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Polymer Chemistry

. . . Is about optimizing technology

A polymer is a chain of small molecules joined together in a repeating fashion to form a single layer molecule. Chemists develop polymers so they can be used to make ingredients for products with unique physical and chemical properties. They manipulate large, complex molecules and capitalize on the connections between their molecular structure and the properties that make them useful. Polymer products can be lightweight, hard, strong, and flexible and have special thermal, electrical, and optical characteristics; they include products from the fiber, communication, packaging, and transportation industries.

The big boom in polymer chemistry occurred largely in the first part of the twentieth century with the advent of polymer materials such as nylon and Kevlar . Today, most work with polymers focuses on improving and fine-tuning existing technologies. Still, there are opportunities ahead for polymer chemists. They work in many industries, creating a variety of synthetic polymers such as Teflon and special application plastics and developing new polymers that are less expensive or that outperform traditional materials and replace those that are scarce.

"The world is changing," says James Shepherd, a research associate in polymer chemistry at Hoechst Celanese. "New demands for polymer materials will be coming down the line. What we have learned over the past ten years will enable us to fulfill new needs. We may not discover a new polyethylene," he says, "but we may find smaller-volume and potentially more cost-effective materials."

. . . Is about research and business

There has been a shift in the economic emphasis and focus of polymer chemistry. Shepherd says when he began working in the field, many projects were purely exploratory. "Only later would we worry about the product." Now, projects are evaluated at the outset on the basis of what they will do for the company and what end-use improvements they will deliver. Therefore, industrial polymer chemists are increasingly in contact with the sales and marketing divisions of their companies and its customers.

This shift has placed a premium on good communication and interpersonal skills. It means chemists must adopt a business outlook in their work. Other skills and disciplines also come into play. "It helps if you are engineering-minded," says Kate Faron, a senior research chemist at DuPont. John Droske, professor of chemistry at the University of Wisconsin Stevens Point, agrees. "This is a field for people who are comfortable looking at the end use as well as the preparation."

Polymer chemistry is product-oriented. However, this does not eliminate the availability of positions outside of industry. Some polymer chemists pursue their research interests in addition to their teaching and administrative responsibilities through employment at colleges and universities.

. . . Touches many scientific disciplines

Polymer chemistry touches many scientific disciplines and is vital in fields that develop products such as plastics and synthetic fibers; agricultural chemicals; paints and adhesives; and biomedical applications such as artificial skin, prosthetics, and the nicotine patch that helps smokers overcome their smoking habit. It is estimated that as many as 50% of all chemists will work in polymer science in some capacity during their careers. Because they work in a field that is so broad, polymer chemists must be flexible

and be able to interact and communicate with others in a variety of disciplines.

Because polymer chemistry today is product oriented, it has some overlap with materials science. However, polymer chemists emphasize that the most important aspect of their work is in the organic synthesis of materials. Most Ph.D. chemists now in the field were trained in organic chemistry. They acknowledge the strengths of degree programs in polymer science, but many say they would still choose to obtain a solid background in organic chemistry before entering the polymer science area. "You should take polymer classes, but not without a strong foundation in organic chemistry," says Jim Mason, senior chemist in the polymers division at the Bayer Corporation. "You learn a lot on the job," he adds. He says that an employer can teach you about polymers, but the fundamentals should be learned while in school. Mason adds, "Traditional training may also provide you with more long-term job security." Faron says, "It helps to be a generalist. If you go into certain polymer programs, you could be specializing too soon."

. . . Is a field open to change

"Things in the area of polymer chemistry will be changing dramatically over the next five to ten years because of the emphasis on 'green' products," explains Shulman. "Ingredients will have to be environmentally friendly, and there will be an emphasis on making polymers biodegradable. Concern about the effects of detergent products on the environment has brought new activity to a relatively mature area of polymer science." Polymer is an exciting field with new frontiers to be discovered.

Jim Mason Blending and Compounding

Today, there is almost no development of entirely new polymer materials. However, blending and compounding existing polymers has become an important part of a polymer chemist's work. "Compounding is both an art and a science," says Jim Mason, a senior chemist in the polymers division of Bayer Corporation. "Quite a bit of chemistry is involved. You need to understand the reactions that go on in an extruder the machine used to compound." Compounding is often done to achieve certain properties needed for a particular application.

One of Mason's recent projects was to develop a compounded polymeric material to be used in the manufacture of lawn tractors. "Body panels for these tractors are typically made of sheet metal," Mason explains. "But many tractor manufacturers would like plastics instead of sheet metal in the body panels. Existing plastics were not suited for this application, so we tried blending different materials to come up with the right combination of properties."

Mason worked directly with the tractor manufacturer to find out what was needed. "One of the big requirements was high impact strength," he says. "Then if the tractor hit a tree, the material would not shatter. We also needed to develop a material that had good weatherability and could be mixed with pigment to get the right color." The chemist and the customer collaborated to develop a material that is suited for this application.

James Shepherd Liquid Crystal Polymers

In the 1970s and 1980s, some of the most lucrative polymer breakthroughs occurred in the area of high-performance polymers. These materials were expensive to produce but had new and desired qualities, such as high strength and temperature resistance.

James Shepherd, research associate for polymer chemistry at Hoechst Celanese, focuses on developing new high-performance polymers. One example of successful high-performance polymer technology is liquid-crystal polymers (LCPs). LCPs are polymers that are highly oriented; that means that when they are heated above a certain temperature, the molecules align and flow easily. The LCP can then be pushed through a spinnaret on a spinning machine and made into a fiber, or can be injected into a small mold for an intricate part used in the electronics business. One of the benefits of LCPs is that they produce a material that is generally much stronger than those produced from traditional plastics.One aspect that Shepherd stresses is the importance of teamwork. "How to make the polymer is a team decision. There are so many different aspects to bring together and different talents required," he says. "It is not just the people in the lab making the decision. We monitor the changing needs of our customers and then determine how to produce the material with the properties they want."

An illustration of this, says Shepherd, was when economics and environmental issues required the molding industry to reuse the scrap material that is a normal byproduct of molding plastic parts. "One problem with doing this," he explains, "is that repeated processing cycles can adversely affect the properties of the material." However, by adjusting the chemistry and processing characteristics of a new LCP formulation, chemists in Shepherd's lab developed a material that maintains its properties after many processing cycles. In this way, basic researchers brought together applications, chemists, and customers to find a mutually beneficial solution.

Terry St. Clair Polymers for Aerospace/NASA

Polymer development at NASA occupies a unique position in the field of polymer chemistry. Terry St. Clair, head of the polymeric materials branch at NASA Langley, explains that his work both serves NASA's polymer materials needs and functions as an incentive for the rest of industry to make the best polymer materials possible. "Our mission," he explains, "is to make sure that the materials that aircraft companies need are available. This, in some cases, forces industry to offer a more optimized product than the one they might want to push.

"We do a lot of the same type of polymer work as is done in industry, but in a broader and freer structure that is not confined by cost," he says. In some ways, this makes NASA a competitor with other polymer makers, the difference being that NASA does not actually manufacture large quantities of polymer materials. In some cases, St. Clair will work directly with an aircraft company to develop the products it needs. "When they have endorsed the material, we both go out into the market to try to find someone to make it," he says.

Another aspect of his job is to develop polymers for highly focused applications, such as the scientific instruments used in the space program. Staff in St. Clair's lab were asked to make a polymer used in the window of an X-ray telescope. "Only about five pounds of this material was needed annually," he says. "We were in a position to develop an exotic polymer where cost was not a factor. They would have been happy to use platinum or gold if it would work."

Jan Shulman Detergent Polymers

Jan Shulman, a formulation chemist at Rohm and Haas, works with polymers used in automatic dishwashing detergent products. "In this field, polymers are key to making products work better," he says. One problem Shulman deals with is the effects of sodium carbonate or soda ash in a dishwashing detergent. "Soda ash is a main ingredient in many formulations," he says. "But when it reacts with water, it can form a chalky film on glasses. When you add polymers to a formula, you can prevent this from happening." Shulman says his lab facility includes dishwashers, plates, and glasses. "We basically replicate what the consumer does at home and conduct research to determine the most effective detergent formulation."

Shulman also works on formulation changes that are needed to address concerns about the effects of traditional detergent ingredients on the environment. "Most of this work involves reformulations around chlorine and phosphates," he explains. Beginning in Europe in 1990, he says, there was a move toward phosphate-free systems and an effort to replace chlorine bleach with oxygen bleaches, such as those found in Clorox 2. "Because this trend was making its way to the United States, it became my job to work on reformulating products," he says. "When you remove phosphates, you need to add a polymer to enhance performance. We try to determine which polymers will fit the bill."

Kate Faron Fibers

The general public is familiar with Lycra, or spandex, the stretch fabric that goes into leggings, fitness wear, and bathing suits. Kate Faron, a senior research chemist at DuPont, knows Lycra on the polymer level. Part of Faron's job is to improve Lycra spandex for continued use in successful fashion items. "When Lycra first replaced rubber thread, the market grew in every segment," she explains. "We need to continue making some changes to the fiber to keep growing. Most of the changes that we make are incremental changes to existing products; but we still seek step-change improvements, and there is always a lot of chemistry involved."

By changing the structure of the polymer or by using chemical additives, Faron changes the properties of the spandex polymer. For example, how it responds to light and heat can be modified chemically.

"Certain fabrics that do not already include Lycra might benefit from elastic properties," she says. "We change the polymer to meet the specifications of these new materials. It is macromolecular engineering," she says. "You need to know how to synthesize small molecules and incorporate them into larger ones. You also have to understand the structure you build and the properties you expect it to have."

John Droske Polymer Education

"Approximately 50% of all chemists will work with polymers at some time in their careers," says John Droske, professor of chemistry at the University of Wisconsin Stevens Point and director of the POLYED National Information Center for Polymer Education. "Because polymer science touches on many areas, it is important for chemists to be trained in polymer science." The POLYED has been working with a National Science Foundation grant to develop materials for polymer chemistry courses at the undergraduate level.

Droske teaches courses on the synthesis and characterization of polymers and the physical chemistry of polymers. He also conducts a polymer lab course. The aspect of polymer science that Droske enjoys most is the challenge of working with large molecules. "There is something unique about studying polymers," he says. "Macromolecules have a greater complexity than do small molecules. Over the years, our understanding of these large molecules has increased so much that, although they remain complex, we have tools that provide us with a better understanding of their properties, enabling us to make connections between their structure at the molecular level and their properties at the use level."

WORK DESCRIPTION

Polymer chemists are concerned with the study and synthesis of large, complex molecules. They manipulate the molecular structure of a material to develop functional characteristics in an end product by chemical processing or through other processing conditions.

PLACES OF EMPLOYMENT

Polymer chemists are employed in industry, government, and academia. However, most jobs are in industry where products are made. Opportunities for polymer chemists in industry exist in areas where adhesives, coatings, synthetic rubber, synthetic fibers, agricultural chemicals, packaging, automotive, aircraft, aerospace, and biomedical industries are made.

PERSONAL CHARACTERISTICS

A polymer chemist's work is interdisciplinary in nature. Individuals should be able to communicate with others in a number of fields. Those who are interested in materials and the end use of polymers as well as their synthesis will be particularly well suited to the field. This is also be true for individuals who like hands-on work as opposed to purely theoretical thinking.

EDUCATION AND TRAINING

Most people employed in polymer chemistry have a Ph.D. and were trained as organic chemists. They stress the importance of a solid education in the fundamentals of chemistry. However, they acknowledge the value of the interdisciplinary degree available through programs in polymer science.

JOB OUTLOOK

Because polymer science is product-oriented, hiring can be expected to follow the economy. Polymer chemists stress the need to remain as broad-based and as flexible as possible for long-term employment security, but creative and well-trained individuals should be able to find positions in this field. Most major chemical companies have made deep cuts in their central research divisions, and industry is still in a downsizing mode. The field remains highly competitive, but some say they think these dynamics are cyclical and that the job market will improve.

SALARY RANGE

Starting salaries for chemists in polymer science are in the high $40,000-per-year range for those with a Ph.D., approximately $35,000-per-year for M.S. degree holders, and in the mid $20,000-per-year range for someone with a B.S. degree. The median salary for a Ph.D. polymer chemist in industry is estimated to be approximately $75,000-per-year; $64,000-per-year for chemists working in government labs; and $55,000-per-year for chemists in academia.

FOR MORE INFORMATION

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WHAT YOU CAN DO NOW

Only a few colleges and universities have programs in polymer science, so a student's best access to experience in the field will be through internships in industry or through summer employment at an institution that has a polymers program.

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