

CHEMICAL ENGINEERING AT

SUNY BUFFALO

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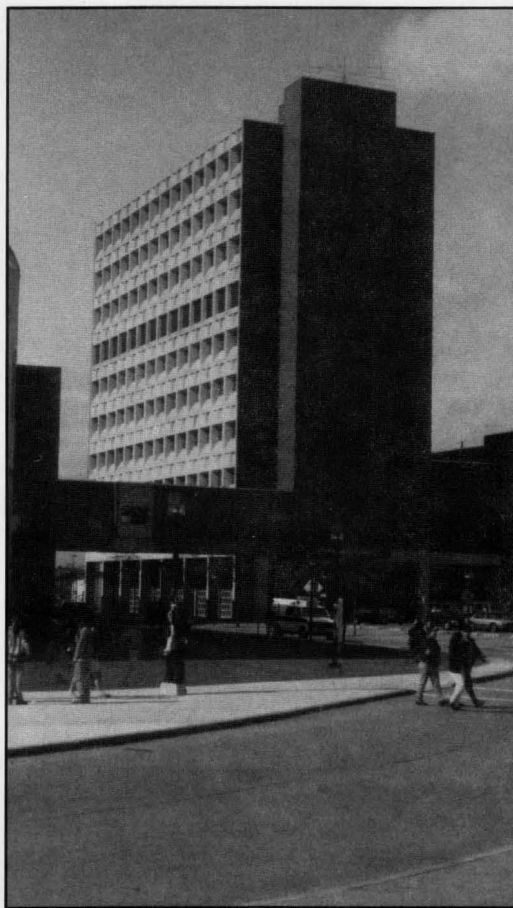
The Chemical Engineering Department at S.U.N.Y. is undergoing great change. Some mirrors the change that the profession itself is experiencing, but more so it reflects the coming of a new generation to the department. Our founders succeeded remarkably well in building a strong teaching and research program, and now our generation bears the responsibility of continuing their tradition of excellence. The changes present new opportunities as well as new challenges.

HISTORY

The University of Buffalo (UB) was founded as a private institution in 1846, and Millard Fillmore served as its first Chancellor. It grew over the next century, and in 1962 it merged into the State University of New York (SUNY) system. Shortly thereafter, planning and construction began for a new campus to be located three miles north of the original UB site.

Our department moved to this "North Campus" in 1977, and it now occupies many of Furnas Hall's ten stories.

The campus continues to expand, most recently with the dedication of an impressive 17,000-seat stadium, a student union, a retail complex, and two spacious, modern facilities for chemistry and fine arts. UB has the highest enrollment of any campus in the SUNY system and offers the widest range of academic programs of any public institution in New York and New England. The Buffalo campus remains the only one in SUNY to offer degrees in chemical engineering.



Furnas Hall, the home of chemical engineering at SUNY Buffalo

Chemical engineering was instituted at UB in 1961, and responsibility for assembling a faculty was placed with Joe Bergantz, our first chairman. Joe recruited aggressively from all sources, and indeed, three of the department founders (Sol Weller, Paul Ehrlich, and Bob Good) were chemists. The role that they played in shaping the professional atmosphere that persists today cannot be overstated. Each retired recently, but they remain active in research and are valued counsel in department activities.

Other founding members of the department include Don Brutvan, Ken Kiser, and Tom Weber. Don has also retired, but returns regularly to help with teaching duties. Ken continues to serve as Associate Dean of Engineering, a title he has held for sixteen years. Tom is very active and well regarded as an educator, and his teaching and service contribute enormously to the department. He is also the author of *Introduction to Process Dynamics and Control*, a widely used undergraduate text.

Later arrivals were also instrumental in the department's development. Eli Ruckenstein came from the University of Delaware after emigrating from Rumania in 1973. Ralph Yang arrived from Brookhaven National Labs in 1978, and Vladimir Hlavacek joined us in 1981 from Czechoslovakia. All three have made tremendous contributions to the profession and science of chemical engineering. Eli holds the rank of Distinguished Professor, and he has received broader recognition for his many achievements through election to the National Academy of Engineering.

Ralph's very active research program is all the more remarkable in light of the additional responsibilities he has assumed as department chair. These three, along with Tom and Ken, form the senior core of our faculty.

The long-term future of the department rests, of course, with the junior faculty. The most senior of these is Mike Ryan, with John Tsamopoulos and Carl Lund rounding out the ranks of Associate Professor. Following them are no fewer than *five new hires over the past four years*: Dave Kofke, Lakis Mountziaris, Scott Diamond, Johannes Nitsche, and Deborah Leckband. The eight junior faculty are establishing solid reputations in teaching and research: four are National Science Foundation PYI/NYI awardees, and other awards include an NIH First Award, a Whitaker Foundation Award, and a Hackerman Young Author Award. All have been successful in acquiring funds to conduct ambitious research programs in a wide array of fields.

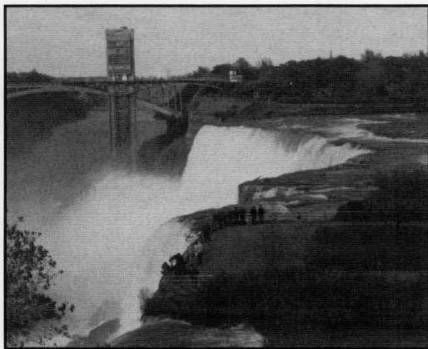
The success of the junior faculty owes much to the selfless support and encouragement they receive from their senior colleagues, and indeed, many significant changes have been instituted at the behest of the newest arrivals. An atmosphere of cooperation and camaraderie has blossomed in this environment, and morale in the department is very high. Evidence is provided by two multi-investigator grants awarded to the department by NSF in the past two years; details follow below.

THE UNDERGRADUATE PROGRAM

The State of New York has an unusually strong commitment to providing accessible higher education to its citizens. In-state tuition remains very low, and consequently a large majority of our undergraduates are State residents. Freshmen arrive with 3.6/4.0 high school averages and SAT scores averaging 650/545 (M/V). Recent graduating classes have numbered approximately thirty, but it seems that future classes will see this figure more than double.

The chemical engineering curriculum at UB is typical of ABET-accredited schools, but some offerings are less common. Close relations with local industry allow our students to gain, as a three-credit elective, the practical experience of an internship. Each intern spends ten hours per week for one semester at an industrial site. Lakis Mountziaris and Mike Ryan have for several years offered undergraduate research projects on paper- and tire-recycling. Scott Diamond has taken this notion a step further by offering a university-wide elective entitled "Biotechnology and Society" which attempts to prepare the non-technical but educated person to make informed decisions about some of the complex issues facing society. The department can boast of *ten* local and national teaching awards, including four instances of the SUNY Chancellor's Award for Excellence in Teaching, the highest teaching award given by SUNY.

The department is now embarking on an ambitious, col-

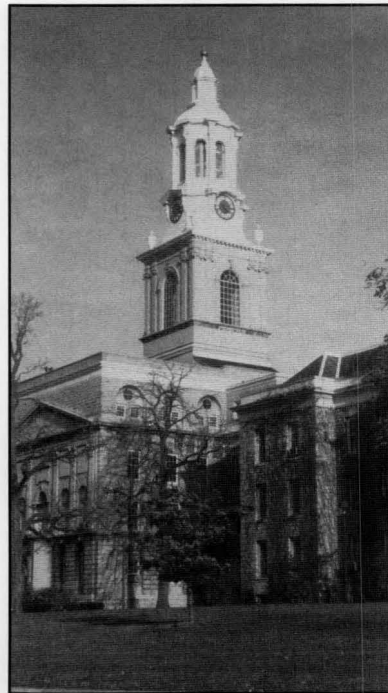


In and Around S.U.N.Y.

Left: World-famous Niagara Falls attracts locals as well as honeymooners from far and wide.

Right: The area's pastoral beauty is typified by this scene from UB's south campus.

Below: The Albright-Knox gallery, home of many treasures of modern art.



laborative project to advance the use of computers in chemical engineering instruction. Seven faculty co-investigators have been awarded funding under the very competitive Leadership in Laboratory Development program in NSF's Division of Undergraduate Education. The goal of the project is to develop a Chemical Engineering Simulation Laboratory (CESL) that will greatly expand the role of simulation as a supplement to the laboratory and classroom experiences.

CESL will be an *interactive* simulation package that instills in students an intuitive feel for chemical processes. The simulation modules will provide virtual laboratory experiences—the student being presented with "equipment" to be characterized by "experiments" of their design. More interesting will be situations in which the student operates a simulated process, drawing on acquired intuition to respond quickly to unexpected changes. We seek eventually to incorporate design elements in which the student must assemble a process to accomplish a particular task.

GRADUATE PROGRAM

We are very proud of the stature our department has acquired for research in the short period of its existence. Each year the department secures *new* external funding at a level of about \$1 million, graduates roughly ten PhD and eight MS students, and publishes nearly a hundred articles in refereed journals. The graduate program displays a healthy balance between experimental and theoretical research, and between fundamental and applied studies.

Catalysis and Reaction Engineering

Research in catalysis and reaction engineering is performed by Yang, Lund, Ruckenstein, Mountziaris, and Hlavacek. The efforts of Mountziaris and Hlavacek are materials-oriented, and both of them rely on an unusually well-balanced combination of theory, computer simulation, and experiments to tackle their research problems. **Vladimir Hlavacek** holds the C.C. Furnas Chair and is Director of the Laboratory for Ceramic and Reaction Engineering, which was established in 1987 with the goal of bridging the gap between chemical engineering and materials science. One of the Laboratory's finest achievements is the development of combustion synthesis methods to produce superhard ceramic materials—nitrides, borides, carbides and the like. In this technology, the reaction precursors are "ignited" to initiate a self-propagating but controlled reaction which yields a very pure, sinterable product without any additional energy input. Hlavacek's group is also very active in studying the dynamics of nonlinear reacting systems.

Hlavacek and **Lakis Mountziaris** both have research interests in chemical vapor deposition (CVD). CVD delicately balances transport processes with both gas- and surface-phase kinetics to produce solid films from reactive gases. Hlavacek uses CVD to make non-oxide ceramic fibers and thick films, while Mountziaris is studying metalorganic CVD

as a means to produce thin films of compound semiconductors for advanced electronic and optical devices. There are many novelties in Mountziaris' research, not the least of which is a counterflow jet reactor for studying the decomposition kinetics of CVD precursor gases.

Mountziaris is also applying CVD to grow diamond films from hydrocarbons at low pressure. The value of such a product is obvious, but Mountziaris takes it a step further—by inserting dopant atoms in the growing film, he is attempting to produce diamond-based semiconductors; diamond's electronic and heat transfer properties would make such a material very useful in electronic devices.

The reaction engineering performed by **Ralph Yang** and **Carl Lund** has a different flavor: it is oriented toward the catalyst and the catalytic processes. Yang, the holder of the Praxair Endowed Chair, is studying catalytic reduction of NO for pollution control from power-plant emissions. Presently this task is accomplished by selective reduction of NO with ammonia over a V_2O_5 catalyst. Yang has found that pillared clays are better catalysts and, moreover, he has developed a new sorbent-catalyst approach to NO reduction without a reducing gas. Also, his work on carbon-gasification reactions continues to be at the forefront of that field.

Lund is enhancing commercial reactions by applying a strategy perfected long ago by biological systems: selective removal of reaction intermediates via transport across a membrane. Selective removal of reaction *products* increases reactor yield by exploiting chemical thermodynamics; this notion is well established and is routinely exploited. Lund's new approach exploits the kinetic features of the process instead: timely removal of reaction *intermediates* prevents them from participating in additional, undesired reactions that degrade the product. The net result is an increased yield.

In one of several other projects, Lund is performing transient kinetic experiments with isotopically labeled reactants to identify the pathways of coke formation in acid catalysts. The enormous network of microscopic pores which endow these catalysts with many wonderful properties also make them susceptible to deactivation by coking. Lund's research is needed to develop strategies that will minimize these coking reactions, and thereby extend catalyst life.

The efforts of **Eli Ruckenstein** round out the department's research in catalysis and materials. His research program is remarkable for its astounding degree of diversity and novelty. Eli has major thrusts in materials, colloids, separations, catalysis, and bioengineering, and in his career he has made significant contributions in transport phenomena and thermodynamics as well. His encyclopedic knowledge of the literature forms the intellectual timber for the inspired works that have earned him such acclaim. Eli's grasp of world history and politics is equally amazing, but that is a story (actually many stories, best told over lunch) in itself.

Ruckenstein's present work in catalysis reflects the diver-

sity of his entire research program. He is building theories for the activity and selectivity of catalytic reactions on supported-metal systems by combining sophisticated experimental techniques with new concepts concerning the active sites. In other work, he has developed bialkali-promoted magnesium-oxide catalysts that are proving effective in many reactions of industrial importance, including the conversion of methane to ethylene, toluene to styrene, and acetonitrile to acrylonitrile.

In the area of materials, Ruckenstein has had several breakthroughs in developing composite polymers with useful properties, such as electrical conductivity or great hardness. Another project has produced a new membrane that is highly permselective yet possesses good mechanical properties. In still another project, he has combined the Debye model of a crystal with a Langevin model for diffusion to generate a new, unified theory for mass transport in solids. His work with colloidal systems continues, and is now directed to the study of the properties of foams, focusing on film drainage and Voronoi analysis of foam structure.

Transport Phenomena

The bulk of the department's research in transport phenomena is done by Mountziaris, Nitsche, Ryan, and Tsamopoulos. **Mountziaris** supplements his reaction-engineering research with computational studies of multiphase flows which display a rich variety of nonlinear phenomena. Also, he—together with Lund—played a major role in initiating the undergraduate simulation lab project described above; before that he served as PI of a collaborative proposal that led to the purchase of a state-of-the-art graphics system for visualizing complex modeling calculations. Mountziaris, perhaps more than anyone, personifies the spirit of cooperation that has overtaken this department.

The behavior of drops and bubbles represents the essential fluid mechanics underlying many multiphase phenomena of interest to the chemical industry. **John Tsamopoulos** is applying asymptotic theories and boundary- and finite-element calculations to understand the behavior of these very complex dynamical systems. His work can be used to describe the coalescence of bubbles suspended in liquids and thereby aid in preparing or destabilizing emulsions and dispersions. The dynamics become particularly interesting when a solid surface is introduced: fluids flowing rapidly near the surface experience a local decrease in pressure, which causes the formation of cavitation bubbles; subsequent collapse of these bubbles contributes to erosion of the surface.

Tsamopoulos shares an interest with **Mike Ryan** in problems that concern the processing of polymers. Tsamopoulos' focus is the fundamental fluid mechanics and finite-element modeling, while Ryan concentrates on the process engineering. Ryan's experiments with injection molding and thermoforming processes will help manufacturers predict the ultimate properties of a finished part, knowing only the

polymer's material properties and details of the forming process. In another area, they are working to develop software that can simulate the various stages of a blow-molding cycle. Of interest here is the ability to predict the final wall thickness of the product (such as a plastic cup): walls that are too thin may fail, while overly thick walls waste material. Ryan is also Director of the Business-Industry Affiliates Program of the New York State Center for Hazardous Waste Management, where he oversees research on the reduction of hazardous waste generation at the source. Specific interests include recycling and reuse of post-consumer scrap rubber and plastics, biodegradable polymers, and the use of additives to enhance the degradability of a polymer material.

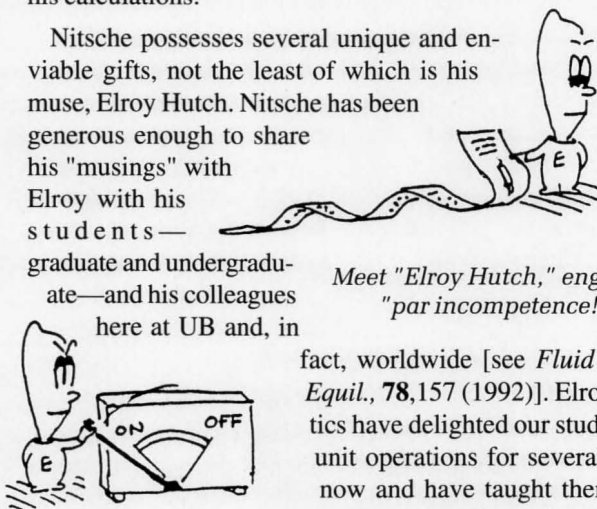
Arguably the busiest man in the department, **Johannes Nitsche** has not let his enormous dedication to teaching detract from his research program. He has great expertise on Brownian transport in confined spaces, and he brings to bear a wide range of mathematical and computational tools to examine these problems in the context of catalysis and separations technology. In diffusion of nonspherical particles in pores, the confining walls couple strongly with particle hydrodynamics to produce unexpected behavior, such as anomalous density distributions. Rotational diffusion is a concept that is relatively unappreciated by many engineers, yet it plays a key role in reactions in porous media. The phenomenon is especially relevant to proteins and other macromolecules that are reactive on only a small portion of their surface. Nitsche is embarking on several experimental investigations to guide and corroborate his calculations.

Nitsche possesses several unique and enviable gifts, not the least of which is his muse, Elroy Hutch. Nitsche has been generous enough to share his "musings" with Elroy with his students—

graduate and undergraduate—and his colleagues here at UB and, in

Meet "Elroy Hutch," engineer "par incompetence!"

fact, worldwide [see *Fluid Phase Equil.*, **78**,157 (1992)]. Elroy's antics have delighted our students in unit operations for several years now and have taught them several lessons of how chemical engineering should *not* be done.



Biochemical Engineering

The department has recently initiated a major concentration in biochemical engineering. Scott Diamond and Deborah Leckband are the principals in the endeavor, along with Eli Ruckenstein and another faculty member who will be re-

cruited soon. The facility assembled for this work is impressive by any standard. Bioengineering occupies the entire ninth floor (6000 ft²) of Furnas Hall, and it features seven fully equipped laboratories: molecular biology, microbial engineering, cell culture, separations, analytical surface science, and video microscopy. Additional facilities, including three environmental chambers, support these labs.

Mammalian cells exposed to laminar shear stresses (as are, for example, the cells lining blood vessels) behave differently than do cells removed from such an environment. The response of living cells to mechanical forces is distinct from the relatively well-understood phenomenon of receptor-mediated signaling. **Scott Diamond** measures intracellular concentrations of key biomolecules and is assembling his findings into a theory for the mechano-biological response. The relevance of this work to the treatment and prevention of coronary and vascular disease has been recognized tangibly by the American Heart Association. The research is also proving useful in the design and operation of bioreactors. In other work, Diamond is examining the transport and kinetics of proteolytic enzymes in entangled, cross-linked protein gels, such as fibrin and collagen. While the work has several direct applications, Diamond's primary interest relates to the design of blood-clot dissolving agents and the design of thrombolytic therapies.

Deborah Leckband's presence strengthens and expands the department's reputation in colloids and interfaces. She uses the surface forces apparatus in concert with sophisticated biochemical and surface analytic techniques to probe the nature of cell- and biopolymer-surface interactions. In one application, Leckband examines the forces that govern molecular recognition to guide her development of very sensitive and localized biomolecular sensors. In another, she uses her surface-forces measurements to improve protein-separation techniques, both by chromatography and by partitioning in aqueous solution. She also performs studies of adhesion at the cellular level, with application to wound healing, cancer cell metastasis, tissue engineering, and flocculation in bioreactors.

Separations

Much of the department's work in separations has been discussed above, but it would be conspicuously incomplete without highlighting the significant achievements of **Ralph Yang**. He complements his work in catalysis with both fundamental and applied studies of adsorption and adsorbent materials. The author of *Gas Separation by Adsorption Processes*, Yang is acknowledged as a leading expert in adsorption and its use as a separation technique. He is now studying the molecular design and synthesis of new sorbents.

Molecular Thermodynamics

Finally, we come to **David Kofke** who, when he isn't

woodworking or speaking about himself in the third person, conducts research in molecular thermodynamics. Computer simulation is regarded by many as the third leg—along with theory and experiment—upon which we build our understanding of nature. Most of Kofke's group is busy developing and applying Monte Carlo and molecular dynamics simulation techniques—"experiments" on model molecular systems. Much of their focus is on methods for evaluating phase equilibria; other topics occupying Kofke's attention include thermodynamics and transport in anisotropic systems (such as liquid crystals) and theories to predict properties of mixtures from data for the respective pure components.

BUFFALO AND ENVIRONS

A local business official recently complained of two major problems with operating in Buffalo—the number 2 problem is getting people to relocate here, and the number 1 problem, he said, is getting them to leave. Buffalo is New York's second-largest city and is, according to recent rankings, its "most livable." Housing is inexpensive, the roads are uncongested, air travel is hassle-free, and (believe it or not) the climate is moderate—temperatures below 15 or above 90°F are rare. We are also just north of the famed snow belt beloved by skiers.

The city is rich in culture: the Albright-Knox gallery possesses one of the world's finest collections of 20th century art; the Buffalo Philharmonic consistently ranks as one of the nation's top orchestras; the theatre district, developed as part of a recent renaissance of the downtown area, provides opportunities to enjoy the best works of local and national theater companies. If that's not enough, Toronto, one of the world's premier cultural centers, is less than two hours away.

But Buffalo's biggest secret is its architecture: the region boasts of a remarkable number of architectural masterpieces, including five Prairie houses by Frank Lloyd Wright and major works by Sullivan, Richardson, and others of similar stature. Buffalo also possesses a beautiful system of parks designed by Frederick Law Olmsted. Outdoor recreation may be found in the waters of Lakes Erie and Ontario, or in the many splendid woodland areas nearby. And, of course, one of the world's greatest natural wonders—Niagara Falls—is a mere twenty minutes from the campus.

THE FUTURE

The enthusiasm and optimism of the faculty, together with their substantive accomplishments in both teaching and research, paint a bright future for the department. This article, we hope, has provided a convincing portrayal of the exciting developments here. We urge any who are contemplating their own future, either as a graduate student or an academic, to give serious consideration to SUNY Buffalo and to the opportunities that await you here. □