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Centers of Polymer Research

Polymer Science and Technology in Universities in Sweden

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Sweden, a country of eight million inhabitants, is located on the Eastern part of the Scandinavian Peninsula in Northern Europe. It is a highly technically developed country with a sizable polymer industry, which presently is producing about 500,000 tons of polymers annually.

Several types of polymers are being manufactured: various kinds of polyethylenes (low density and high density), poly(vinyl chloride), polystyrene, polyacrylates, unsaturated polyesters, and several types of thermosetting resins for plastics, adhesives and surface coatings. Polymers for specialty plastics, rubber and synthetic fibers are not produced in Sweden. The annual consumption of polymeric materials is more than 100 kg per person, which is one of the highest in the world. Polymer research, especially the material science of polymers, has a high priority in Sweden and is well supported by research councils.

Sweden is a country of extensive forests, and rich mines; many rivers and water falls have been harnessed to produce hydroelectric power. These resources were the basis of the early developments of wood, paper and steel industry and the manufacturing of many goods. Synthetic polymers, plastics and rubber industries began their development later and these efforts grew to large scale production of polymers in the late 1950's. The first petrochemical plant for the production of polyolefins started in 1963.

Macromolecular research has a long history in Sweden. Already, in the 1920's when the macromolecular concept was being formulated from the organic chemical point of view, an independent line of macromolecular research was carried out in Sweden. The physical chemist Theodor Svedberg, a colloid chemist at the University of Uppsala and the first professor of physical chemistry in Sweden, constructed the ultracentrifuge and made the first measurements of molecular weights of proteins in 1925. Svedberg showed conclusively that the proteins were macromolecules of well-defined molecular weight and shape and not random aggregate or gel particles as was generally assumed at that time. The sedimentation and diffusion studies of macromolecules in solution were extended in the next twenty years to the study of polysaccharides, polyuronides and synthetic polymers. Other

separation methods e.g. electrophoresis and chromatography also were developed in Uppsala by Arne Tiselius, a professor of biochemistry and Stig Claesson, Svedberg's successor in physical chemistry and applied to macromolecules. The early work on natural polymers at the University of Uppsala had a considerable impact on the development of the early research in biochemistry and biophysics of biopolymers.

Teaching in polymer science and research on synthetic polymers started at a number of Universities in Sweden as the need for this type of education arose. Programs were developed first in Stockholm and later at Göteborg, Lund and Luleå. Several professorships have been created over the last 20 years in polymer science and several research groups are now active in polymer science and technology in a number of Swedish Universities.

Polymer research in Sweden is mainly supported by grants from the National Swedish Board for Technical Development (STU), the research Council for Applied Sciences, by grants from the National Science Research Council (NFR), the Swedish Council for Building Research (BFR) and several other public agencies and private foundations. Since 1977 there is also a Plastics and Rubber Institute (PGI) in Sweden (with Dr. Göran Malhammar as its director), where projects of interest to the polymer processing industry are being investigated. Meetings of various aspects of polymer science and technology, sponsored by the Swedish Chemical Society, have been held regularly since 1963.

The Swedish Universities have a long and well established tradition in biopolymer research, especially in research on proteins and polysaccharides. During the last two decades, research on synthetic polymers and teaching of polymer chemistry has been organized in a number of Swedish technical universities, first in Stockholm and then in Göteborg, Lund, Linköping and Luleå.

The Royal Institute of Technology. - Teaching of polymer science and research in polymer science and technology started in 1960 at the Royal Institute of Technology in Stockholm when the Department of Polymer Technology was created. The department is part of the School of Chemistry and Chemical Engineering. Professor of Polymer Tech-



The Royal Institute of Technology, Stockholm, Sweden, main entrance (in center), University library (right), Administration building (left).

nology and Chairman of the department since its beginning is Bengt Rånby, a student of Svedberg. The department now has a second chair in Polymeric Materials to which Jan-Fredrik Jansson was appointed in 1983. Students majoring in polymer science and technology take lecture and laboratory courses. The classes cover polymer chemistry and polymer physics with industrial applications. All chemistry students majoring in polymer science are required to take polymer courses in the two main areas (chemistry and physics) and are offered other elective polymer courses such as polymer processing, organic coatings, and biopolymers. Students from other departments or schools, those majoring in organic or physical chemistry, material science or mechanical engineering, may select courses in polymer chemistry, polymer physics, polymer processing, coatings, or biopolymers as part of their education. The graduate students in polymer technology are offered courses in polymer chemistry, physics and mechanics (rheology) and specialize in polymer chemistry or material science involving polymers.

Research programs of Professor Bengt Rånby, involve free radical polymerization, grafting using chemical or photochemical initiation, and degradation of polymers, (a new redox catalyst (Mn) for grafting onto polysaccharides was developed) ultraviolet, infrared and nuclear magnetic spectroscopy are extensively used in this research. Pioneering work has been done in the use of electron spin resonance and ESCA spectroscopy.

With Associate Professor Jan F. Rabek, Professor Rånby

is studying reactions of oxygen (especially singlet oxygen) with polymers. J. F. Rabek is also investigating new stabilizers to prevent photochemical reactions. Associate Professor Ann Christine Albertsson is investigating biological degradation of synthetic polymers and the synthesis of biomedical polymers.

An important general problem is the longterm chemical and mechanical stability of polymeric materials, especially in outdoor applications. Some of these problems are being investigated jointly with laboratories in the United States. Ultraviolet initiated photocrosslinking and photopolymerization of organic coatings, plastics, and elastomers are also being explored in Professor Rånby's laboratory.

In Professor Jan-Fredrik Jansson's materials science laboratory, stress relaxation, creep, and physical aging of thermoplastics are being investigated; the properties and use of superdrawn polyethylene fibers (with Ulf W. Gedde) and the compressionset and relaxation of rubbers (with Bengt Stenberg) are some of the projects of the materials science laboratory. The preparation, mechanical properties and fracture behavior of fiber reinforced composite materials are also being studied in Professor J. F. Jansson's group.

The Chalmers Technical University, Göteborg - Polymer research at Chalmers Technical University started in 1967 when a professorship was created and the Department of Polymeric Materials in the School of Mechanical Engineering was formed. Chairman of the Department since the beginning is Professor Josef Kubat. Courses in the polymer program

deal with processing of polymers and properties of polymeric materials, especially those which have the potentials of industrial application. The graduate research programs in polymeric materials are involved in several areas of polymer engineering: injection molding at high pressure, stress in molded plastic pieces, biaxial orientation of blown film, recovery, recycling, and processing of used plastic materials, processing of reinforced thermoplastics, and electrical conductivity of polymers filled with carbon black. This work is done in Professor Kubat's laboratory particularly by Associate Professors Mikael Rigdahl and Carl Klason.

The Department of Polymer Technology was formed in 1978 in the School of Chemistry and Chemical Engineering at the Chalmers Technical University and Per Flodin was appointed Professor and Chairman of the Department. The teaching program in this department is mainly involved with general polymer chemistry and application of plastic materials. Polymer research in Professor Per Flodin's group is concerned with the characterization of polymeric materials, the thermooxidation of polymers, and gel permeation chromatography of polyolefins at elevated temperatures. ^{13}C NMR spectroscopy in the solid state ("magic angle NMR") is also being studied, as are polymer based fiber composites and cellulose fibers as plastic reinforcements. Hydrophilic gels are being synthesized for the separation of biopolymers and macroporous gels for the absorption of vapors, and as ion-exchange resins. With Associate Professor Bertil Helgee, the synthesis of aromatic high-modulus fibers and with Associate Professor Göran Canback, interpenetrating networks are being studied. A polymer research group which had been originated in the 1960's is now under the leadership of Associate Professor Erling Sörvik; work is being done on vinyl chloride polymerization, and thermal degradation and oxidation of poly(vinyl chloride) and polyethylene. This research group has recently been incorporated into Professor Flodin's department.

The Technical University in Lund. - Teaching and research in polymer science and technology in Lund is carried out in the Chemistry Center, which is jointly operated by the University of Lund and the Technical University of Lund.

Polymer research in Lund is organized as a polymer group in the Department of Chemical Technology, which recently (1976) was reorganized into a department of Polymer Technology with Professor Bertil Törnell as its head. The polymer courses are given in the senior and junior years of the undergraduate education program and are concerned with polymer chemistry and chemical technology of polymers.

The polymer research program was initiated in 1969 by Professor B. Törnell, who started to work on water-soluble polymer systems. New initiator systems for emulsion and suspension polymerization are now being investigated as is the mechanism of particle formation, especially in vinyl chloride polymerization.

Associate Professor Bengt Wesslen and his group are broadly interested in the surface properties of polymers, in thermosetting resins for high-impact plastics and in new polymeric surfactants.

Other Universities and Institutes. - Teaching and research in polymer science and technology is also carried out in University and Research Institutes other than those mentioned earlier. At the University in Umeå, the activity in polymer science is part of the research and teaching program in physical chemistry, medical chemistry, and biochemistry. At the University in Luleå and at the Technical University in Linköping the interest in polymer science is part of the activities in materials science and technology. In the local colleges at Sundsvall, Växjö, Örebro and Västerås, polymer science is taught as part of the chemistry courses.

In Sweden, research on biopolymers is being carried out in all medical schools (Stockholm, Göteborg, Lund, Linköping and Umeå). Research on cellulose, hemicellulose and lignin is done at the Swedish Forest Products Laboratory, a joint state-industry organization.

The University of Stockholm has an extensive research program on polysaccharides, especially those isolated from bacteria and other microorganisms (Professor Bengt Lindberg and Per Garegg), and at the University in Uppsala on solution and gel properties of macromolecules (Professor Lars-Olof Sundelöf).