INTRODUCTORY POLYMER SCIENCE AND TECHNOLOGY

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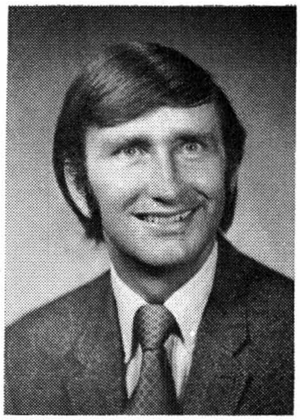
IN THE COURSE OF THIRTY years the polymer industry has grown enormously to the present levels of production comparable to that of steel. It is estimated that 30% of all chemistry and ChE graduates are employed in some field of endeavor involving polymeric materials. In this time period the industry matured and many scientific and engineering principles of polymerization, polymer processing and polymer fabrication have been well established. A general course and laboratory experience in polymers certainly will be an important aspect of ChE education for years to come.

Today the maturing and importance of the polymer field have resulted in many new courses being adapted in well established programs as well as the proliferation of basic courses in polymers for many departments which, up until recently, have not had a course in polymer science and technology. The first level foundation course is of great importance since it should acquaint students with the basic subject material, reveal the breadth of the polymer field, and yet challenge the gifted student. Wisconsin has had such a course for many years which has been continually updated. An interesting development, particularly in the past five years, is the variety of backgrounds of students taking such a course. Students representing chemistry, metallurgy, physics, materials science, engineering mechanics, mechanical, electrical as well as chemical engineering, have elected to take this course. The course is aimed mainly for senior and graduate ChE level students, although interested junior level students, who have had thermodynamics, physical chemistry and organic chemistry are also encouraged to take the course. Graduate students from other departments who have not had basic prerequisites in two of the three aforementioned areas are generally discouraged from taking the course. The course has been very well received and enrollments have been large, averaging about 35 students each semester.

The course is developed to achieve a balance of many of the disciplines of polymer science and technology. This necessitates, a survey approach. However, homework probiems are specific enough for the student to obtain a deeper insight into many of the topics covered in lecture. In a sense, the course is designed to "whet the appetite" as well as feed specific information about the polymer field. Classroom demonstrations of polymer properties have been of particular educational value and are listed as follows: solution, mechanical (modulus, elasticity, shrinkage on annealing, time effects and fracture), optical (birefringence, scattering, and spherulitic structure), wettability and flammability. Also the



J. Koutsky obtained his BS and MS in Chemical Engineering and his PhD in Polymer Science and Engineering (1966) from Case Institute of Technology. He has been at the University of Wisconsin-Madison since 1966. His research interests involve solid-state structure studies of polymers, adhesion of thermosetting polymers and cryogenic recycling of polymer wastes.

examination of various commercial forms of typical plastic materials has been quite enlightening to the students. For instance, the film, fiber and molded articles made from polyethylene, polyethylene terephthalate and the polyamides reveal the enormous flexibility of property design via polymer processing methods.

The course outline is as follows:

TABLE I. Course Outline

	APPROXIMATE NO. OF LECTURES
I. INTRODUCTION	1
A. Basic Definitions	
B. Unique Properties of Polymers	
C. Cohesive Energy Density and Properties	
II. POLYMERIZATION	
A. Condensation	3
B. Addition	3
C. Copolymerization	1
D. Polymer Reactions	1
III. STRUCTURE AND PROPERTIES OF POLYMERS	
A. Measurement of Molecular Weight and Size	3
B. Polymer Solutions	2
C. Analysis of Polymers	2
D. Testing of Polymers	2
E. Morphology and Order in Crystalline and Amorphous Polymers (Processing Effects)	2
F. Polymer Structure and Mechanical Properties	2
G. Polymer Structure and Diffusion Properties	1
H. Polymer Structure and Optical Properties	1
I. Polymer Structure and Electrical Properties	1
IV. PROPERTIES OF COMMERCIAL POLYMERS	
A. Olefin Polymers	2
B. Diene Polymers	2
C. Vinyl and Vinylidene Polymers and Copolymers	2
D. Heterochain Polymers (Polyamides, Polyesters, Polyimides, Polyethers)	3
E. Cellulosic Polymers	1
F. Thermosets	2
V. POLYMER PROCESSING	
A. Resin and Plastics Technology (Molding, Extrusion, Compounding, Calendering, Casting)	4
B. Fiber Technology (Melt and Solution Spinning, Annealing, Dyeing)	1
C. Elastomer Technology (Compounding, Vulcanization, Molding)	2
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Any required background text for such a course usually has certain limitations. Therefore additional supplementary material introduced in the lectures is necessary to expand the concepts found in the required text. Even though this requires additional work in terms of pedagogy the rewards are great since one can "flavor" the course with different approaches. Presently the

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required text is F. W. Billmeyer's, *Textbook on Polymer Science,* 2nd edition, Interscience publishers (1971). Additional texts, which have been used for supplementary information include the following:

Polymerization

Organic Chemistry of Synthetic High Polymers, R. Lenz, Interscience (1967).

Polymer Chemistry, B. Vollmert, translated by E. H. Immergut, Springer-Verlag (1973).

Polymer Science and Engineering, D. J. Williams, Prentice-Hall, (1971).

Structure and Properties of Polymers

Engineering Design for Plastics, ed. E. Baer, Reinhold (1964).

Viscoelastic Properties of Polymers, J. Ferry, John Wiley (1970).

Principles of Polymer Chemistry, P. J. Flory, Cornell University Press (1953).

Modern Plastics Encyclopedia, ed. S. Gross, McGraw-Hill.

Polymer Processing

Plastics Processing, J. M. McKelvey, John Wiley (1962).

Rubber Technology, M. Morton, Reinhold (1973).

Plastics Film Technology, W. R. R. Park, Reinhold (1969).

As one can see from the outline and references, the course is broadly based and includes a great deal of information. For handling the supplementary lecture material not covered in the required text, extensive handouts are given to the students to facilitate questions in class and allow more specific homework problems to be assigned.

LABORATORY EXPERIENCE

AN EXCELLENT COMPLEMENTARY course for students is a basic laboratory experience which includes experiments on polymerization, polymer fabrication and polymer properties. The following is an outline of a course which is offered on a yearly basis and has enrollments of 12 to 15 students of which 30% have been of graduate standing. Larger enrollments have been handled by giving the laboratory twice a year. This approach has allowed for more individualized instruction which is quite necessary in a laboratory of this type since the equipment is generally expensive and chemicals are somewhat toxic.

The course is developed to achieve a balance of many of the disciplines of polymer science and technology. This necessitates a survey approach. However, homework problems are specific enough for the student to obtain a deeper insight into many of the topics covered in the lecture.

The course is divided into three one credit sections for flexibility. A list of the required experiments is given in Table 2.

TABLE 2. Laboratory Experiments

I. POLYMERIZATION (1 credit)
 1. Suspension Polymerization of Polystyrene
 2. Preparation of Phenol-Formaldehyde and Phenol-Resorcinol Resins
 3. Preparation of Polyurethane Foams
 4. Kinetics of Polyesterification
 5. Preparation of Polysiloxane Elastomer

II. CHARACTERIZATION (1 credit)
 1. Infrared Analysis of Polymers
 2. Fractionation of Polystyrene and Molecular Weight Measurements by Solution Viscosity
 3. Flammability of Polymers
 4. Differential Scanning Calorimetry of Polymers
 5. Nuclear Magnetic Characterization of Polymers

III. FABRICATION AND TENSILE TESTING (1 credit)
 1. Molding of Phenolic Laminates and Composites
 2. Tensile Testing of Rigid, Thermoplastic, and Elastomeric Polymers
 3. Compression and Injection Molding of Thermoplastics and Thermosets
 4. Extrusion of Thermoplastics (Polypropylene)

The text used for the laboratory is, *Laboratory Preparation for Macromolecular Chemistry*, E. L. McCaffery, McGraw-Hill (1970).

Before the students can begin each experiment they must hand in a short report on the toxicity and carcinogenic properties of each chemical (including common solvents) which is used in the experiment. I might add this single requirement has produced desirable, positive effects on laboratory techniques. The students work in squads of two or three since most of the experiments are elaborate enough to be difficult for one person either to control or set up. It normally takes three hours for completion of most of the experiments, however certain long experiments are split into two laboratory periods. The polymerization reactions which unfortunately cannot be split can take long times, especially the pearl polymerization of styrene. Some undaunted students have been known to stay ten hours to complete that experiment after two initial failures!

Additional experiments on light scattering, adhesion and fracture, and copolymerization have been designed and will be included in the following year.

These introductory courses have been useful for many graduate students embarking on higher level courses specific to polymers and particularly useful for the undergraduate ChE student who wishes a background of polymers to round out his academic career. Although the department does not yet require such a course for undergraduates, a large majority of our students avail themselves of the opportunity. □

LEMLICH: Adsubble Methods

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