteins' active conformations and their turnover, named folding quality control, is remarkably delicate. Thus, alterations in the amino acid chain by inherited sequence mutations or acquired age or stress related modifications might compromise the folding and the stability of proteins, and often result in cellular dysfunction and disease. Because proteins have a remarkably wide variety of functions, protein misfolding can lead to the development of a large number of human diseases, ranging from late onset neurodegenerative diseases, such as Alzheimer's and Parkinson's, to early childhood metabolic diseases, such as lysosomal storage disorders, to cancer. Professor Segatori's laboratory studies the ensemble of competing and integrated biological pathways within the cell that control the biogenesis, folding, trafficking and turnover of proteins and maintain protein homeostasis, or proteostasis. Particular interest is devoted to the design of protein engineering strategies to manipulate the proteostasis network and reprogram the innate folding capacity of the cell with the ultimate goal to rescue native folding of unstable, misfolding-prone proteins. The Segatori's lab specifically investigates i) loss-of-function phenotypes caused by excessive protein misfolding and degradation, using cells derived from patients with Gaucher's disease, ii) gain-of-toxic-function

phenotypes characterized by aberrant accumulation of misfolded proteins and aggregation, using a cell model of Parkinson's disease, and ii) the macromolecular machinery that catalyzes degradation of misfolded proteins in mammalian cells.

Thomas P. Senftle. Assistant Professor, Chemical and Biomolecular Engineering. BS (2010) University of Notre Dame, and Ph.D. (2015) Pennsylvania State University.
Dr. Senftle's research focuses on the development and application of hybrid simulation techniques for assessing complex, multi-component catalysts at both the electronic and atomistic level. Catalytic processes play a central role in improving the efficiency of low-carbon energy technologies, such as the utilization of fossil resources with fuel cells, or the electro-chemical processing of H2O and CO2 to produce fuels. Successful catalysts must feature complex surface morphologies (e.g., metal nanoclusters of varying size and composition on oxide supports, or functionalized semiconductor electrodes in equilibrium with multicomponent electrolyte solutions), as multiple functionalities will be required to achieve conversion that is both active and selective. In Dr. Senftle's work, emphasis is placed on developing fundamental structure-activity relationships informing the rational design of catalytic systems, leading to concrete optimization principles for tailoring catalysts to the operating environment of their application. Current research projects include the computational design of semiconductor materials for photoelectrochemical applications, as well as metal-oxide materials for catalytic reforming applications.

Francisco Vargas, Assistant Professor, Chemical and Biomolecular Engineering. BS (1999) and MS (2002) Monterrey Tech, Mexico; Ph.D. (2010) Rice University. Dr. Vargas' research group is focused on developing innovative experimental approaches and simulation tools to understand and predict the structure, phase behavior and thermodynamic and transport properties of complex fluids, at high temperatures and pressures. A major component of the current research program is dedicated to finding solutions to major flow assurance problems in the oil industry, such as asphaltene deposition. These complex problems require an interdisciplinary approach to look into the molecular structure, micro and macroscopic morphology, optical, thermodynamic and transport properties complemented with advanced thermodynamic and computational fluid dynamics modeling. The interests of Dr. Vargas' research group also include the development of integrated approaches for an efficient and sustainable enhancement of the production of conventional and unconventional energy resources.

Rafael Verduzco. Associate Professor, Chemical and Biomolecular Engineering, Materials Science and Nano Engineering, B.S. (2001) Rice University; M.S. (2003), Ph.D. (2007) California Institute of Technology. Polymeric materials are ubiquitous in consumer products, and they also represent an integral part of emerging technologies that promise to solve our society's most urgent challenges in energy, sustainability and public health. An overarching theme of research in the Verduzco group is to understand and control macroscopic properties of polymeric materials by manipulating molecular level structure. One particular area of focus in the group is to understand the impact of liquid crystalline ordering on the structure and functionality of polymeric materials. Materials with liquid crystal order are used in displays, and the same type of ordering is potentially useful for developing stimuli-responsive materials and optical sensors. Polymer self-assembly is another common theme, and directing the spontaneous structure generation of block copolymers can lead to nanostructured polymeric templates and tailored interfaces. A third area of research focuses on conjugated or semi-conducting polymers for organic electronics, photovoltaics and sensing. Current challenges in the field of polymeric semiconductors is understanding the relationship between macromolecular conformation and electro-optic properties and finding new ways to tune the materials' electro-optic properties. Professor Verduzco brings together polymer synthesis techniques along with a variety of characterization methods including electro-optic measurements, rheological experiments, and scattering to design and study polymeric materials.

Michael S. Wong. Professor, Chemical and Biomolecular Engineering and Chair of the Chemical & Biomolecular Engineering Dept., Professor, Chemistry, Materials Science and Nano Engineering and Civil and Environmental Engineering, B.S. (1994) California Institute of Technology; M.S. (1997), Ph.D. (2000) Massachusetts Institute of Technology.
Treating nanoparticles as building blocks and assembling them into functional structures is a powerful concept in materials synthesis and chemical engineering, in which the dimension-dependent properties of the nanoparticles can be handled and exploited in a usable form. Within the research group and with collaborators, Professor Wong is interested in understanding the fundamentals of nanoparticle synthesis and self-assembly, and in using these techniques to design and engineer new nanoparticle-based applications in industrial and environmental catalysis and bio-encapsulation. His research group has been developing Pd/Au bimetallic core/shell nanoparticles for enhanced degradation of chlorinated compounds in water, which have great potential as a catalyst technology in groundwater remediation. They have been studying the surface chemistry and catalysis of thermally stable amorphous metal oxides supported on ceramic nanoparticles. Amorphous metal oxides generally are neglected in high temperature reactions because of their propensity to crystallize, but the underlying ceramic nanoparticles hinder the crystallization of the amorphous overlayer, enabling their use as potential heterogeneous catalysts for methanol conversion. They also have been studying the ability of charged nanoparticles to self-assemble in the presence of polymer molecules to form hollow microcapsule structures. This room-temperature, aqueous-phase self-assembly chemistry allows the nondestructive encapsulation, delivery and release of water-soluble compounds, such as therapeutic molecules and enzyme molecules, for applications in drug delivery and biotechnology. Finally, Professor Wong's group has been studying fluorescent semiconductor nanoparticles known as quantum dots, specifically their scale-up issues and their photocatalytic properties.

Kyriacos Zygourakis. A.J. Hartsook Professor, Chemical and Biomolecular Engineering, Professor of Bioengineering, Dipl.Ch.E. (1975) National Technical University, Athens, Greece; Ph.D. (1981) University of Minnesota.
The research interests of Dr. Zygourakis span several areas of reaction engineering and bioengineering. Using video microscopy, digital image analysis, and computer simulations, his group is studying the mechanisms through which cell migration affects the dynamics of cell populations and the growth rates of tissues. Dr. Zygourakis also is collaborating with other faculty in the development of a novel framework that combines experimental, theoretical, and computational tools to study heterogeneous cell populations as complex and highly interconnected systems with interacting components. This system-based approach will change the design principles used to develop tissue substitutes with desirable structure, materials with novel properties, and other bio-based, environmentally friendly, and sustainable technologies. In the reaction engineering area, experimental and theoretical studies are carried out to determine which structural and process parameters control the large-scale production of nanoparticles, the reactivity of porous solids, and the degradation of scaffolds used for tissue engineering applications.

Pulickel M. Ajayan. *Joint Appointment.* Benjamin M. and Mary Greenwood Anderson Professor, Mechanical Engineering and Materials Science and Nano, Professor, Chemical and Biomolecular Engineering, and Materials Science and Nano Engineering. Ph.D. (1989) Northwestern University.
Professor Ajayan's research focuses on the development of functional nanostructured materials for a variety of applications. His research group looks at the materials science and engineering aspects of these novel materials with three different focused application areas: nanomaterials in energy generation and storage; multifunctional composites and nano-enabled bio-mimetic systems; and nanoelectronics, nano sensors and active systems.

George Bennett. *Joint Appointment.* E. Dell Butcher Professor of Biosciences. Professor, Chemical and Biomolecular Engineering. B.S. (1968) University of Nebraska, Ph.D. (1974) Purdue University.
Professor Bennett's research focuses on genetic engineering of metabolic pathways of microbes for production of biofuels and chemicals. In order to construct an effective biocatalyst and carry out effective modification of the metabolic pattern of cells, knowledge of the native regulatory processes, enzymes and pathways of the microbe must be understood. We study the responses of bacteria to stresses either encountered in nature or in an industrial fermentor, such as pH, oxygen limitation or salt concentration. These fundamental studies have developed our approaches to metabolic engineering: cofactor engineering-the modification of the availability of redox factors such as NADH; the "cellular refinery" approach of producing multiple compatible products during a process; and the modeling and use of available genetic resources from the large genomic and biochemical databases for optimal metabolic performance.

Cecilia Clementi. *Joint Appointment.* Professor, Chemistry, Professor, Chemical and Biomolecular Engineering and Chair of Weiss Career Development. B.S. (1995) Universitá degli Studi di Firenze; M.S. (1996); Ph.D. (1998) Trieste, Italy.
Dr. Clementi's research activity lies at the interface of physics, chemistry and biology. Her current research interests concern the theoretical and computational investigation of protein folding, protein interactions and functions. Her most recent research has focused on the definition and exploration of protein models with different levels of complexity aimed to study, and possibly predict, the folding mechanism of proteins. The modeling procedures rely mostly on the application of statistical mechanics techniques to capture the important ingredients of the protein systems. The kinetic and thermodynamics of the protein models are studied extensively through molecular dynamics simulations to compare with the experimental data. The models and theories developed so far have been successfully applied to a set of monomeric proteins. Dr. Clementi's group is currently enlarging and improving the methodologies to include protein–protein interactions and assembling in order to proceed toward an understanding of biological functions. Moreover, applications to proteins systems of biomedical relevance are in progress. Dr. Clementi has ongoing collaborations with Baylor College of Medicine, the Department of Biochemistry and Cell Biology, the Department of Chemical Engineering and the Department of Computer Science. For more information, see the Web site at leonardo.rice.edu/~cecilia.

Eilaf Egap, Joint Appointment, Assistant Professor Materials Science and NanoEngineering, Chemical and Biomolecular Engineering. BS (2005) Stony Brook University, Ph.D. (2011) University of Washington.
Dr. Egap's research focuses on developing fundamentally new materials with novel photonic, electronic and optoelectronic properties, utilizing tools from polymer chemistry and materials science and nanoengineering to address challenges in energy conversion, sustanbility and early diagnostics. Her interests lie in molecular–engineering, elucidation of structure–property relationships, self–assembly, and creating new device architectures in applications ranging from biological imaging, sensing, early diagnostics and delivery of therapeutics, to photovoltaics and magneto–electronic and optoelectronic devices. The Egap group has established the following three thrust areas of research: (i) the molecular-engineering of well-defined block copolymers with precisely controlled nanostructured architectures for photonic, electronic and optoelectronic applications; (ii) engineering excited states and spin-polarization of soft materials and hybrid organic/inorganic nanostructures to understand and control the role of electron spin dynamics in magneto-optic and optoelectronic devices; and (iii) the development of a modular platform to engineer responsive and well–defined multifunctional polymeric nanostructures for diagnostics. Our approach combines careful measurements, synthesis of new materials and structures, elucidation of structure-property, study of photophysics and dynamics, controlling and understanding the self-assembly and morphology, device fabrication, and when possible theory and simulation.

Rob Griffin. *Joint Appointment.* Professor and Chair, Civil & Environmental Engineering, Professor Chemical & Biomolecular Engineering. BS (1993) Tufts University, MS (1997) and Ph.D. (2000) Caltech.
Dr. Griffin's research interests lie in performing field, laboratory, and computational experiments designed to understand the effects and behavior of organic species in the troposphere. These projects have been supported by NSF, NASA, EPA, NOAA, HARC, EPRI, CARB, the Dreyfus Foundation, and the Coordinating Research Council. Dr. Griffin's previous work has been published in journals that include Science, Environmental Science and Technology, The Journal of Geophysical Research - Atmospheres, Geophysical Research Letters, Atmospheric Environment, and The Journal of Atmospheric Chemistry. Dr. Griffin's teaching interests are focused on undergraduate courses in air pollution control and fluid mechanics and on graduate courses in atmospheric chemistry and atmospheric aerosols. He is a member of the American Association of Aerosol Research, the American Chemical Society, and the American Geophysical Union.

Anatoly B. Kolomeisky. *Joint Appointment.* Professor, Chemistry and Professor, Chemical and Biomolecular Engineering. M.S. (1991) Moscow State University; M.S. (1996), Ph.D. (1998) Cornell University.
Dr. Kolomeisky's field concerns theoretical physical chemistry, biophysics and statistical physics. He is interested in the problems of biological transport systems; random walks; stochastic processes in chemistry, physics and biology; traffic problems; polymer dynamics; driven lattice gases; thermodynamic properties of electrolytes and systems with long-range interactions; theory of hydrophobicity; and polymer translocation.

Qilin Li. *Joint Appointment.* Associate Professor, Civil and Environmental Engineering, Chemical and Biomolecular Engineering, Materials Science and NanoEngineering. BE (1995) Tsinghua University; MS (1999) and Ph.D. (2002) University of Illinois at Urbana-Champaign.
Dr. Li teaches courses and conducts research on physical and chemical processes that impact water quality in natural aqueous environment as well as water/wastewater treatment systems. Dr. Li's current research focuses on the behaviors of environmental colloids and macromolecules at aqueous-solid interfaces and the subsequent impact on their fate and transport in natural and engineered systems. Ongoing research projects investigate fouling of membrane materials during surface water filtration, seawater desalination and wastewater reuse, nanotechnology enabled drinking water disinfection and surface microbial control, the environmental fate, transport and ecotoxicity of engineered nanomaterials, and sustainable water infrastructure. Dr. Li's research group is devoted to finding a solution to sustainable water supply.

Antonios G. Mikos. *Joint Appointment.* Louis Calder Professor, Bioengineering, Professor, Chemical and Biomolecular Engineering, Director, Center for Excellence in Tissue Engineering and Director of the John W. Cox Laboratory for Biomedical Engineering. Dipl.Ch.E. (1983) Aristotle University of Thessaloniki, Greece; M.S.Ch.E. (1985), Ph.D. (1988) Purdue University.
Professor Mikos conducts research in the areas of biomaterials, drug delivery, gene therapy and tissue engineering. His work emphasizes the use of synthetic biodegradable polymers as supportive scaffolds for cells, conduits for guided tissue growth, specific substrates for targeted cell adhesion, stimulants for a desired cellular response, carriers for controlled drug delivery, and nonviral vectors for gene therapy. Professor Mikos is particularly interested in bone regeneration and repair using injectable, *in situ* polymerizable and biodegradable polymer scaffolds. In addition, his group studies the effects of mechanical forces and flow on bone cells and is developing new CAD/CAM and polymer chemistry fabrication technologies for the production of synthetic biomimetic materials.

Peter J Rossky. *Joint Appointment.* Harry C. and Olga K. Wiess Professor of Chemistry, Chemical and Biomolecular Engineering, Dean, Weiss School of Natural Sciences. Ph.D. (1978) Harvard.
Dr. Rossky's research includes the elucidation of the fundamental molecular-level origins of chemical behavior in condensed phases and clusters.

Ka-Yiu San. *Joint Appointment.* E.D. Butcher Professor, Bioengineering and Professor, Chemical and Biomolecular Engineering. B.S. (1978) Rice University, Ph.D. (1984) California Institute of Technology.
Professor San's research focuses on various engineering aspects of utilizing biological systems as catalysts to create useful products. The scope of his research activities encompasses metabolic engineering of microorganisms, bioreactor design and optimization, and control algorithm development and implementation. Through these efforts, he is trying to answer some of the questions that are critical in the design and operation of a successful bioprocess. In the area of metabolic engineering of *Escherichia coli*, Professor San and Professor Bennett of the biochemistry and cell biology department at Rice are using recombinant DNA techniques to systematically alter the metabolic activities of *E. coli*.

Ned Thomas. *Joint Appointment.* Professor, Material Science & NanoEngineering, Chemical & Biomolecular Engineering, Chemistry, Ph.D. (1974) Cornell University.
Dr. Thomas's research focus is polymer physics and engineering, photonics and phononics and mechanical and optical properties of block copolymers, liquid crystalline polymers, and hybrid organic-inorganic nanocomposites.

EMERITUS FACULTY

Constantine D. Armeniades. Professor Emeritus, Chemical and Biomolecular Engineering. B.S. (1961) Northeastern University, M.S. (1967) Case Institute of Technology, Ph.D. (1969) Case Western Reserve University.
Polymeric materials, biological as well as synthetic, have been the subject of Professor Armeniades' research over the past 30 years. He has studied the particular structural features in collagenous tissue, responsible for function or malfunction in specific organs; investigated nonsurgical treatments for opthalmic vitreoretinopathy; and developed instrumentation for control of fluid pressure inside the eye during closed-system surgical procedures. In the area of synthetic polymers, he has developed novel prepolymer compositions, suitable for generating nonflammable foams, as well as macromolecular matrices with enhanced strength and thermal stability; he has also conducted experimental and theoretical studies on strengthening mechanisms in high-performance polymers and their composites. His most recent work includes the development of interpenetrating networks, consisting of entangled carbon nanotubes, infused with epoxy or poly (amide-imide) resins.

Sam H. Davis Jr. Professor Emeritus, Chemical and Biomolecular Engineering and Computational and Applied Mathematics. B.A. (1952), B.S. (1953) Rice University; Sc.D. (1957) Massachusetts Institute of Technology.
Professor Davis has conducted experimental and theoretical studies of several problems associated with atmospheric control of spacecraft. Experimental studies center on the collection of multicomponent absorption and adsorption data. Professor Davis also is interested in computer education for engineering students and maintains web sites used in chemical engineering, computer applications and applied mathematics.

Derek C. Dyson. Professor Emeritus, Chemical and Biomolecular Engineering. B.A. (1955) University of Cambridge, Ph.D. (1966) University of London. Professor Dyson has conducted research on interfacial phenomena and their applications to petroleum recovery. He has investigated the stability of blobs of oil in an oil-rock-water or oil-rock solution system in order to obtain a better understanding of the mechanics of mobilization of blobs. These studies led to general results that permit the prediction of blob stability for isolated single-interface systems.

Clarence A. Miller. Professor Emeritus, Chemical and Biomolecular Engineering. B.S. (1961) Rice University, PhD. (1969) University of Minnesota. Professor Miller's research focused on interfacial phenomena, especially those involving surfactants. The shift of the chemical industry toward specialty products brought with it increased interest in surfactants and their applications in detergency, pharmaceutical and food products, petroleum production, groundwater cleanup, agricultural chemicals and personal-care products. Professor Miller was able to use video microscopy to investigate various dynamic phenomena such as stability of emulsions and foams, spontaneous emulsification and dissolution rates of surfactants. Dr. Miller is a fellow of the American Institute of Chemical Engineers.

INTERDISCIPLINARY RESEARCH

Smalley Institute for Nanoscale Science and Technology
Established in 2001 as one of six Nanoscale Science and Engineering Centers funded by the National Science Foundation, the Smalley Institute is the first to focus on applications of nanotechnology to human health and the environment.

The Institute's research activities explore the wet/dry interface between nanomaterials and aqueous systems at multiple length scales, including interactions with solvents, biomolecules, cells, whole-organisms and the environment. These explorations form the basis for understanding the natural interactions that nanomaterials will experience outside the laboratory, serve as foundational knowledge for designing engineered systems that will improve human health or protect the environment, and help us develop sustainable processes for large-scale production of nanomaterials.

Collaborations with industry, entrepreneurs, and the Jesse H. Jones Graduate School of Management are integral to the Institute's mission of creating sustainable nanotechnology.

Energy and Environmental Initiative
The power of the Energy and Environment Initiative stems from engaging the market strategically and globally. At Rice, that demands setting the bar with a series of grand challenges and pursuing those challenges with transformative solutions from the basic sciences, engineering, public policy, the social sciences and the humanities.
To meet these challenges, the Energy and Environment Initiative engages expertise from multiple research disciplines, along with industry leaders and government agencies, NGOs and the public to develop safer, more affordable and environmentally sustainable carbon-based fuels.
We are committed to:
- Sustainable drilling by utilizing advanced materials and systems designs.
- Maximizing the impact of high-performance computing to generate real-time information designed to de-risk investment, enhance productivity and ensure long-term sustainability.
- Simulating, visualizing and modeling reservoirs to better predict their production potential and to realize that potential.
- Reducing the environmental footprint associated with energy production and consumption.
- Ensuring that Gulf Coast communities and oil operations, on and off-shore, are resilient in extreme weather.
- Maximizing the impact of putting nanotechnology and biotechnology for the treatment of water in fracking and unconventional exploration.

Educating the next generation of energy leaders to ensure they have a holistic understanding of the technological, economics, policy and human dimensions of energy.

IBIO-Advanced Biomanufactoring Initiative
iBIO is an interdisciplinary initiative to focus its strengths in advanced biomanufacturing techniques to solve grand challenges. The initiative brings Rice's faculty and student talents to bear on problems that can be solved by programming bacteria, proteins and other biological agents to produce chemicals, catalyze reactions or sense conditions. Students use biology to solve problems that are not necessarily biological in nature such as making a molecule with applications as a polymer. iBIO not only serves as a clearinghouse for industry to seek the help of Rice scientists and engineers, but also proactively looks for opportunities to apply Rice research and participate in industry motived research problems.

Molecular Nanotechnology (MolNan)
The emphasis of the research program is sustainable energy (carbon-based, electron-based, water-based) catalysis, and polymers/soft-matter. This newly formed initiative will serve a number of strategic goals for Rice: strengthen the university's globally recognized research programs in molecular nanotechnology and materials science, grow and reinvigorate Rice's Department of Chemical and Biomolecular Engineering and better position the university to compete for prestigious center-level federal grants.

NEWT-Nanotechnology Enabled Water Treatment Center
NEWT is applying nanotechnology to develop transformative and off-grid water treatment systems that both protect human lives and support sustainable economic development. It is a joint effort by Rice University , Arizona State University, University of Texas at El Paso and Yale University. NEWT is the first national center to develop next-generation water treatment systems enabled by nanotechnology. Our vision is to enable access to suitable water almost anywhere in the world by developing next-generation high-performance, easy-to-deploy drinking water and industrial wastewater treatment systems enabled by nanotechnology. NEWT's technologies will safely exploit the unique properties of engineered nanomaterials (ENMs) to treat water using less chemicals, less electricity and smaller reactors than current technologies, enable re-use or regeneration of ENMs to decrease treatment costs, and use interchangeable treatment modules to accommodate different feed-water quality and treatment objectives. The center research will have direct impact on a fundamental necessity for life – water, which is also a critical resource for economic and social development, and intricately connected to energy production. Through its fundamental and transformative research as well as innovative educational programs, NEWT will also educate the next-generation workforce to be creative, versatile leaders in the burgeoning industry of sustainable technologies for water treatment.

Shell Center for Sustainability
Chemical and Biomolecular Engineering is a key player in the Shell Center for Sustainability. This center embraces the central theme of Rice's environmental initiative: that implementation of a strategy for sustainable development requires both new tools for achieving sustainability and a transformation in our understanding of society's common needs.

The Center has a three-pronged mission of education, research, and community service to:

- provide new knowledge to remove current technological barriers to sustainability;
- create the knowledge base required to enable development of novel sustainable processes and products;
- promote an interdisciplinary approach to sustainability that integrates research, education, and public policy; and
- serve as an independent forum for open discussions on sustainable development issues and policies.

The Ken Kennedy Institute for Information Technology
The Ken Kennedy Institute for Information Technology (K2I), formerly the Computer and Information Technology Institute, is a research-centric institute dedicated to the advancement of applied interdisciplinary research in the areas of computation and information technology. K2I's heritage and primary strengths are in the areas of high-performance computing and computational science and engineering. K2I's goals are to support, foster, and develop a strong community of research and education across a wide area of computing technologies, computational engineering, and information processing.

ADMISSION

The selection of students for admission to our graduate program is based on careful evaluation of all materials required in the application package. The following criteria are particularly important:

- Academic record and ranking in class. In general, applicants should have at least a 3.0 (B) grade point average in their undergraduate work.
- Evaluation by teachers and advisors
- Graduate Record Examination (GRE) scores; TOEFL scores for foreign applicants

HOW TO APPLY

Online application forms and additional information may be obtained at: chbe.rice.edu, then select the graduate program tab.

Or write to:

Chair, Graduate Admissions Committee
Chemical and Biomolecular Engineering Department–MS 362
P.O. Box 1892
Houston, TX 77251-1892

Phone: 713-348-4901
Fax: 713-348-5478
E-mail: chbe@rice.edu

- Completed application forms, transcripts of grades, and three letters of recommendation must be submitted by December 15. Early application is encouraged.
- An application fee of $85 must be submitted with the application.
- The Graduate Record Examination should be taken no later than the December before the fall for which student is applying. Testing early is encouraged. Arrange to take the GRE directly through:

  Educational Testing Service
  Box 6000
  Princeton, New Jersey 08541-6000
  Telephone: 609-771-7670
  Send email to gre-info@ets.org or visit the GRE Web site at www.gre.org.
- The Test of English as a Foreign Language (TOEFL) is required for students whose native language is not English. Rice requires a minimum TOEFL score of 600 on the paper-based test, 250 on the computer-based test or 90 on the Internet-based test. Arrange to take the TOEFL through:

  Educational Testing Service
  Box 6151
  Princeton, New Jersey 08541-6151
  Telephone: 609-771-7100
  Send e-mail to toefl@ets.org.

Students whose native language is not English also may use the International English Language Testing System (IELTS). IELTS is owned, developed, and delivered through the partnership of the British Council, IDP Education Australia: IELTS Australia and the University of Cambridge ESOL Examinations. More information about the IELTS is available at www.ielts.org or send an email to ielts@ieltsintl.org.

The TOEFL and the IELTS may be waived for an international student who receives a degree from an accredited university in which English is the official language of communication.

DEGREE REQUIREMENTS

Doctor of Philosophy:

The Ph.D. candidate in chemical and biomolecular engineering must:

- Satisfactorily complete 24 semester hours of advanced course work, including both general and specialized topics (students who already have an M.S. degree in chemical engineering may be excused from required core courses if course work is substantially equivalent to the Rice chemical engineering course.) Students will still be required to take 24 hours in graduate level courses.
- Pass oral examinations demonstrating a general understanding of reaction engineering, thermodynamics, transport phenomena and mathematics
- Prepare and present a thesis proposal
- Complete a publishable thesis representing research that is an original and significant contribution to the field of chemical and biomolecular engineering
- Pass a public oral examination in defense of the thesis
- Fulfill a residency requirement
- Complete required teaching assignments

No foreign language courses are required for an advanced degree in chemical and biomolecular engineering. Four to five years of study are normally required to complete the Ph.D. degree.

Master of Chemical Engineering:

To obtain the non-thesis M.Ch.E. degree, students must complete 30 hours of courses beyond those counted for their undergraduate degree. All courses must be at the 500 level or higher. Students are required to take core graduate chemical engineering courses and maintain a B- or better in each course.

Joint M.B.A./M.Ch.E.:

A Joint M.B.A./M.Ch.E. degree also is available in conjunction with the Jesse H. Jones Graduate School of Business. See department website for further information at: rice.edu/chbe.

Teaching Requirement:

Teaching is a graduate degree requirement for PhD students. Students spend the equivalent of about five hours per week on teaching assignments during four semesters in residence. The teaching assignment usually involves supervising work in the undergraduate laboratory, tutoring or grading papers. Teaching experience not only helps fortify previously learned material but also plays a vital role in solidifying concepts and clarifying ideas in the graduate student's own mind. Students planning to pursue an academic career may request more involved teaching assignments.

FINANCIAL ASSISTANCE

Most chemical and biomolecular engineering graduate students at Rice receive financial support throughout the calendar year. Entering doctoral students normally are awarded Rice University fellowships, which carry competitive stipends, plus another grant to cover tuition. The department also has a few special awards for Ph.D. applicants with outstanding credentials that are awarded on a competitive basis. These awards carry an additional monetary stipend. Stipend levels are reviewed annually by the department and are periodically adjusted to reflect changes in the cost of living in the Houston area.

Eligible incoming students are encouraged to apply for National Science Foundation (NSF) predoctoral fellowships and other federal or industrial fellowships. Applications for NSF awards must be made by the student in October or November. The appropriate forms may be obtained from:

The NSF Fellowship Office
4201 Wilson Blvd.
Arlington, Virginia 22230

CAMPUS VISIT

We encourage you to visit Rice at any time for a firsthand look at the department and the beautiful, tree-lined campus near the heart of historic Houston. Take a virtual campus tour at: graduate.rice.edu/virtualtour to experience our 300-acre campus. You may contact the department to schedule a personal visit. Email us at chbe@rice.edu.

ABOUT RICE AND HOUSTON

Rice is a leading American research university—small, private and highly selective—distinguished by a collaborative, interdisciplinary culture and a global perspective. Only a few miles from downtown Houston, it occupies an architecturally distinctive, 285-acre campus shaded by nearly 4,000 trees. State-of-the-art facilities and laboratories, internationally renowned centers and institutes and one of the country's largest endowments support an ideal learning and living environment.

The university attracts a diverse group of highly talented students and faculty with outstanding graduate and professional programs in the humanities, social sciences, natural sciences, engineering, architecture, music and business. With just 2,934 graduate students and 3,970 undergraduates, it offers an unusual opportunity to forge close relationships with eminent faculty scholars and researchers and the option to tailor graduate programs to specific interests.

Houston offers all the expected educational, cultural and commercial advantages of a large urban center, and more. It's home of the Texas Medical Center, the largest concentration of medical schools, hospitals and research facilities in the world, as well as several other universities. Rice has cooperative programs with the University of Houston, Baylor College of Medicine, the University of Texas Health Science Center and Texas Southern University. Houston is one of the few U.S. cities with resident companies in all four major performing arts—drama, ballet, opera and symphony. It also boasts a museum district featuring exhibits of national and international prominence.

As urban as it is, Houston also is a surprisingly green city. Houstonians enjoy the outdoors in more than 300 municipal parks and 120 open spaces, and many frequent the beach at Galveston Island, only a 45-minute drive away. Other short trips include Austin, the state's capital, and historic San Antonio, both of which are a little more than three hours away.

RICE

FOR MORE INFORMATION:

Rice University homepage:
www.rice.edu
Rice University Office of Graduate and Post-doctoral Studies homepage:
graduate.rice.edu
Graduate Student Association homepage:
gsa.rice.edu
City of Houston homepage:
www.houstontx.gov

Houston information from the *Houston Chronicle:*
www.chron.com
Houston information from the Greater Houston Partnership:
www.houston.org
Houston information from Citysearch:
http://houston.citysearch.com