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Centers of Polymer Research

Polymer Science at Kyoto University, Kyoto, Japan

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Kyoto is a city of about 1.5 million people located in the center of Japan, about 35 kilometers from Osaka. The city was the capital of Japan for over 1,000 years, from 794 to 1867. It is the most important cultural center of Japan.

Polymer Science has played a major role in Kyoto, especially at Kyoto University. Professor Y. Nishijima, who held, for many years, the chair of Structure of Polymers at Kyoto University, was president of Kyoto University from 1985 to 1991. This was the first time that a polymer scientist had held this position in a major university. In Kyoto, polymer science is also a major component of teaching and research at the Kyoto Institute of Technology [see *Polymer News* 18 1 (1993)]. Kyoto University has previously been described in a 1980 issue of *Polymer News* by Professor Akio Nakajima.

History of Kyoto University

Kyoto Imperial University was founded on June 18, 1897 by Imperial Ordinance as the second university to be established in Japan. It was renamed Kyoto University in 1947. The Dai San High School (Third High School), an institution which had been providing education in liberal arts in Japan since 1894, was affiliated with Kyoto University in May 1949. Its origin can be traced to the Seimi-Kyoku, one of the first institutions to teach western sciences in Japan. It was founded in



Y. Nishijima

Osaka in 1869, but in 1949 it was established as a new college of the University (later to be called the College of Liberal Arts).

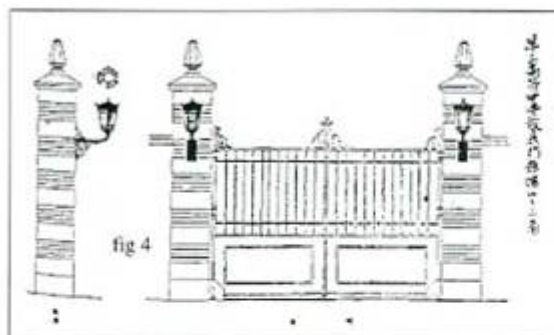
Within ten years of the foundation of Kyoto University, Colleges of Science and Engineering, Law, Medicine and Letters were opened. In July 1914, the College of Science and Engineering was divided into the College of Science and the College of Engineering, giving the University five Colleges. In accordance with the new Imperial University Law, the Colleges were reorganized in February 1919 into five Faculties, i.e., Law, Medicine, Engineering, Letters and Science. In May 1919, the Faculty of Economics was established.

With the growth of University autonomy, a President was chosen by election for the first time in 1915. In 1923, the Faculty of Agriculture was established. With the advancement of education and the requirements of the times, the number of students rapidly increased, and a succession of research institutes attached to the faculties and of various establishments were created. With the end of World War II, the University regained its liberal academic atmosphere.

In March 1947, the School Education Law was enacted, and the educational system in Japan was greatly reformed. The aims of this reform were to affirm the principles of equal opportunity and to expand it to all levels of education, including higher education. In May 1949, the National School Establishment Law was enacted and Kyoto University was reorganized as a four-year instead of a three-year university. In addition to the seven faculties which then existed, a Faculty of Education was newly established.

* This article is based primarily on the information which was available in the *Kyoto University Bulletin*, 1990/91, Kyoto University Pub., November 1990, and on discussions with Y. Nishijima, President, Kyoto University.

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Original Design of the Main Gate. Constructed in 1893.

Kyoto University

In September 1949, a branch of the University to take charge of instruction in liberal arts was opened. In April 1953, the Graduate School was organized under the new system. It consisted of eight Graduate Schools, i.e., Letters, Education, Law, Economics, Science, Pharmaceutical Sciences, Engineering and Agriculture. In April 1954, the College of Liberal Arts was established. In July 1955, the Graduate School of Medicine was established, and in April 1960, the old Faculty of Medicine was divided into the Faculty of Medicine and the Faculty of Pharmaceutical Sciences. In April 1991, the Graduate School of Human and Environmental Studies was established. At present, Kyoto University has nine faculties, the College of Liberal Arts, thirteen research institutes and other establishments which have their own administrative systems.

The Kyoto University staff consists of the president, professors, associate professors, lecturers, instructors, and administrative and technical officials. The University has a University Council, which has faculty meetings, institute boards and many organs of consultation.



Gate at Hyakumanben

Kyoto University is a large organization with relatively few students. As of May 1992, it had a total of 699 professors, 148 of whom are in the Faculty of Engineering. There are also 712 associate professors, 139 in the Faculty of Engineering, 160 lecturers, 31 in the Faculty of Engineering, and 1,057 instructors, 249 in the Faculty of Engineering. The non-teaching staff numbers 2,754. Kyoto is an

attractive place to study and to carry out research; consequently, Kyoto University also has 548 scholars from abroad. The total student enrollment at Kyoto University is about 13,000 undergraduates, 4,452 of whom are in engineering. Of the 1,882 students enrolled in the doctoral program, 300 are in engineering. There are 2,573 in the master's program, with 1,298 in engineering. For comparison, only 513 students are enrolled in the doctoral program in medicine.



**Jane
Vogl**

**Otto
Vogl**

**President
Yasunori
Nishijima**

The President has a term of office of four years and, if reelected, he can serve two additional years. Kyoto University is associated with the Kyoto University Foundation, Inc., an entity which is separate from the University. It was established for the promotion of the academic activities of the University. It plays an important role in international academic exchange through its financial support. Kyoto University has a tuition which amounts to about \$3,000 per year.



Administration Building

The ten separate Graduate Schools have a Doctor's Program for five years, of which the first two years can be completed for a Master's Degree. For practical purposes, the Master's Program is the first two years and the Doctor's Program fills the following three years at the Graduate School. For the Master's Program, the student must be a university graduate, have completed a 16-year school

education either in Japan or abroad. A student may enter the Master's Degree Program's two-year course and then continue on for the Doctor's Program. The Master of Engineering degree is called *Kogaku-Shushi*, and the Doctor of Engineering, *Kogaku-Hakushi*. Kyoto University has a budget of 694 million dollars provided by the government, which amounts to about 90% of its budget. If grants in Aid for Scientific Research from the Ministry of Education, Science and Culture, and donations from industry were included, the total budget would be about 760 million dollars.

The activities in Polymer Science take place, for the most part, at the Faculty of Engineering.

Faculty of Engineering

The Faculty of Engineering has its origin in the College of Science and Engineering established in 1897, which originally consisted of two departments, Civil Engineering and Mechanical Engineering. The college was divided into the College of Engineering and the College of Science in 1914; the former was renamed the Faculty of Engineering in 1919. Currently, the Faculty of Engineering is organized into 23 departments with 148 chairs (*kozas*), six chairs for fundamental courses independent of departments and four research laboratories. The Graduate School of Engineering at the new educational system was started in 1953. Education and research for graduate students in the Graduate School of Engineering are conducted by the academic staff of the Faculty of Engineering and by a related academic staff of other Faculties, Colleges and Research Institutions.



Faculty of Engineering

Polymer Science can be studied in the Department of Hydrocarbon Chemistry, which was first established in 1939, the Department of Polymer Chemistry (1941), the Department of Synthetic Chemistry (1960), and the Division of Molecular Engineering (1983).

The Department of *Hydrocarbon Chemistry* was founded in 1939 under the name of the Department of Fuel Chemistry; it was renamed the Department of Hydrocarbon Chemistry in 1958. The department currently consists of seven chairs covering Physical Chemistry, Organic Chemistry, Chemistry Engineering and Catalysis in the field of hydrocarbon chemistry. Instruction and research for graduate

students in the Division of Hydrocarbon Chemistry are conducted by the academic staff of the Department and two research sections of the Institute for Chemical Research. The 1981 Nobel Prize for Chemistry was awarded to Professor Kenichi Fukui, who was a professor of this Department until 1982.

Some research in polymer chemistry is also carried out in the Division of *Molecular Engineering*, which was founded in 1983 in response to the potential needs for the development of high technology in the chemical industry. The Division consists of seven chairs covering molecular science and technology in the fields of design of functional molecules, molecular energy conversion processes, applied quantum molecular processes, molecular processes in hetero- and homogeneous catalysis, electronic structures and properties of solids, applied solid state chemistry, and molecular materials science.



University Library

Twenty-four graduate students are admitted to the Master's degree program of the Division each year. One chair of the division is occupied by Takeo Shimidzu in the area of Molecular Energy Conversion. His interest is in functional molecules and functional molecular devices as well as in membrane chemistry. He is assisted by Tomokazu Iyoda, who is an expert in Functional Molecular Devices, and by Hiroshi Segawa, whose primary interest is Molecular Energy Conversion. Current research activities of the chair cover functional molecular systems and materials for energy and information transfer, molecular devices and synthetic membranes; photoelectrochemistry for photo-energy conversion; functional molecules for energy and information transfers including biologically important molecules; functional molecular device by materialization of functional molecules for molecular devices; synthetic membranes for selective and active transport.

Areas of interest in this division include Molecular Design by Isao Morishima, Quantum Molecular Science and Technology headed by Hiroshi Fujimoto, Molecular Science and Technology of Catalysis headed by Professor Satoshiro Yoshida, Applied Molecular Science headed by Professor Tokio Yamabe, Applied Solid State Chemistry headed by Professor Koichiro Nakanishi and Molecular Materials Science headed by Professor Sumio Sakka.

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The Department of Synthetic Chemistry

The Department of Synthetic Chemistry was initiated in response to the rapid demand of synthetic chemistry by the chemical industry in 1960 and completed in 1963 with the successive appointments of six professors for the six chairs. The originator of this department was Professor Riohei Oda. The principal aim of instruction in the department is to teach not merely a broad knowledge of current needs of the chemical industry, but to train students in a spirit of independent research in the hope that they become pioneers in new scientific fields. The Department admits 45 students per year to the undergraduate program, 19 graduate students to the Master's degree program and six to the Doctor's degree program. Teaching in the Department is concentrated on organic chemistry, but it also offers courses in organic chemistry of high polymers.

The chair of Synthetic Organic Chemistry is held by Tatsuya Shono, assisted by Associate Professor Yoshihiro Matsumura and Instructors Shigenori Kashimura and Naoki Kise. Their interest is in organic synthesis, electroorganic chemistry and organic reactions in boundary phases. The chair of organic and bio-organic catalysis is headed by Hisanobu Ogoshi, whose interest is in biomimetic chemistry, enzyme model and enzyme mechanism, biomimetic synthesis and physical chemistry. He is assisted by the two instructors, Yasuhisa Kuroda and Takashi Hayashi. The chair of Physical Organic Chemistry is led by Hiroshi Nakatsuji, Associate Professor Toyonari Sugimoto and the Instructors Sadao Miki and Masahiko Hada. Their interest is in physical organic chemistry, quantum chemistry, quantum theory of catalysis, molecular excited states and novel electron systems.

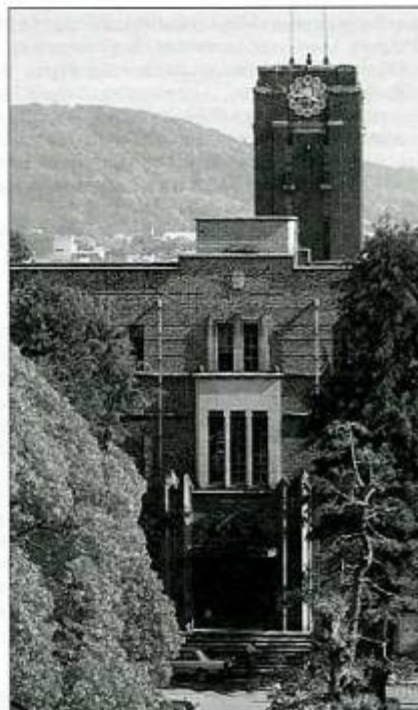
The chair of Organometallic Chemistry is headed by Professor Yoshihiko Ito, whose interest is in organic chemistry, organometallic chemistry and inorganic chemistry. He is assisted by Associate Professor Kohei Tamao and Instructors Masahiro Murakami and Masay Sawamura. The Chair of Free Radical Chemistry is headed by Associate Professor Isao Saito, who is assisted by the Instructors Yoshikatsu Ito and Hiroshi Sugiyama. Their interest is in free radical chemistry, bio-organic chemistry and bio-organic photochemistry.

The chair of Polymerization Chemistry is not occupied at this time. It was originally occupied by Professor Junji Furukawa and, until March 31, 1991, by Professor Takeo Saegusa. The research activities in this "koza" were concerned with the exploration of polymerization reactions, functional polymers and synthetic reactions with emphasis on macromolecule design of unusual polymeric structures. In this chair, Associate Professor Tetsuo Tsuda is interested in organic synthesis and polymerization chemistry. Lecturer Yoshiki Chujo and Instructor Masato Suzuki are both involved in polymer polymerization chemistry.

The Department of Polymer Chemistry

The Department of Polymer Chemistry was founded in 1941 under the name of the Department of Textile Chemistry. It had consisted of four chairs until it was reorganized as the Department of Polymer Chemistry in 1961; it now has eight chairs. The department offers instruction in a wide field of polymer science, including not only polymer chemistry but also polymer physics. Research activities of the department also cover a variety of fields in polymer science.

Each year, 45 students are admitted to the undergraduate program, 30 to the Master's program, and about 10 to the Doctor's program.



The University Tower

The following subjects are offered in the undergraduate program: Introduction to Polymer Chemistry; Introduction to Computer Systems; Physical Chemistry; Organic Chemistry; Introduction to Chemical Engineering; Analytical Chemistry Laboratory; Physical Chemistry Laboratory; Polymer Chemistry Laboratory; Chemical Engineering Laboratory; and also subjects on Naturally Occurring Molecules, Molecular and Supramolecular Structure of High Polymers, Mechanism of Polymerization Reactions, Mechanical Properties of High Polymers and Polymer Solutions, Material Science of High Polymer, Polymer Reactions and Introduction to Chemical Reaction Engineering as well as a general course in Electronics.

In the Graduate Program, the following elective subjects are available: Electrochemistry of Macromolecules, Synthesis of Polymers, Fiber and Textile Technology, Polymer Statistical Mechanics, Chemistry of Biorelated Polymers, Chemically Functional Polymers, Structure of Polymer Solids, Polymer Characterization, Solid State of Crystalline Polymers, Medicinal Polymers, Biorheology and various aspects of advanced polymer chemistry.

The chair for Fundamental Study of Polymer Chemistry, which was originally held by the legendary Professor Ichiro Sakurada, is now held by Professor Norio Ise; he is assisted by Associate Professor Tsuneo Okubo, Lecturer Hiromi Kitano and Instructor Hideki Matsuoka. Their interest is in Naturally Occurring Macromolecules; Colloid Chemistry; Physical Chemistry of Polyelectrolyte Solutions; Thermodynamics of Polyelectrolyte Solutions; Applied

Biochemistry; and Raman Spectroscopy of Polymer Solutions. The current activities of this chair cover the biopolymer-oriented fields of polymer chemistry: small-angle X-ray scattering study of polyelectrolyte solutions; ultramicroscopic observation of polymer latex particles in solution; interaction of biopolymers with various ligands on surfaces of artificial polymers; Raman spectroscopic studies of polyelectrolyte solutions are used extensively.

The chair of Structure of Polymers was originally held by Professor Nishijima, and is now headed by Professor Masahide Yamamoto, whose main interest is in Molecular Spectroscopy. He also studies Organic Chemistry, Photophysics and Photochemistry of Polymer Systems. Instructor Shinzaburo Ito, who is involved in the study of Photophysics and Photochemistry in Polymer Systems, is also working in this "koza." The following programs are under investigation: molecular orientation behavior in polymer solids, liquid crystals and Langmuir-Blodgett (LB) films, as studied by photophysical methods; Micro-Brownian motion of polymers in solution, as studied by the fluorescence depolarization method; photophysical processes in polymer solids and LB films and electronic energy transfer in relation to supramolecular structures; photochemical processes in polymer systems and photoinduced electron transfer in relation to molecular structures and relaxation.



Department of Electrical Engineering and International Hall, Faculty of Engineering

The chair of Polymer Synthesis is headed by Toshinobu Higashimura, whose main interests center on the Synthesis of Functional Polymers, Cationic Polymerization and Ionic and Transition-Metal Catalyzed Living Polymerizations. He is assisted by Associate Professor Toshio Masuda, who is interested in Transition-Metal Catalyzed Polymerization, Synthesis of Substituted Polyacetylenes and Polymer Membranes for Separation. Instructor Mitsuo Sawamoto is working on Living Cationic Polymerization, Cationic Polymerization for New Polymer Syntheses and Chemistry of Carbocations in Solution. The current research activities of this chair cover the following subjects: living cationic polymerization of vinyl compounds and synthesis of novel polymers with regulated structures and functions; fundamental study of ionic polymerization, chemistry of growing carbocations and design of controlled polymerization reactions; substituted polyacetylenes, catalyst exploitation, synthesis of new polymers, living polymerization and

polymer characterization; functional polymers for gas-separation membranes.

Polymer Mechanics in the Solid State is being investigated by Professor Suetō Kawabata, who is interested in Solid Mechanics of Polymers, Fiber and Textile Materials. Associate Professor Takeji Hashimoto is working on Supramolecular Structure and Bulk Properties of Polymer Blends, Block and Graft Copolymers, X-ray and Optical Studies of Polymers in the Solid State. Instructors in this chair are Shoji Suehiro and Hirokazu Hasegawa; they are involved in the study of Structure and Mechanical Properties of Crystalline Polymers, Synthesis and Characterization of Block Copolymers and Polymer Morphology. The general research activities of this "koza" are: mechanics of fractures of solid polymers including fibers, rubbers, composite systems and fibrous materials such as yarns and fabrics; characterization of supermolecular structures and their deformation and relaxation behavior studied by electron microscopy, optical microscopy, small- and wide-angle X-ray scattering and light scattering; statistical-mechanical studies on phase transition of polymers, phase separation, microphase separation, crystallization and gelation.

The chair of Macromolecular Properties of Polymers is headed by Professor Hiromi Yamakawa, who is interested in Polymer Statistical Mechanics, Polymer Transport Theory, Polymer Dynamics, Light and X-ray Scattering from polymer solution. Associate Professor Yoshiyuki Einaga is interested in Polymer Characterization by Scattering Methods and Thermodynamics of Polymer Solutions. Instructor Takenao Yoshikazi is investigating Small Angle X-ray Scattering from Polymer Solutions and Polymer Chain Dynamics. The research activities of this chair cover theoretical and experimental studies of the static and dynamic properties of polymers and oligomers in solution at molecular and atomic levels. The individual research activities include the following subjects: statistical mechanics of chain molecules; light and small angle X-ray scattering from polymer solutions; steady-state transport processes of polymers in solution; and dynamics of polymers in solution.



Toji Temple, Kyoto

The "koza" of Polymer Physics is led by Associate Professor Tadahiro Asada. He is interested in the study of Molecular Structure and Chemical Physics of Polymers, Rheo-optics of Polymers, Structure and Properties of Polymers and the Structure and Property Relationship of Polymer Liquid Crystals. In the same research

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group, three instructors are active: Takayoshi Matsumoto, on Rheology of Disperse Systems; Akira Tanaka on Rheo-optical and Viscoelastic Properties of Crystalline Polymers; and Masaoki Takahashi on Polymer Rheology. The research activities cover investigations on the physical properties of polymeric systems, including liquid crystalline polymers. The individual research activities include the following subjects: structure and physical properties of crystalline and liquid crystalline polymers; rheo-optical properties of polymer liquid crystals; rheological properties of crystalline and liquid crystalline polymers; deformation and nonlinear viscoelasticity of polymeric systems; rheological properties of suspension and colloidal systems.

Materials Science of Polymers is studied by the research group of Professor Junzo Sunamoto, whose main interest is in Materials Chemistry, Artificial Cell Technology and Biosimulating Chemistry. He is assisted by Instructor Kazunari Akiyoshi, who is studying Biofunctional Chemistry, Supramolecular Assembly Systems and Polysaccharide Chemistry. Their general area of research is: physicochemical characterization of various molecular assembly systems such as liposomes, oil/water-microemulsions and lipid bilayers; reconstitution and activity control of membrane enzymes in liposomal membranes; synthesis of cell specific polysaccharides and their physicochemical and biological characterization; development of cell-recognizable polymer materials.

The chair of Radiation Polymer Chemistry is Professor Yukio Imanishi, whose interests lie in Reactions of Polymers, Radiation, Photo Polymer Chemistry, Biofunctional and Biomedical Polymers. He has two instructors: Shunsaku Kumura, who is working on Membrane-Active Peptides and Receptor Modulation Polymers, and Yoshihiro Ito, whose interest is in Biocompatible Polymers, Biocomposite Materials and Drug Delivery Systems. The current research activities cover Radiation Chemistry and Biologically Important Polymers. The individual research projects are: radiation and photo polymer chemistry to develop long-range through-space energy- or electron-transferring chromophoric polypeptides; protein engineering and cell engineering to synthesize functional materials,

simulating biopolymers and modulating cell functions; design and synthesis of biomedical polymers to design and synthesize biocompatible materials and signal-responsive drug-delivery systems.

The Institute for Chemical Research in Uji

About one hour south of Kyoto, in the town of Uji, the Institute of Chemical Research of Kyoto University is located. The Institute had its origin in a laboratory created in 1915 in the College of Science to study and manufacture SALVARSAN, which was in short supply during the first World War. In the following years, it became apparent that facilities should be developed to promote several research programs in pure and applied chemistry.

The Institute was formally founded in 1926 with the objective of conducting theoretical studies and their application to special fields of chemistry. Before World War II, the activities were mostly led by professors from faculties of Kyoto University and directed toward the development of such new materials as colloidal metallic germicidal paints, glass fibers, ferroelectric ceramics, synthetic fibers, synthetic rubber and polyethylene. After World War II, the Institute chose to appoint full professors who could direct research there. Currently, the Institute consists of 26 laboratories involved in research in various fields of chemistry. The Institute has grown considerably, and its research activities required sophisticated facilities. The research buildings at the original site at Takatsuki City in Osaka Prefecture became crowded and obsolete.

Under the circumstances and in accordance with the policies of Kyoto University to concentrate its five Institutes of Natural Science in one location, the Institute moved to the present buildings in Uji, near Kyoto, in May 1968.

The Institute provides research opportunities for graduate students through association with several graduate schools at Kyoto University. Currently, 13 laboratories of the institute are affiliated with the Graduate School of Science, 9 with Engineering, two with Agriculture and two with the Pharmaceutical Sciences. The



Uji Campus (May, 1989)



Kyomizu-dera

laboratories contribute to graduate studies through lectures by their staff at the graduate school as well as through the supervision of their thesis research and providing their facilities. The Institute publishes its own memoirs, *The Bulletin of the Institute for Chemical Research of Kyoto University*, a bimonthly magazine.

The Laboratory of Fundamental Materials Properties is associated with the Division of Industrial Chemistry and with the Department of Polymer Chemistry of the Faculty of Engineering of Kyoto University. An important group in this laboratory includes Professor Keisuke Kaji, Associate Professor Toshiji Kanaya and Instructor Koji Nishida. Their interest is in Physico-Chemical Studies of Macromolecules with the objective of obtaining a clear understanding

of the interrelation between structure and properties of polymeric materials and composites, including: molecular motion of macromolecules in solution using dynamic light scattering; viscoelasticity of polymeric substances and composites; conformation and molecular motion in crystalline and amorphous polymers using NMR and neutron scattering techniques; small angle X-ray and neutron scattering of polyelectrolyte solutions; permselectivity of polymer membranes to separate gas mixtures; high-resolution solid-state NMR studies of multi-phase polymer materials.

Another laboratory, the Laboratory of Polymer Separation and Characterization, is headed by Professor Takeaki Miyamoto, assisted by Associate Professor Takeshi Fukuda, Lecturer Hidematsu Suzuki, Instructors Yoshinobu Tsujii and Masahiko Minoda. The research activities can be classified into three categories: science of separation and characterization of polymer molecules; physical chemistry of polymer solutions and solids; molecular and functionality conversion of naturally occurring polymers, particularly studies of new separation techniques, preparation of new types of polymer alloys and composites and their structure-function relationships.

The Laboratory of Polymer Crystals is headed by Professor Ken-ichi Katayama assisted by Associate Professor Akiyoshi Kawaguchi and Instructor Masaki Tsuji. This "koza" is basically interested in polymer physics and polymer physical chemistry. The research activities concentrate mainly in the field of structural and morphological studies of polymers in their solid state. Some recent research projects are as follows: observation of molecular images of polymer crystals by high-resolution electron microscopy; epitaxial crystallization of molecules on oriented polymer films; shear-induced crystallization in relation to crystallization kinetics and structural formation; deformation processes of polymers studied with X-ray TV systems.

Radiation Chemistry is being investigated at the *Research Reactor Institute* by Professor Hitoshi Yamaoka and Associate Professor Tomochika Matsuyama. At the *Research Center for Biomedical Engineering*, Professor Yoshito Ikada and Associate Professor Toshio Kayashi are studying Biomaterials; Professor Toshiro Masuda and Instructor Kiroko Sato are interested in Bioengineering.

Other laboratories at the Institute for Chemical Research in Uji are involved in Nuclear Radiation, Radiochemistry, Surface Chemistry, Crystal and Powder Chemistry, Dielectrics, Ceramic Chemistry, Solid State Chemistry, Organic Unit Reaction, High Pressure Chemistry, Petroleum Chemistry, Fundamental Material Properties, Molecular Designs for Physiological Functions, Physical Chemistry of Enzymes, Plant Product Chemistry, Microbial Biochemistry, Cancer Drug Research and Molecular Biology.

A total of 28 professors, 23 Associate Professors and 45 Instructors and Lecturers are presently active in the Institute. Currently, 70 students are working in the Master's Program and 37 in the Doctoral Program.