A Program in . . .

POLYMER SCIENCE AND ENGINEERING
at the University of Cincinnati

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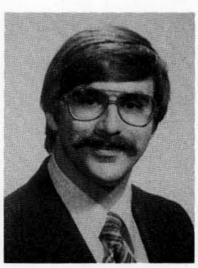
Chemical engineering at the University of Cincinnati is the sixth oldest program in the United States and one of the first thirteen programs accredited by the AIChE in 1925. Since that time the program has been accredited continuously by both AIChE and ABET.

In the early 1930*s*, a graduate program in chemical engineering was established, and the first PhD degree was awarded in 1938; the 100th doctoral degree was awarded in 1988. Today, more than fifty students from nine countries are studying towards graduate degrees in chemical engineering, and the majority of them are working towards PhD degrees. Fifteen new students are expected to join the department at the start of the 1990-91 academic year.

Areas of graduate research represent all traditional areas of chemical engineering, with principal emphasis focusing on the research areas of four university centers which have their homes within the chemical engineering department. They are the Polymer Research Center, the Center-of-Excellence in Membrane Technology, the Clean Coal Center, and the Center for Aerosol Processes.

The purpose of this article is to focus on polymer education and research in the chemical engineering department, which involves the activities of the university-wide Polymer Research Center and includes strong interaction and collaboration with the Membrane Center.



Joel R. Fried *received B.S. degrees in biology (1968) and chemical engineering (1971) from Rensselaer Polytechnic Institute and graduate degrees in chemical engineering (RPI, M.E., 1972) and polymer science and engineering (University of Massachusetts, M.S., 1975; Ph.D., 1976). He is presently professor of chemical engineering and Director of the Polymer Research Center at the University of Cincinnati. He is the author of over sixty journal articles and book chapters and is presently finishing a textbook in polymer science and technology.*

HISTORICAL NOTES

The origins of polymer research at the University of Cincinnati go back a long way. In the 1920*s*, the Tanners Council Research Laboratory was located on campus to study leather and its products. This facility is still active and interacts with chemical engineering, notably through the undergraduate professional practice program (the first such program in North America). In the 1930*s*, a Basic Science Research Laboratory was established in the College of Engineering, and Paul Flory (1974 Nobel laureate in Chemistry) accomplished much of his pioneering work in the area of polyesterification while working in this laboratory. Then in the mid-1950*s* the chemical engineering department had the distinction of offering the first polymer chemistry course at Cincinnati.

Formal coordination of polymer research and educational activities within the university was established in 1977 by the formation of the Polymer Research Center. Then in 1989 the Center was reorganized to reflect the growth of polymer research within the university, particularly within the College of Engineering. An Executive Board, consisting of the Director and a Co-Director, guides the educational and research activities of the Center, including its seminar program. Eight faculty members of the Center, thirty-five graduate students, and fifteen postdoctoral students and visiting scholars are engaged in a wide variety of research activities. Total annual external funding for this research exceeds $1 million in individual grants and contracts. Another six faculty, who have polymer-related research activities within the departments of aerospace engineering, physics, and chemistry, are affiliated with the Center.

EDUCATIONAL OPPORTUNITIES

The University of Cincinnati operates on an academic quarter system. A minimum of thirty-six course credits are required for the MS degree and ninety credits are required for the PhD degree. The majority of these graduate credits may be taken from a large list of technical electives offered as graduate- and dual-level courses (available for credit for undergraduate or graduate students). Of these, seventeen polymer courses are offered by the three participating departments of chemistry, chemical engineering, and materials science and engineering (see Table 1).

Undergraduate students in chemical engineering may enroll in either Polymer Technology (offered in chemical engineering) or Introduction to Polymers (offered in materials science and engineering) for their first polymer course, while graduate students would typically take Introduction to Polymer Science (offered in materials science and engineering). A total of fifteen polymer courses (listed in Table 1) are available to satisfy graduate elective requirements in chemical engineering.

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TABLE 1
Polymer Course Offerings

- **Polymer Configurations and Rubberlike Elasticity**
  Chemistry; dual-level
- **Preparation and Reactions of Polymers**
  Chemistry; dual-level
- **Polymer Properties Laboratory**
  Chemistry; dual-level
- **Solution Properties of Polymers**
  Chemistry; dual-level
- **Readings in Polymer Chemistry**
  Chemistry; graduate
- **Polymer Technology**
  Chemical Engineering; undergraduate
- **Properties and Applications of Hydrogels**
  Chemical Engineering; dual-level
- **Polymer Engineering**
  Chemical Engineering; graduate
- **Polymer Engineering Laboratory**
  Chemical Engineering; dual-level
- **Polymer Viscoelasticity**
  Chemical Engineering; graduate
- **Introduction to Polymers**
  Materials Science and Engineering; undergraduate
- **Polymer Characterization**
  Materials Science and Engineering; dual-level
- **Properties of Polymers**
  Materials Science and Engineering; graduate
- **Polymer Spectroscopy**
  Materials Science and Engineering; graduate
- **Solid-State Polymer Systems**
  Materials Science and Engineering; graduate
- **Polymerization, Degradation, and Characterization Techniques**
  Materials Science and Engineering; graduate
- **Introduction to Polymer Science**
  Materials Science and Engineering; graduate

The Polymer Engineering and Polymer Viscoelasticity courses are given once every two years, with the lecture course on polymer engineering rotated every Spring quarter on an alternate-year basis with the laboratory course described below. Coverage includes an introduction to polymer rheology, dynamic equations, constitutive relationships, and the modeling of simple processing operations such as extrusion. Middleman's textbook *Fundamentals of Polymer Processing* is normally used as the text for Polymer Engineering. The book for the viscoelasticity course is *Introduction to Polymer Viscoelasticity* by Aklonis and MacKnight. Coverage in this course includes the principles of linear viscoelasticity and rubber elasticity with applications to dynamic mechanical and dielectric spectroscopy.

The dual-level laboratory course in polymer engineering contains experiments in capillary extrusion, rheology, gas permeation, impact testing, crystallization kinetics, solution viscosity, and polymerization. Experiments utilize both commercial and custom fabricated instrumentation, often with computer acquisition and analysis of data. Theoretical background, experimental procedures, and questions related to each experiment are provided in a laboratory manual.

A dual-level course on polymer gels is offered which focuses on the properties of polymeric hydrogels including synthesis, swelling, solute transport, phase transitions, and network structures and their use for chemical separations and biomedical/pharmaceutical applications. Both a written and an oral report on a research project involving theoretical, computational, or laboratory work in the area of hydrogels are required.

In addition to these courses, several other courses with strong polymer content are routinely available within the university. For example, the Department of Materials Science and Engineering offers a dual-level course (Advanced X-Ray Diffraction) with strong emphasis on polymeric systems. In the Department of Chemical Engineering a novel course (Scaling Phenomena in Chemical Engineering—Applications of Fractal Concepts and Nonlinear Dynamics) was introduced during the 1989-90 academic year. It included scaling phenomena, renormalization group theory, and percolation as applied to polymer systems. The Department of Chemical Engineering also offers a dual-level course (Membrane Technology) which includes material on polymer membrane preparation and transport phenomena.

Graduate student Hsieng-Cheng Liu examines the morphology of a polymeric membrane in an ISI Scanning Electron Microscope.

FRONTIERS OF POLYMER RESEARCH

Research areas within the Polymer Research Center include studies of composites, block copolymers, polymer blends, rubber elasticity, polymer gels, and polymeric controlled drug release, to name only a few. Within the Department of Chemical Engineering, seven (out of a total of twelve) faculty members have one or more projects involving basic or applied polymer research. A brief summation of these follows:

□ Research interests of Joel Fried include the study of polymer blends and composites and the transport of organic liquids and permanent gasses through polymeric membranes. Specific research projects include

• development of a polymeric membrane system for the pervaporation of methanol from an organic catalyst slurry

• development of a molecular sieve membrane from the partial pyrolysis of ceramic precursor polymer membranes

• investigation of the sorption and permeability behavior of plasticized PVC films to carbon dioxide and methane

• development of a model for the flow of biopolymers through affinity membranes (macroporous polymer membranes to which biospecific organic ligands can be attached at the surface and which may represent an important new technique for industrial bioseparations)

• using laser scattering techniques to study phase separation in binary and ternary blends of different polycarbonates for which experimental data is compared with theoretically obtained phase diagrams

• using semi-empirical quantum mechanical and molecular mechanics methods to correlate polyimide structures with thermal properties such as the glass transition temperature and thermal stability.

□ Stevin H. Gehrke joined the department in 1986 and his interests have focused primarily on the synthesis, properties, and applications of polymeric hydrogels. (Steve also directs a successful program of Research Experience for Undergraduates in which undergraduates from different colleges pursue supervised research projects.) His ongoing graduate research projects include

• phase behavior of novel cellulose ether hydrogels (thermally responsive hydrogels produced by crosslinking of various cellulose ethers, providing a material with pharmaceutical value and a model system enabling critical analysis of thermodynamic theories for the swelling of such gels)

• investigation of the permeability of a synthetic, thermally responsive hydrogel, crosslinked poly(N-isopropylacrylamide), to different drugs (requires separation of the complex dependencies of the diffusion and partition coefficients of solutes)

• pursuing the control of the microstructure of responsive polymer gels and the relation of this structure to the response rate of the gel

• exploration of the novel use of recyclable absorbent gels as a means of dewatering the fine and ultrafine coal slurries generated by precombustion coal cleaning operations.

□ Rakesh Govind is extremely active in a large number of research areas including process synthesis, clean coal technology, and membrane systems. One project is developing the technology to use polymeric hollow fibers with attached microorganisms as bioreactors for the anaerobic treatment of organics in wastewater.

□ Sun-Tak Hwang joined the department in 1982 as its Department Head. Under his leadership the department received a five-year $2 million grant from Sohio in 1983 to establish a Center-of-Excellence in Membrane Technology. Since then, the Center has grown and currently has an active Industrial Partnership program. Many of the research areas within the Center are concerned with gas and liquid transport through polymeric material.

□ Glenn Lipscomb joined the department in 1989 and has research interests in the thermodynamic analysis of gas sorption in glassy polymeric materials, the design of hollow fiber polymeric membrane separation devices, boundary layer analysis of various polymer processing operations, and the study of structure formation in

slow flows of concentrated suspensions.

- **Neville Pinto joined the department in 1985. His recent interests have focused on ion-exchange separations and chemical sensors. One project seeks to develop polymer-based chromatographic supports with novel cylindrical geometries for the downstream processing of biomolecules. The focus of another polymer-related project is the use of low molecular weight ionic and nonionic polymers as displacers for the large-scale chromatographic separation of biomolecules.**

FACILITIES

Excellent instrumentation for polymer research is available within the department of chemical engineering. Facilities include several Digilab Infrared Spectrophotometers, ISI Scanning Electron Microscope, Perkin-Elmer System 7 Differential Scanning Calorimeter and Thermogravimetric Analyzer, Waters Gel Permeation Chromatograph, Instron model 1122 Mechanical Tester, Cahn C-1100 High-Pressure Balance, Rheovibron, Rheometrics Mechanical Spectrometers, and Weissenberg Rheogoniometer. In addition, fine facilities are also available in the departments of chemistry and materials science and engineering. They include transmission electron microscopy, cryogenic microtome, X-ray diffraction, ESCA, and infrared and Raman spectrometers. ❐

VIDEOTAPED TUTORIALS

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video format) exists which can be used to promote higher levels of student activity during video-based learning processes: videodiscs. The technology, although still expensive, has been shown to be effective in learning environments [11]. The most desirable aspect of videodiscs is their interactive capability; any number of video sequences (limited only by the disc's storage capacity) can be accessed under the correct recall conditions. For example, under computer control from an interactive program run by the student, any sequence of video segments can be combined to take the student through a lesson. Not only can videodiscs store anything from laboratory demonstrations to example problems and solutions, but they can also be recalled in any sequence determined by the student. The use of videodiscs will certainly become more widespread on all educational levels as their price decreases.

CONCLUSIONS

Our experience with the videotaped module was rewarding in spite of the great amounts of time and effort it required. To produce the two forty-five minute videotapes, we invested approximately twenty hours of script preparation, taping, and editing time. The result, though, is a complete module of instructional material which can be dispensed with minimum effort of copying and distribution. The facts that the students felt the videotapes were a good medium for teaching and that the quality of student-teacher interaction was improved should be pedagogical driving forces for investigating the use of videotapes an an alternative approach to biochemical engineering education. Additionally, the students experienced another teaching medium and were exposed to a biochemical engineering laboratory without the expense of equipping the lab.

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REFERENCES

1. Bungay, H.R., "Biochemical Engineering with Extensive Use of Personal Computers," Chem. Eng. Ed., 20, 122 (1986)
2. Ng., T.K.-L, J.F. Gonzalez, and W.-S. Hu, "Biochemical Engineering," Chem. Eng. Ed., 22, 202 (1988)
3. Squires, R.G., and D.V. Frank, "Supplemental TV Taped Problems," Chem. Eng. Ed., 17, 117 (1983)
4. Newell, R.B., P.L. Lee, and L.S. Leung, "A Resource-Based Approach to ChE Education," Chem. Eng. Ed., 19, 36 (1985)
5. Baasel, W. D., "Why PSI? How to Stop Demotivating Students," Chem. Eng. Ed., 12, 78 (1978)
6. Bailey, J.E., and D.F. Ollis, Biochemical Engineering Fundamentals, second edition, McGraw-Hill Book Co., New York (1986)
7. Pirt, S.J., Principles of Microbe and Cell Cultivation, John Wiley and Sons, New York (1975)
8. Dutton, J.C., "A Comparison of Live and Videotaped Presentations of a Graduate ME Course," Eng. Ed., January, 243 (1988)
9. Salomon, G., and H. Gardner, "The Computer as Educator: Lessons from Television Research," Ed. Researcher, 15(1), 13 (1986)
10. Salomon, G, "Television is 'Easy' and Print is 'Tough': The Differential Investment of Mental Effort in Learning as a Function of Perceptions and Attributes," J. of Ed. Psychology, 76(4), 647 (1984)
11. Clark, D.J., "How do Interactive Videodiscs Rate Against Other Media," Instructional Innovator, 29(6), 12 (1984) ❐