Department of Macromolecular Science

Macromolecular Science was born in the middle of the last century and made rapid progress in the last several decades to fill the gap between traditional disciplines and to meet the practical needs of the new era. However, macromolecular science is not a mere extension of chemistry or physics but stands at the crossroads of chemistry, physics, and life science. Especially, macromolecular science has been regarded as an important field of science for understanding of biological phenomena at a molecular level. Macromolecules are known as a typical complex system and have recently attracted the great interest of many scientists in the field of physics. Thus, macromolecular science must be one of the most important fields of natural science in this new century.

There are several universities having departments of macromolecular science in Japan. However the department of macromolecular science of Osaka University is unique in the sense that it belongs to the graduate school of science. The others belong to the faculty of engineering, aiming at practical applications. This indicates that the objective of our department is basic research on macromolecules. The department consists of four major research groups: there are a total of ten laboratories covering major subjects of the macromolecular science as described below. The staffs of each laboratory are famous over the world.

The department is active in international exchange. Many leading scientists of macromolecular science visit our department. The department organizes the international symposium named as "Osaka University Macromolecular Symposium" (OUMS) every two or three years. Of course there are many foreign students.

The macromolecular science course devotes itself to training graduate students by offering a systematic lecture course in macromolecular chemistry and physics. It also guides students by making them engaged in basic researches at one of the ten laboratories. Through their graduate studies, students acquire various professional knowledge and techniques leading to the degrees of the master or doctor of science.

Research Group of Polymer Synthesis and Reaction Chemistry

In order to create new polymer materials with special functions and/or excellent properties, similar to biopolymers, the Laboratory of Polymer Synthesis aims to investigate new ideas and methods which allow us to control the structure and the molecular weight of these polymers in a precise manner. For example, this group could find out the highly selective living polymerization system with no side reactions through the research on the cationic polymerization reaction mechanism. As a result, it is now possible to produce various types of polymers such as polymers with homogeneous chain length and structure, polymers with special shape or unique properties, polymers which are highly sensitive to external stimulus, etc.

In the Laboratory of Macromolecular Reaction Chemistry, a wide variety of studies on syntheses and functionalization of macromolecules has been done based on macromolecular science, coordination chemistry and organometallic chemistry. Unique reactivity of metal complexes is applied to development of a new polymerization catalyst and precise design of macromolecular complexes. Metalloenzyme can be recognized as a representative example of functional biomacromolecules incorporating metal complexes. To understand the mechanism of metalloenzyme function, synthesis and structural characterization of a model of active site and non-natural peptides are investigated.

Research Group of Structure, Function, and Properties of Polymers

Polymer chain molecules have a large number of the internal degrees of freedom and sometimes form higher-order structures. They can easily respond to the change of external fields such as mechanical and electric fields by changing their internal structures. This is a common feature of “soft matters” including micelles, liquid crystals, supramolecules, and so on. The laboratory of Polymer Physical Chemistry investigates physicochemical and rheological properties of the soft matters through viscoelastic, dielectric, rheo-optical, and nuclear magnetic resonance relaxation meaaasurements in order to elucidte the nature of macromolecules.

Molecular recognition by macromolecules plays an important role, for example, in substrate specificity of enzymes and antigen-antibody reactions in human life. Selective molecular recognition among macromolecules is achieved through a large number of weak interactions. Monoclonal antibodies can recognize a larger and complicated compound with high specificity. The Laboratory of Functional Polymer Chemistry constructs functionalized sensing, catalytic, and energy conversion systems by utilizing monoclonal antibodies. We also develop novel materials through hybridization of bio-related macromolecules with synthetic molecules.

The Laboratory of Supramolecular Science discovered the formation of complex between polymer chains and cyclodextrins, which has a necklace-like structure. The factors governing this complex formation were investigated by X-ray diffraction, NMR, and so on. This study is now being developed as a so-called supermolecular science. They succeeded also in the artificial construction of supramolecular structures on the binding of antibody to antigen. They try to build supramolecular structures using transition metal catalysis, which should show quite new functions.

Research Group of Macromolecular Assemblies

Any small change in the primary structure may lead to some serious effect on its higher structural hierarchy. For example, lack of vitamin C causes the fatal disease “scurvy” because that stops formation of normal collagen fiber. That is, without vitamin C, no hydroxylation of proline takes place and thereby no further stabilization of collagen fiber. The Laboratory of Macromolecular Structure aims to elucidate the relationship between structure and physical properties (or functions) of macromolecules at atomic resolution using X-ray diffraction, neutron scattering and infrared and Raman spectroscopy.

Polymers bearing functional groups of strong attractive interactions like the hydrophobic and ionic interactions as well as hydrogen bonding form various types of polymer aggregates to exhibit unique properties and functions. Basic understanding of these polymers is important in the fields not only of polymer industry but also of molecular biology. The Laboratory of Polymer Assemblies investigates interrelation among the chemical structure, self-associating structure, and properties of polymer aggregates in solution. Currently this laboratory studies amphiphilic polyelectrolytes, intra- and intermolecularly hydrogen-bonding polymers, polymer living anions, helical polymers, and so on.

Research Group of Informative Polymer Science

Laboratory of Protein Folding: Protein folding is a process in which an extended polypeptide chain acquires a unique folded conformation with biological activity. Laboratory of Protein Folding is investigating the mechanism of protein folding and misfolding to improve our understanding of the structure and function of proteins. This topic is also important for understanding of many critical biological processes and disease states because these involve protein misfolding such as amyloid fibril formation. We are studying the mechanism of protein folding and misfolding with various approaches including spectroscopies (NMR, fluorescence, CD), physicochemical measurements (calorimetry, analytical ultracentrifugation) and fluorescence microscopy.

Laboratory of Protein Crystallography: In 1959 the lab was established as the division of Protein Crystallography to elucidate the molecular structure of proteins by X-ray crystallography. Nowadays the X-ray method has become the most powerful tool to determine protein structures. One of our aim is to spread the application of this method throughout biological science. Current research projects are focused on biological macromolecular assemblies and membrane proteins. Especially, our lab is interested in studying the structure and function of biological energy transducing proteins, such as photosynthetic electron transfer complex and microtubule dynein motor.

The aim of the Laboratory of Supramolecular Crystallography is to elucidate the structure of biological macromolecules and biological macromolecular assemblies to understand their functions based on the atomic structures. X-ray crystallography is one of the most powerful tools for structure determination of biological macromolecules and biological macromolecular assemblies, and we are also working on the development of new technologies and methodologies of protein crystallography, including the synchrotron radiation beamline at SPring-8.

Laboratory of Chemistry for Environment and Safety: Li ion battery has now become a fundamental device in our daily life. However, the use of organic solvents and very high energy density in Li ion batteries introduce the battery include dangerous hazards such as ignition accidents. In this laboratory, we are developing a new class of solid polymer electrolytes, named low-barrier ion conductive polymer electrolytes, for Li ion batteries to realize the safety of these batteries. In addition, this laboratory aims at developing new photo-chemical energy conversion system. As the laboratory belongs to the department for the administration of safety and hygiene, we carry out the research projects to contribute to the safety of science and technology, together with the activity for maintaining the safety level of university research work and experiments.

E-mail Addresses of the staffs.

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Department of Macromolecular Science

Laboratory of Polymer Synthesis

Members Sadahito AOSHIMA (Professor), Shokyoku KANAOKA (Associate Professor), Arihiro KANAZAWA (Assistant Professor)

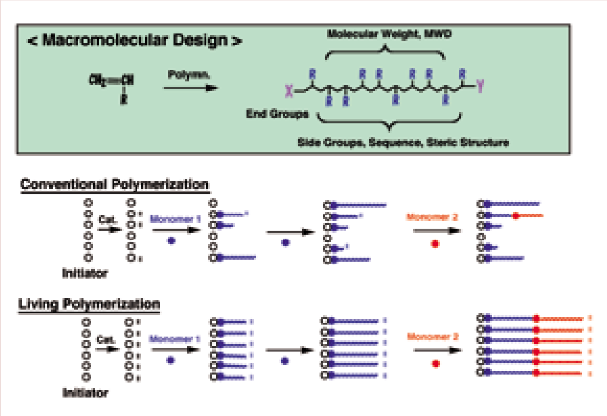
Home Page http://www.chem.sci.osaka-u.ac.jp/lab/aoshima/e_index.html

[Research Projects]

Recently, well-designed stimuli-responsive polymers have attracted much interest as precursors of advanced polymer materials such as nano-organized self-assemblies, intelligent hydrogels, and DDS. In particular, recent progress in living polymerization has encouraged us to design various types of block copolymers in order to examine their stimuli-induced self-association. We have prepared a variety of functional polymers with well-controlled structures and molecular weights by living cationic polymerization in the presence of an added base. On the basis of these results, we have designed a new strategy for preparing block copolymers with various types of stimuli-responsive properties such as thermosensitive physical gelation.

[Research Area]

1) Syntheses of well-defined polymers with various characteristic properties by living cationic polymerization.
2) Syntheses of advanced stimuli-responsive block copolymers.
3) Investigation of polymerization mechanism and design of novel living polymerization.



Concept of macromolecular design and living polymerization for syntheses of well-designed stimuli-responsive polymers

Department of Macromolecular Science

Laboratory of Macromolecular Reaction Chemistry

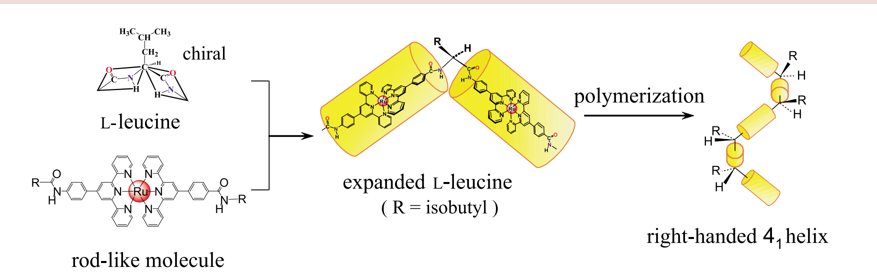
Members Kiyotaka ONITSUKA (Professor), Taka-aki OKAMURA (Associate Professor), Naoya KANBAYASHI (Assistant Professor)

Home Page http://www.chem.sci.osaka-u.ac.jp/lab/onitsuka/en/

[Research Area]

Our research involves the development of new polymer synthesis and functionalization incorporating a characteristic feature of metal elements. For example, precise design of new transition metal complexes and investigation of their reactivity lead to the development of new polymerization catalysts. Functionalization of polymers based on the control of molecular structure is investigated by using the methodology of organic synthesis. Our research interest is also focused on metalloenzyme. Model complexes of active sites and non-natural peptide are designed and structurally characterized.

1) Development of new organometallic polymerization catalysts and their application to synthesis of functional polymers
2) Functional macromolecular complexes composed of organometallic units
3) Investigation of the reactivity controlling mechanism in the active center of metalloenzyme using model complexes having simple ligands and/or short peptides.
4) Synthesis of non-natural amino acid polymers for higher order structure formation and expression of novel functions.



Department of Macromolecular Science

Laboratory of Polymer Physical Chemistry

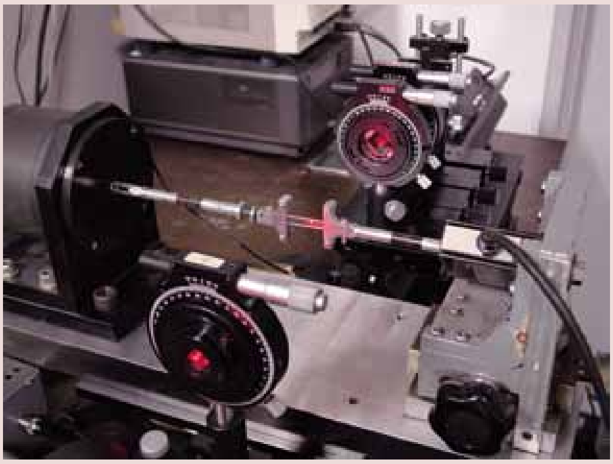
Members Tadashi INOUE (Professor), Osamu URAKAWA (Associate Professor)

Home Page http://www.chem.sci.osaka-u.ac.jp/lab/inoue/index_Eng.html

[Research Projects]

1) Shear induced structures of soft matters.
2) Nonlinear rheology and rheo-optics of polymer solids.
3) Molecular motions of hyper-branched polymers.
4) Structure and molecular motions of supramolecules.
5) Hydration and molecular motions of water-soluble polymers.
6) Structure and dynamics of polymer composites.

Soft matter stands for soft materials including polymers, liquid crystals, suspensions, and self-assembling molecules which form a large mesoscopic structure much larger than atoms. Soft matters are “soft” and therefore they can easily respond to external fields like strain fields, flow fields, electric fields and so on, and sometimes show drastic structural changes. We have been studying their unique physicochemical properties, particularly nonlinear responses under strong external fields, in addition to their fruitful equilibrium properties and dynamics. Our research is focused on molecular interpretation of rheological phenomena of polymers and micelles as a model system of soft matter.



Department of Macromolecular Science

Laboratory of Functional Polymer Chemistry

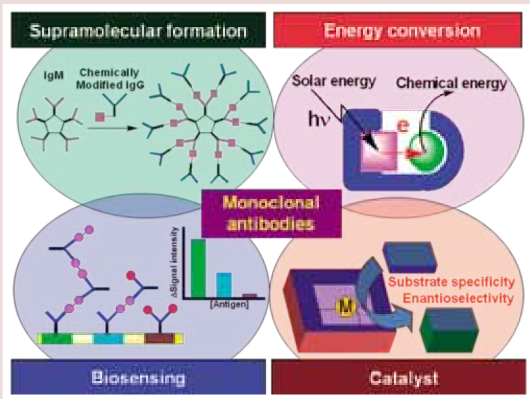
Members Hiroyasu YAMAGUCHI (Professor)

Home Page http://www.chem.sci.osaka-u.ac.jp/lab/yamaguchi/english/index.html

[Research Projects]

1) Development of a high performance sensing element.
2) Construction of energy conversion and catalytic systems using hybrids of biomacromolecules with synthetic molecules.
3) Creation of functionalized materials based on self-assembly of bio-related and/or synthetic polymers.

In biological systems, life process is led by the unique behavior of macromolecules such as proteins and DNA. Molecular recognition by macromolecules plays an important role, for example, in substrate specificity of enzymes and antigen-antibody reactions in human life. Selective molecular recognition among macromolecules is achieved through a large number of weak interactions. We have focused our attention on the special behavior of antibodies, especially monoclonal antibodies, because they can recognize a larger and more complicated compound with high specificity than that can synthetic host molecules or enzymes. In this laboratory, we develop novel materials through hybridization of bio-related macromolecules such as monoclonal antibodies with synthetic molecules. We construct functionalized sensing, catalytic, and energy conversion systems via specific molecular recognition of biomacromolecules and selective assembly of bio/synthetic molecules.



Functionalized antibodies

Department of Macromolecular Science

Laboratory of Supramolecular Science

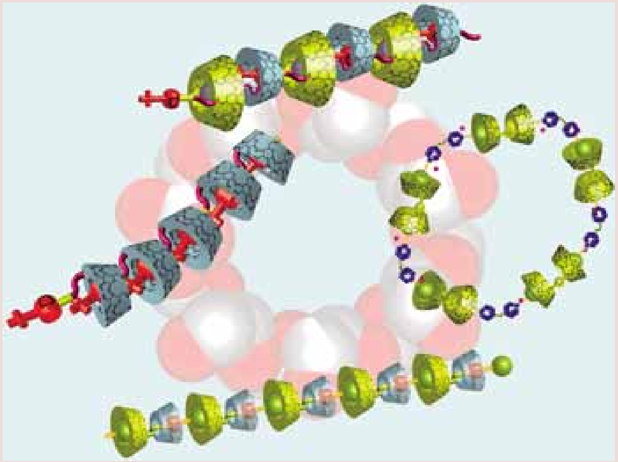
Members Akira HARADA (Professor), Yoshinori TAKASHIMA (Assistant Professor)

Home Page http://www.chem.sci.osaka-u.ac.jp/lab/harada/eng/

[Research Area]

1) Construction of supramolecular structures using cyclic and linear building blocks.
2) Synthesis of interlocked compounds, such as rotaxanes, catenanes, polyrotaxanes.
3) Construction of supramolecular structures by antigen-antibody interactions. (ex. Antibody dendrimers)
4) Preparation of catenanes using macrocyclic DNA (plasmid).
5) Synthesis of new polymers by organometallic catalysts.

As atoms can be put together to form molecules, molecules can also be put together to give supramolecules. Interactions between molecules give characteristic features of materials, and create unique properties and structures of living creatures. This group (supramolecular science group) is aiming at creation of unique compounds or materials using interaction between molecules (low molecular weight compounds, polymers, biopolymers).



Department of Macromolecular Science

Laboratory of Macromolecular Structure

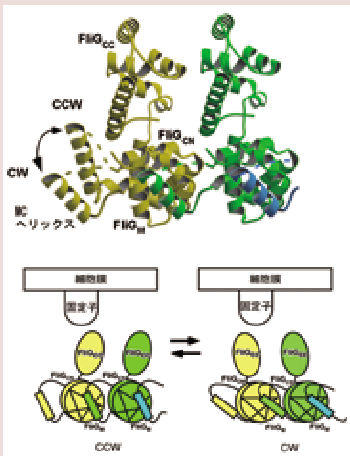
Members Katsumi IMADA (Professor), Fumitoshi KANEKO (Associate Professor), Tatsuya KAWAGUCHI (Assistant Professor)

Home Page http://www.chem.sci.osaka-u.ac.jp/lab/imada/en/index.html

[Research Area]

Biological process is driven by complex molecular machines composed of biological macromolecules. The flagellum, which is an organelle for bacterial motility, is one of those molecular machines. The flagellum is a huge protein assembly composed of a helical filamentous screw, a molecular universal joint, a highly efficient ion-driven motor and a protein export apparatus for self-construction. The Laboratory of Macromolecular Structure aims to proved fundamental understanding of operating principles and the self-assembly mechanism of biological macromolecular machines, such as the bacterial flagellum, through the studies of molecular structure at atomic resolution and reconstitution of the molecular machines. We also study structures of polymer complexes with low molecular weight compounds and the relationship between their structures and functions.

1) Rotational mechanism of the bacterial flagellar motor.
2) Self-assembly mechanism of the bacterial flagellar motor.
3) Structural and functional studies on bacterial protein secretion systems
4) Structural and functional studies on environmental sensing units of bacteria.
5) Study on the structure of polymer complex with small molecule and its formation mechanism.



A plausible model for rotational switching in bacterial flagella.

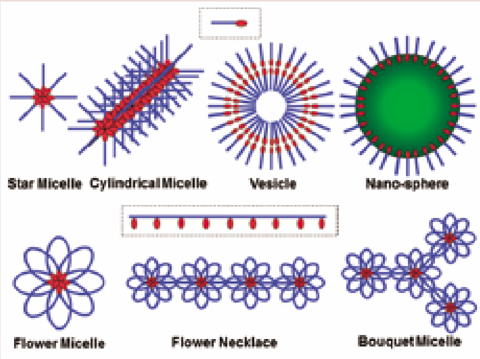
Department of Macromolecular Science

Laboratory of Polymer Assemblies

Members Takahiro SATO (Professor), Akihito HASHIDZUME (Associate Professor), Ken TERAO (Assistant Professor)

Home Page http://www.chem.sci.osaka-u.ac.jp/lab/sato/index-e.html

Polymers often form aggregates in solution and polymer aggregates play important roles in industries of foods, cosmetics, paints, and pharmaceutics, as well as in living cells where proteins and nucleic acids associate and dissociate during biochemical reactions. Polymer aggregates, or polymer assemblies, usually take very complex conformations and their characterization is not easy. Our group aims at understanding the structures and properties of polymer assemblies through the following projects.



[Research Projects]

1) Syntheses of novel associating polymers with strong attractive interactions, like amphiphilic polyelectrolytes, random copolymers bearing carboxyl and amide (or amino) groups, etc.
2) Establishment of methods for characterizing polymer conformation in aggregates, self-associating structure, and interaction among polymer aggregates, by using light scattering, fluorescence, NMR, size-exclusion chromatography, viscosity, ultracentrifuge, and so on.
3) Interpretation of various properties of associating polymer solutions, like viscosity, liquid crystallinity, circular dichroism, reaction kinetics, and interaction with functional molecules, in terms of self-associating structure and intermolecular or inter-aggregate interaction.

Department of Macromolecular Science

Laboratory of Protein Folding

(Institute for Protein Research)

Members Yuji GOTO (Professor), Hisashi YAGI (Assistant Professor)

Home Page http://www.protein.osaka-u.ac.jp/physical/

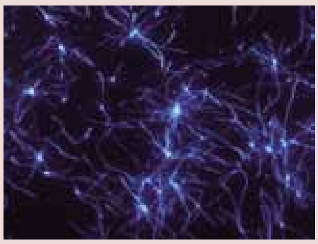
[Current Research Programs]

1) Observation of folding processes and clarification of the mechanism of protein folding.
2) Analysis of structural stability and dynamics of protein molecules.
3) Analysis of structural stability and the mechanism of formation of amyloid fibrils.

Protein folding is a process in which an extended polypeptide chain acquires a unique folded conformation with biological activity. However, the exact molecular mechanism remains unknown. Clarifying the mechanism of protein folding is essential to improve our understanding of the structure and function of proteins. It is also important to design engineered proteins with improved functions.

Moreover, protein folding plays important roles in many biological phenomena. For an example, the deposition of amyloid fibrils has been suggested to play a central role in over 20 degenerative disorders including Alzheimer's and prion diseases. Because the amyloid fibril deposition is often caused by misfolding of an originally functional protein, these diseases are called “folding disease”. In order to establish therapeutic treatments, clarifying the molecular mechanism of folding diseases is essential.

We are studying the conformational stability of proteins, molecular basis of folding reaction, and structures and formation of amyloid fibrils. These studies are performed using various observation methods, including spectroscopies (NMR, CD, IR), physicochemical methods (calorimetry, ultracentrifugation), and fluorescence microscopy, as well as gene manipulations for recombinant proteins by using the *E.coli* and yeast expression systems.



An image of amyloid fibrils of amyloid-β peptide obtained using total internal reflection fluorescence microscopy.

Department of Macromolecular Science

Laboratory of Protein Crystallography
(Institute for Protein Research)

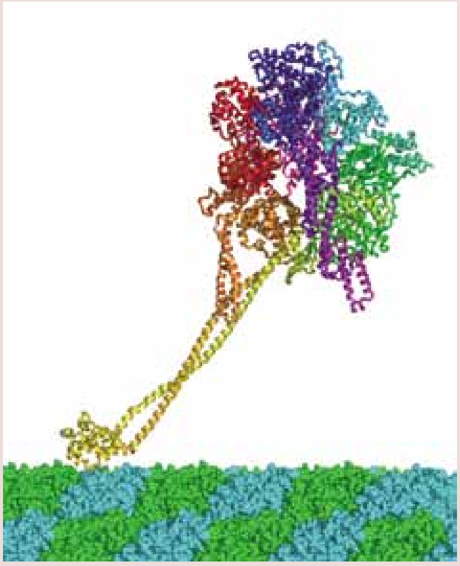
Members Genji KURISU (Professor), Hideaki TANAKA (Assistant Professor)

Home Page http://www.protein.osaka-u.ac.jp/crystallography/EngHP/

[Research Interests]

1) Structural studies of photosynthetic energy-transducing membrane protein complex and related redox enzymes
2) Crystal structure analyses of dynein motor
3) High resolution structural analysis of rat liver vault

Three-dimensional protein structure brings us a deeper insight into the biological function. X-ray crystallography is the best method to determine atomic coordinates of protein molecules. The main aim of our group is the X-ray structure determination of the biological macromolecular assemblies including membrane protein complexes, in order to elucidate the molecular mechanism of the highly organized biological processes at atomic level.



Crystal Structure of the dynein motor domain

Department of Macromolecular Science

Laboratory of Supramolecular Crystallography
(Institute for Protein Research)

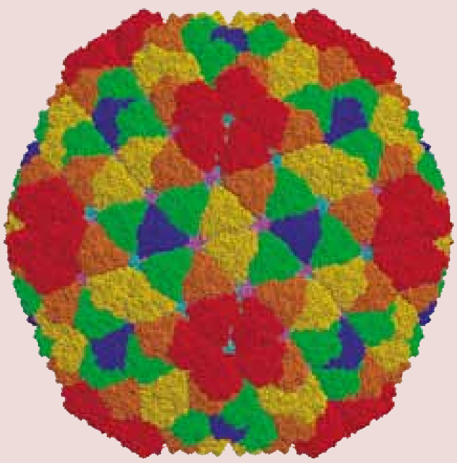
Members Atsushi NAKAGAWA (Professor), Mamoru SUZUKI (Associate Professor), Eiki YAMASHITA (Assistant Professor)

Home Page http://www.protein.osaka-u.ac.jp/rcsfp/supracryst/index.html

[Current Research Projects]

1) Operating a synchrotron beamline for biological macromolecular assemblies at SPring-8.
2) Developing a new crystallographic techniques for structure determination of biological macromolecular assemblies.
3) Structural studies of biological macromolecules and biological macromolecular assemblies.
4) Structural studies on proteins working in brain and nervous system.

Macromolecule assemblies, consisting of proteins, nucleic acids, and other substances, play key roles in all living system. Our laboratory works on structure determination of biological macromolecular assemblies using X-ray diffraction technique. Development of tools for X-ray crystallography of biological macromolecular assemblies, including the synchrotron radiation beamline at SPring-8, is also one of our main works.



Department of Macromolecular Science

Laboratory of Chemistry for Environment and Safety

(Department for the administration of safety and hygiene)

Members Hitoshi YAMAMOTO (Professor), Kengo TOMITA (Associate Professor)

Home Page http://www.osaka-u.ac.jp/jp/facilities/anzen/kankyou/

[Research Projects]

1) Development of low barrier ion conductive polymer electrolytes.
2) Development of the photo-switching functional molecules.
3) Development of detection methods for environmental chemicals.
4) Construction of education system for realization of safety concious culture in the university.
5) Research and analyses of university accidents in the world.

This laboratory belongs to the department for the administration of safety and hygiene, whose mission is managing safety and hygiene of all people constituting the university. The research in this laboratory aims to contribute to the safety of wide area in science and technology.

At present, our research projects focus on development of new functional molecules such as low barrier ion conductive polymers for the safety of Li ion batteries, photo-switchable hydrogen bonds for environmental chemistry, etc.

In addition, our laboratory proposes safe methods and techniques for conducting research and experiments through investigation and analyses of university accidents in the world.