Development and Implementation of a New Industrial Internship Program in Polymer Synthesis and Processing

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Abstract: A new master's level internship program in polymer synthesis and processing offered in the chemistry and physics departments at the University of Oregon is described. The program is designed to meet the needs of the burgeoning number of polymer and semiconductor companies that are moving into Oregon. Students with an undergraduate degree in chemistry or physics are admitted to the one-year program. The program starts with intensive coursework in the summer. In the fall, following the successful completion of their summer coursework, the students are placed in a local industrial laboratory for a period of about nine months. During this time they gain practical experience and knowledge. The students meet with their university committee and industrial supervisors once a month to turn in progress reports and give talks on their work. The possible pitfalls in setting up an internship program are discussed.

Introduction

A large fraction of chemistry graduates from the University of Oregon take jobs in the chemical industry or with high-technology companies. Feedback from these alumni and from our industrial affiliates made us aware that there is a need for a more focused curriculum that prepares students better to excel in industrial environments. In response to that need, we decided to incorporate targeted technical training into our curriculum by starting two new master's level programs, one in polymer chemistry and the other in semiconductor processing. These master's programs consist of new lecture courses designed specifically for the program, an intensive laboratory course, and a nine-month industrial internship [1]. The new programs have had many positive benefits that include the following [2–4].

- They provide our students with identifiable and marketable technical skills.
- They foster increased interaction between the university and local industry.
- They provide an excellent means of recruiting new students into our undergraduate and graduate programs.
- They provide fresh context for other courses in our regular curriculum.

An additional benefit of these programs is that, because of the improved communication with our industrial affiliates, both parties have a better understanding of the needs and challenges faced by the other. This paper describes the polymer internship program and provides insights that may be useful for others considering a similar program.

The New Polymer Program

The new polymer curriculum was designed with appreciable input from local industry. They told us they wanted new hires who

- can work in teams,
- have good communication skills,
- have good leadership skills,
- have a focused technical expertise, and, most importantly,
- have good problem-solving skills.

Furthermore, they told us that, in their experience, most Ph.D's are too narrowly focused on only a single aspect of research and most BS-level students have no practical training. With these requests in mind, we designed a master's level program that is targeted toward chemistry and physics majors with bachelor degrees and that gives them additional training that focuses on applied research and development rather than basic research. The new program consists of three parts: two lecture classes, an intensive laboratory class, and an industrial internship [5]. The overall goal of the program is to produce graduates who have the five skills mentioned above with a general emphasis on producing students who will thrive in an industrial environment. In addition to this overriding goal, an important specific aim is also to help prepare students to make informed career choices.

The catalog descriptions for the two lecture classes in the polymer program are given below. As can be seen from their titles, one class covers polymer synthesis, characterization, and processing, and the other class covers polymer physical chemistry. With regard to content, these courses are generally similar to polymer courses taught elsewhere, but selected topics are also included that are not mainstream subjects in general polymer courses. For example, at the request of our industrial affiliates, a unit on the environmental aspects of polymer production is included in the synthesis course [6].

Synthesis, Characterization, and Processing of Polymers (Lecture course). Methods of polymer synthesis and characterization; kinetics and mechanisms of the principal polymerization reactions. Classification of polymerization reactions; theory and practice of step growth polymerization, radical polymerization, emulsion polymerization, ionic polymerization, ring-opening polymerization, olefin metathesis polymerization, and polymerization by transition metal catalysts. Introduction to mechanical properties and fabrication

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techniques. Methods of structural characterization for important morphological classes of polymers. Techniques for predicting the engineering and physical properties of polymers from their molecular structures. Environmental aspects of polymer production.

Polymer Chemical Physics (Lecture course). Statistical and thermodynamic models for the equilibrium configuration, conformation, structure, mechanical properties, and phase transitions of polymer solutions, dense melts, liquid crystals, mixtures, block copolymers, surfaces and interfaces, and electronic polymers. Techniques for polymer characterization, including light, electron, x-ray, and neutron scattering; light and electron microscopy; and optical, infrared, and nuclear magnetic resonance spectroscopy.

These classes are followed by an intensive laboratory course that focuses on experimental techniques for polymer synthesis, characterization, and fabrication. The catalog description is given below and the specific experiments are described in the Appendix.

Polymer Synthesis and Characterization Laboratory (Laboratory course). Preparation and physical characterization of polymers with emphasis placed on those of commercial interest. Students synthesize a variety of polymers. The synthetic methods will encompass several different techniques for polymer formation, for example, homogenous solutions, phase-transfer methods, emulsions and suspensions. Characterization of the resultant products includes molecular weight determination by light scattering, vapor phase and GPC methods, viscosity measurements, determination of glass transitions by DSC, measurement of temperature- and frequency-dependent mechanical properties, and investigations of structure by solid-state NMR and IR spectroscopy.

The laboratory course is arguably the most important component of the coursework;. therefore, in the polymer laboratory course, we build on the students' understanding of each major topic. The students apply what they have learned in the lecture courses and get hands-on experience. For most of them, this is their first training in, for example, polymer synthetic techniques, laser light scattering, and differential scanning calorimetry and their first exposure to measuring mechanical properties. Additionally, the laboratory course exposes students to the application of nontraditional emergent materials (e.g., conducting polymers, diblock copolymers, dendrimers, etc.). The laboratory course content is continually being revised and updated because of input from our industrial partners. For example, recent additions include new casting and extrusion experiments, which were added at the request of one of our affiliates.

Further details about the timing and duration of the courses are as follows. The two lecture courses and the laboratory course are taught during the summer session over nine weeks. The synthesis, characterization, and processing course is taught first (3 weeks), followed by the physical chemistry course (3 weeks), and then the laboratory course (3 weeks). The lecture courses meet every weekday for three and one-half hours. There are daily homework assignments and group homework assignments. The latter are specifically designed to give students experience working in teams, something our industrial affiliates stressed was important. A common strategy is to have the students work on these group assignments over their lunch break and then to discuss their answers in the lecture session following the break. Several plant tours are also schedule during the afternoon. The laboratory class meets from 9 a.m. to 5 p.m. every day for three weeks. Thus, all three courses are extremely demanding and students are cautioned at the outset of the program to keep up with the assigned work. Because the courses are so intensive, students do not take other classes concurrently because they need most of their available non-classroom time to do homework assignments, read the text, work on group assignments, go on plant tours, etc. Following their successful completion of the three courses, the students are ready to begin their internship.

The Internship

The classroom and laboratory training forms the basis for the internship experience. Thus, following the summer coursework portion of the program, the students are placed in internships with companies starting in the fall term of the academic year. Here they gain practical experience in polymer production and analysis. The general goal of these 9-month-long (academic year) internships is to provide students with an introduction to the industrial work experience. The procedure for placing the students in the internships is not as difficult as it might seem. Following the completion of their coursework, the students are interviewed by all of the industrial affiliates. Because the students are motivated and generally among the top students in our department, most of them ordinarily receive multiple offers. In no case have we ever had a student not get an internship offer. Thus, the students usually have some choice about where they will do their internship. Students are paid by the industrial partners and work with an industrial mentor during their internships. This type of practical experience is becoming indispensable as a means of preparing students for the challenges of the industrial workplace [2–4, 7]

The structure of the internship is not fixed and is generally dependent on the particular company. Some students work on quality control problems, others on formulating new materials, and yet others on bona fide research projects. Although the particulars are left up to the company, before they accept an intern the companies are well-versed by the faculty in charge of the program as to what the goals of the program are, what types of projects are appropriate, and so on.

Although the internship programs provide an intensive experience, they alone do not provide sufficient exposure to the diverse career paths available. Thus, to augment the internship programs, during the academic year we invite representatives (including our graduates) from a diverse range of industrial settings to present seminars on their experiences and talk with the interns and faculty about career opportunities. These monthly seminars provide opportunities for all of the interns to share their experiences with each other and with the faculty during the course of their internships.

Monitoring the Progress of the Interns

In addition to the monthly meetings with the interns, at least one meeting is scheduled between the faculty members in charge of the internship program and the industrial mentors during the nine-month internship period. The purpose of this meeting is to make sure everything is going smoothly, to discuss concerns, and to discuss improvements for the following year. The faculty members are also in frequent email contact with the industrial mentors and the interns, so that if problems should arise they can be resolved quickly.

Comparison to Existing Programs

Courses in polymer synthesis, processing, and characterization and in physical chemistry are not new. They are traditionally taught in chemistry departments or in materials science, polymer, and engineering schools around the country. The unusual and unique aspect of our new program, however, is that it is designed to embellish the traditional chemistry or physics degree and is tightly coupled to the internship program. Another key aspect of our program is that it was designed with substantial input from local polymer companies. Their input ensures that we cover the material that is essential for an industrial polymer chemist (problem-solving skills, teamwork, leadership, good communication skills, and technical expertise). Because of these features, we believe our project to be innovative, and our experiences will be of broad interest around the country. The curriculum is short compared to a more traditional polymer curriculum, but the entering students are already highly trained (they have bachelor's degrees) and our focus is quite distinct, so the final product is of high quality. Note that, in addition to the three courses and the internship, students must have an additional 12 units (3 courses) in order to fulfill the requirements for a master's degree. The students typically satisfy this requirement by taking one class each quarter during the three quarters of their internship or by coming back to the university for the additional classwork following their internship.

Practical Concerns

Starting a new master's level program at a university is time-consuming in an administrative sense and also expensive. It is essential, therefore, to have the full support of the university administration. At the University of Oregon, we had the support of the administration, and consequently they provided extensive monetary support for faculty salaries (for the extra teaching load in the summer), for the new laboratory teaching assistants (for the new polymer laboratory course), for equipment match money (for new equipment in the polymer laboratory course), and for advertising the new program to attract students. The support of one's colleagues is also worth cultivating. Invariably, faculty squabbles about a new curriculum arise. For example, some faculty in our department were concerned about whether students retained as much from an intensive summer course as from a more drawn-out course taught during the academic year; should the same number of credits therefore be given for the summer course as for an academic-year course? While it is hard to foresee all possible objections, good communications and the generally unconditional support of one's colleagues facilitates solutions to these problems.

Another practical tip is to advertise early and often. Our goal is to attract students from around the Pacific Northwest, and we have found that the number of inquiries we receive about the program is proportional to the amount of advertising we do.

As anyone who has any industrial contacts knows, acquiring new industrial contacts and keeping existing contacts is time-consuming and a year-round job. Our department is giving serious consideration to the idea that people involved with these internship programs will get some relief from their other administrative duties, simply because the amount of time involved in maintaining the industrial contacts is so copious.

Finally, there is a perception at some universities that internship programs give the industrial affiliates too much control of the university and that this reduces the academic freedom of the faculty. Our own experience is that this has not been an issue. As discussed above, the program reported herein was designed with input from local companies, but that input was in the form of *suggestions* about course content, not academic procedures or policies. We were happy to receive those suggestions because they came from experts, who clearly understand what is necessary to succeed in the polymer area. The faculty in charge of the program, however, made the final decisions about course content (and all other matters relating to the program).

Practical Outcomes

Students are excited about the new internship program because it teaches them practical and marketable skills. They know that if they successfully complete the demanding lecture and laboratory courses, they will get an internship with a respectable company. Our industrial affiliates are generally looking for new employees, and of course the interns are looking for their first real job. Thus, during the internship period both parties are eyeing the other with regard to the possibility of long-term employment. In practice, many of the internships do turn into real jobs once the internship is over.

Despite the intense schedule and pace, professors find teaching in the program immensely satisfying. Unlike regular academic-year classes, every student in these classes wants to be there. The students are, therefore, eager to learn and willing to work hard. They pay rapt attention and ask good questions. Professors who have taught in the polymer program all agree that these conditions make for a fantastic teaching experience.

The internship programs have increased the number of—and improved the quality of—our relationships with local industry. Industry sees the value of the program because they are getting smart new hires with practical skills; thus, it is to their advantage to participate in the program and maintain their ties with us. A practical advantage to the department is an increase in the number of industrial donations of laboratory equipment. In fact, many of the instruments used in the laboratory course are instruments donated by the companies.

An unforeseen benefit of increased university–industry relations is that the companies are sending full-time employees to take the lecture and laboratory course. They see these courses as "refresher" or continuing-education-type courses for their employees. Having these employees participate in the program benefits the regular students enormously because they get to interact with "real" polymer chemists and learn about their jobs. In addition, the employees' knowledge and first-hand experience is often invaluable when we cover their areas of expertise in the courses. Finally, it is noteworthy that several area high school teachers have expressed an interest in participating in the summer courses. We are eager to oblige because it should lead to better relations with the high schools and in a general way increase the level of scientific literacy in the community.

Thus far, there has been sufficient demand by polymer companies in Oregon that all of the internships have been with local companies. As the program increases in size, it will probably be necessary to include companies outside the state. There should be no particular impediments to including companies outside of Oregon, and in fact the program will be strengthened by the new diversity of companies participating in the program.

More Information

Further information about the internship programs at the University of Oregon can be obtained from the website: http://jersey.uoregon.edu/~amy/MSI_intern/coop.html. Prospective students can also apply online at this site.

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Appendix

The laboratory experiments are listed below. Polymer characterization techniques are introduced as early as possible. Processing and fabrication methods are introduced where appropriate. It is important to emphasize that the methods and techniques covered below were selected by consultation with our industrial contacts. Throughout the laboratory there is an emphasis on the relationship of polymer properties to polymer structures. The laboratory course entails over 90 hours of hands-on instruction per student.

a) Radical polymerization: synthesis of polystyrene. Effect of temperature and initiator concentration on polymer composition. Introduction to molecular weight measurements by GPC/MALLS (multi-angle laser light scattering) and viscometry. Introduction to infrared and solution-phase NMR spectroscopy of polymers.
b) Emulsion polymerization: synthesis of polystyrene. Comparison to properties of polystyrene synthesized by a nonemulsion method. Analysis with GPC/MALLS. Introduction to foaming techniques. Determination of tensile strength and comparison of mechanical properties to commercially available samples.
c) Polymer tacticity: synthesis of PMMA by radical and anionic polymerization methods. Use of air/moisture sensitive techniques. Analysis of tacticity by IR and solution NMR spectroscopy. Introduction to thermal analysis and characterization using DSC to measure the glass transition temperature. Introduction to extrusion techniques.
d) Copolymers: synthesis of a PS/PMMA random copolymer by a radical polymerization method. Comparison to microscopic, thermal, and mechanical properties of the individual polymers using GPC/MALLS, DSC, and tensile stress measurements. Introduction to solid-state NMR and use of IR and NMR to estimate copolymer composition.
e) Step growth polymerization: synthesis of nylon 66 by solution and solid-state methods. Determination of tensile strength and comparison of mechanical properties to commercially available samples. Analysis by DSC, GPC, and NMR.
f) ROMP (ring opening metathesis polymerization): (a) living polymerization of an oxanorbornene derivative in water, and (b) vulcanization to give a crosslinked material. Characterization of the product polymers by NMR, GPC/MALLS, DSC, and tensile strength measurements to compare their physical properties.
g) Formaldehyde resins: synthesis of phenol-formaldehyde, urea-formaldehyde, and melamine-formaldehyde resins. Analysis with GPC/MALLS, DSC, and tensile strength measurements. Introduction to thermoset polymers: curing and molding techniques (injection, compression, and transfer molding). Effect of fillers on mechanical properties. Effect of antifoaming agents in the manufacturing process.
h) Microscopic polymer structure and mechanical properties: spin-casting and annealing of semi-crystalline polymers and study of their domain sizes by optical microscopy. Study of polymer phase separation in blends by differential-interference-phase-contrast (DIC) microscopy. Prediction of blend properties by QSAR program.

References and Notes

1. The internship program described in this paper is analogous to what many universities call a “coop” program. It is interesting to note that some in industry prefer to use the term “apprenticeship.” The generally accepted difference between an apprenticeship and an internship or coop is that students in an internship or coop program return to school, whereas in an apprenticeship the student is done with school and is learning practical skills in a job. As described in the text, students who complete the coursework and internship program are still three courses shy of fulfilling the credit requirements for a master’s degree. Hence, most of the students in the program plan on returning to the university to finish their degree requirements, and the program is appropriately called an internship (or coop).
2. The value of internships for science majors is now generally recognized; see, for example, Steering Committee for the Workshop on Graduate Student and Postdoctoral Education and Training, J. Armstrong, Chair *Graduate Education and Postdoctoral Training in the Mathematical and Physical Sciences;* NSF 96-30; National Science Foundation: Washington, DC, 1995.
3. American Chemical Society Committee on Chemistry and Public Affairs. Shaping the Future: The Chemical Research Environment in the Next Century. *Chemtech* August 1994.
4. National Academy of Sciences, National Academy of Engineering, Institute of Medicine *Reshaping the Graduate Education of Scientists and Engineers;* National Academy Press: Washington, DC, 1995.
5. The lecture courses and the laboratory course are each four credits. The internship is ten credits per quarter.
6. In addition to input from our industrial affiliates, the following materials proved invaluable in designing these courses: Droske, J. P. *Polymer Education Resource Materials, University of Wisconsin, Stevens Point;* POLYED National Information Center for Polymer Education, 1992.
7. Greene, R. G.; Hardy, B. J.; Smith, S. J. Graduate Education: Adapting to Current Realities. *Issues in Science and Technology*, Winter 1995–96, 59.

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