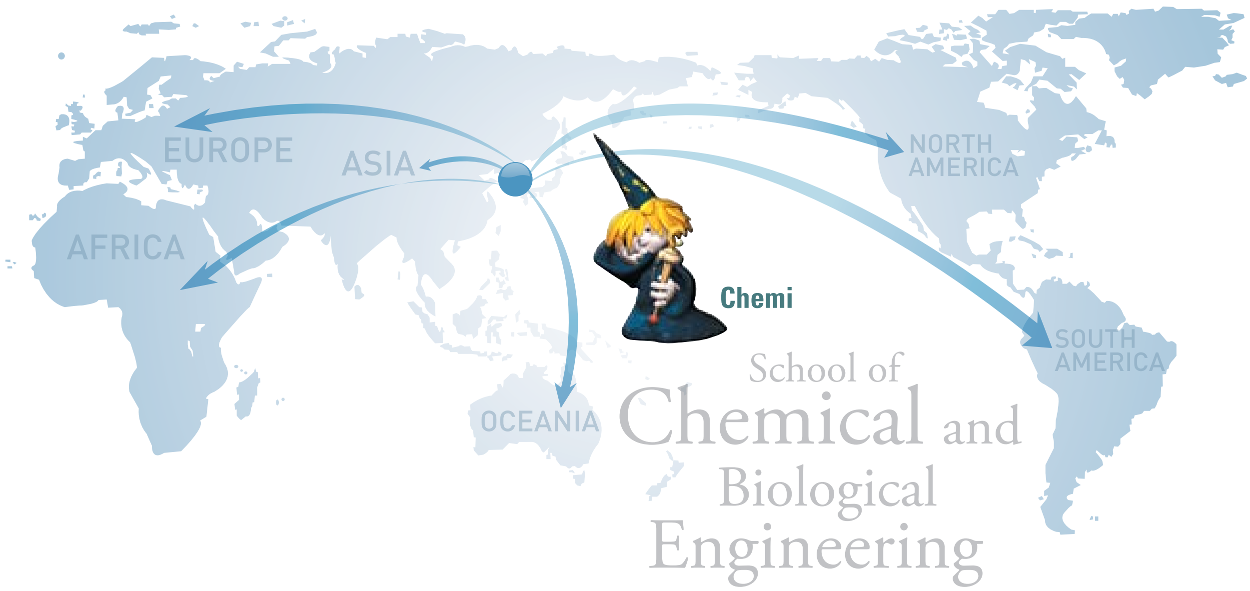
SCHOOL OF CHEMICAL AND BIOLOGICAL ENGINEERING

From the Premier National University to the World-Class University for 21st Century

http://cbe.snu.ac.kr

Contents



Vision

The vision of the School of Chemical and Biological Engineering (CBE) of Seoul National University is to nourish students for creative global leaders with entrepreneurial minds. In addition, we strive to provide world-class education and research opportunities in order to cultivate responsible leaders in all the areas related to chemical and biological engineering.

Educational Goal

- First, the CBE aims to fosters next generation of leaders all areas related to chemical and biological engineering.
- Second, the CBE aims to provide fundamental engineering and basic science disciplines to educate and train as world-class engineers.
- Third, the CBE strives to provide students with education curriculums that are designed for rational and creative thinkings in order for them to solve real-world engineering problems.
- Fourth, the CBE guides students to have relevant work ethics as well as social responsibility for international competitiveness.

SNU

From the Premier National University to the World-Class University for 21st Century

COLLEGE OF ENGINEERING

SCHOOL OF CHEMICAL AND BIOLOGICAL ENGINEERING

History

October 15, 1946

Seoul National University was first founded with 9 Colleges.
Department of Chemical Engineering was established as
one of the 9 engineering departments.

December 16, 1963

Department of Applied Chemistry was established.

February 28, 1975

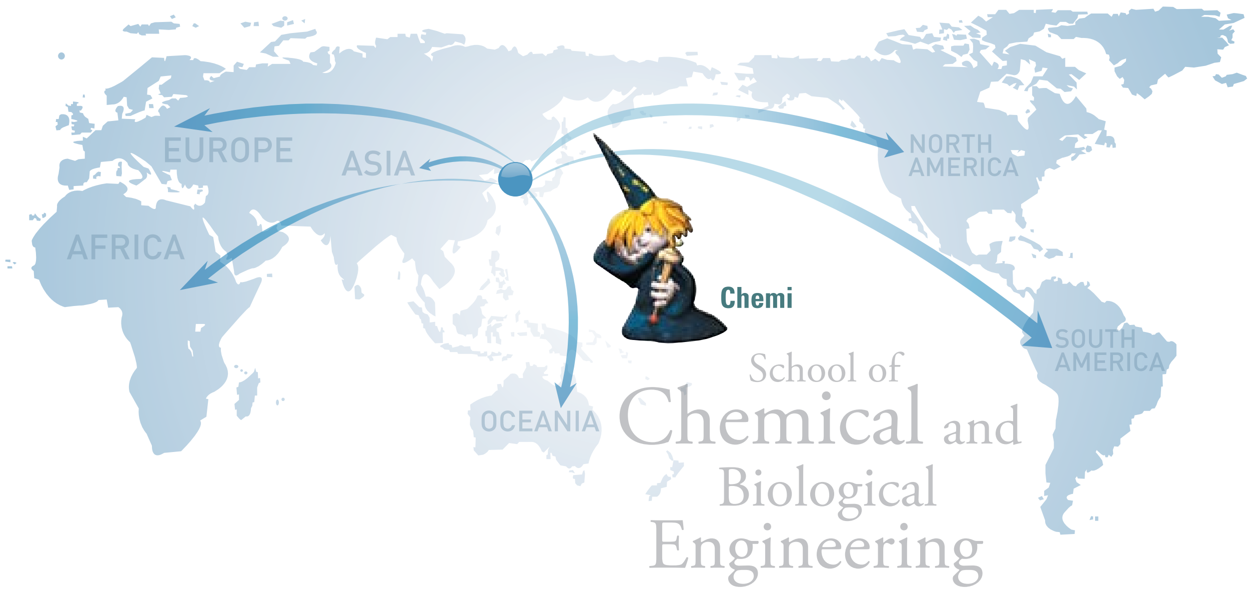
Department of Applied Chemistry was abolished.
Department of Chemical Technology was established.

September 10, 1998

Department of Chemical Engineering and Department of Chemical
Technology were integrated into the School of Chemical Engineering.

February 28, 2005

School of Chemical Engineering was renamed as
the School of Chemical and Biological Engineering.



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Seoul National University

Founded in 1946 as the first National University in Korea, Seoul National University (SNU) has been the undisputable leader of higher education in Korea. Over 260,000 SNU alumni play leading roles in every sector of Korean society, ranging from business, politics, science, and technology to arts. More than one-third of CEOs in the top 500 companies in Korea and 44% of the ministers and vice-ministers of Korean government are the SNU graduates.

The University consists of sixteen colleges and ten professional schools. More than 3,500 full-time faculty members have dedicated themselves to research and education on 16,000 undergraduate students as well as over 11,000 graduate students. SNU has gained the reputation of being the international institution by partnering with many renowned universities around the world.
As of 2016, the university has signed more than 500 academic exchange agreements with Universities and institutions in 40 different countries.

College of Engineering

The Seoul National University College of Engineering fosters future global leaders, promotes the values of civilized society and sustainable development, and conducts unparalleled outstanding research to serve the people of Korea as well as the world.

The College of Engineering is composed of 11 departments, whose comprehensive curricula emphasize creativity, engineering fundamentals, problem-solving skills and management skill/business mind. Within the college, there are 13 research institutes focusing on both theory and practical applications while working closely with top institutions in other countries. Furthermore, there are twenty research centers aiming at providing fundamental knowledge for industry. The graduate schools provide research-oriented academic programs. Within these schools, departments cover various branches of engineering disciplines. Research conducted here at the College is currently well recognized by many evaluation standards through top-notch publications as well as international exchange programs with many renowned foreign universities and research institutes.

School of Chemical and Biological Engineering

CBE

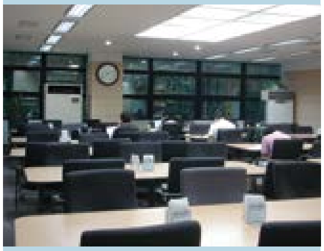
School of chemical and Biological Engineering has so far produced the many industries and academic leaders in Korea. Since the beginning of our department, the CBE has been admitting only the top 1% of high school graduates in Korea. About 15% of top executives of all major chemical engineering-related corporations in Korea are the alumni of our department.

The School of Chemical and Biological Engineering is currently focusing on the development of revolutionarily new engineering technologies that would dramatically change the society and strongly influence chemical and biological engineering industries. Major areas of interest include nanostructured inorganic materials, electrochemical materials, catalysis, rheology, transport phenomena, green chemistry, environmental technology, process systems engineering, semiconductor materials, display materials, energy materials, biotechnology, biomedical engineering, next-generation polymers, and fine chemical synthesis. Current research programs seek to develop the convergence technology through the combination of different disciplines such as nanotechnology (NT), environmental technology (ET), biotechnology (BT), and information technology (IT).

Pride and Prestige

As the Undisputable
Leader of Higher Education

Education & Research Facilities



The School of Chemical and Biological Engineering is now located in the new engineering building premises (Building 302). The School takes pride in its best facilities including 32 faculty offices, 55 laboratories and a digital departmental library.

Facilities

Professor Office	963.04m^2
Administration Office	325.87m^2
Lecture Rooms & Undergraduate Laboratories	2,064.40m^2
Remote Video Lecture Room(s)	88.02m^2
Research Laboratories	7381.3m^2
Library	466.22m^2
Lounge	54.28m^2
Public Center for Research Facilities	227.22m^2
Total	**8,468m^2**

Research Equipments

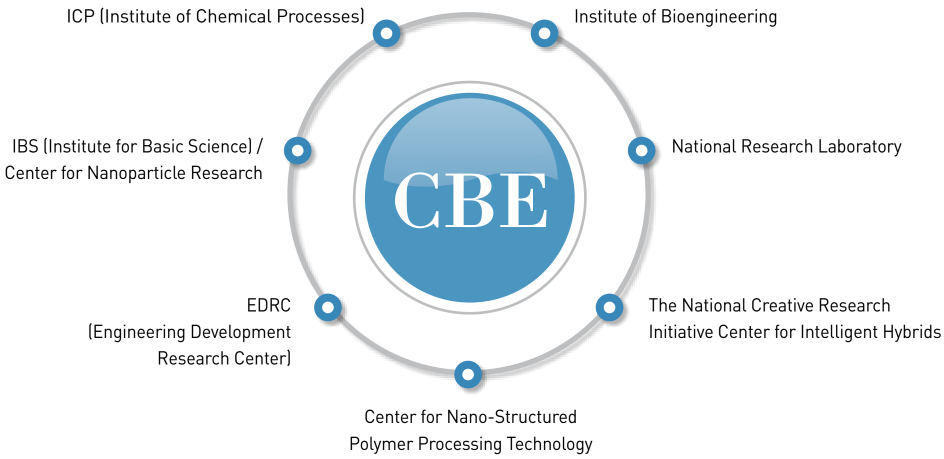
Department Common Equipment

AFM, BET, CLSM, FE-SEM, FT-IR, FT-NMR, GC/MS, GPC, HPLC, RAMAN, TGA/DSC, XPS, XRD, EA, ICPS, etc.

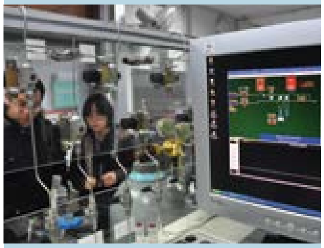
Plus More Cutting Edge Equipments in each Research Laboratory

Institutes & Research Centers Associated with the Department

The School of Chemical and Biological Engineering has several associated institutes and research centers aiming at leading chemical and biological engineering fields through the global networking as well as intimate communications with global industries.



Research Achievements



Indicators of International Competitiveness

SNU, School of Chemical and Biological Engineering

MIT, Department of Chemical Engineering

UC Berkeley, Department of Chemical Engineering

(2013)

The best BK21 program in Chemical Engineering

Two years in a row in 2007 and 2008

Global Standing

- **QS(Quacquarelli Symonds) World University Ranking, 2013**

  The School of Chemical and Biological Engineering, SNU, ranked as 17th in the world

- **Department Review by World-Renowned Scholars, 2007**

  The School of Chemical and Biological Engineering at SNU was rated as top 20 chemical engineering program in the world.

  Howard Ted Davis (Dean, University of Minnesota and the Chairman of the Review Committee) concluded: "Best Chemical and Biological Engineering Program in the Asian-Pacific region"

Curriculum

The curriculum of School of Chemical and Biological Engineering has been designed to teach engineering fundamentals and to conduct creative research related to the disciplines of Chemical and Biological Engineering.

Undergraduate Curriculum

Grade / Semester	1	2	3	4
Spring Semester	Fundamentals of Chemical and Biological Engineering*	• Physical Chemistry 1* • Engineering Biology* • Organic Chemistry 1* • Basic Computer Methods in Chemical and Biological Engineering** • Analytical Chemistry**	• Chemical Reaction Engineering 1* • Process Fluid Mechanics * • Chemical and Biological Synthesis Lab * • Chemical and Biological Process Lab * • Chemical Engineering Thermodynamics • Polymer Chemistry	• Introduction to Quantum Mechanics • Process and Product Design • Introduction to Catalysis • Introduction to Environmental Engineering • Properties of Polymers • Biochemical Engineering • Instrumental Analysis • Seminar *** • Undergraduate Research • Field Applications of Engineering Knowledge
Fall Semester		• Physical Chemistry 2 ** • Elementary Lab. For Chemical and Biological Engineering * • Organic Chemistry 2 * • Applied Biochemistry *	• Heat and Mass Transfer * • Chemical and Biological Synthesis Lab * • Chemical and Biological Process Lab * • Process Control and Design ** • Inorganic and Materials Chemistry • Separation Processes	• Chemical Reaction Engineering 2 • Organic Chemistry for Fine Chemicals • Environmental Biotechnology • Electrochemistry • Molecular Biochemical Engineering • Computer Applications in Chemical Engineering • Cell Biotechnology • Management in Chemical Industries *** • Undergraduate Research • Field Applications of Engineering Knowledg

* Compulsory major subjects, ** elective major subject(s), students are allowed to choose 2 out from 4 subjects
*** elective major subject(s), students are allowed to choose 1 out from 2 subjects
**** elective major subject(s), students are allowed to choose 1 out from 2 subjects

Graduate Curriculum

Major	Process System Eng.	Inorganic & Semiconductor	Organic& Polymers	Bioengineering & Environment	Etc.
Subjects	• Transport Phenomena * • Molecular Thermodynamics * • Advanced Chemical Reaction Engineering • Process Dynamics and Control • Chemical Engineering Mathematics • Numerical Methods in Chemical Engineering • Mass Transfer • Polymer Rheology • Modelling and Simulation of Chemical Processes • Process Synthesis • Polymer Processing	• Advanced Electrochemistry * • Advanced Surface Chemistry * • Chemical Processes in Semiconductor Fabrication • Energy Engineering • Catalyst Engineering	• Bioorganic Chemistry * • Synthesis of High Polymers * • Structures and Properties of Polymers • Advanced Organic Chemistry for Fine Chemicals • Topics on Polymeric Materials • Interfacial Engineering in Polymers • Polymeric Reactions • Advanced Organic Synthesis	• Biological Reaction Engineering * • Advanced Environmental Engineering * • Bioseparation Engineering • Advanced Molecular Biochemical Engineering • Protein Engineering • Advanced Biochemical Engineering • Advanced Nanobiotechnology • Enzyme Engineering	• Management of Safety, Environment and Health in Energy Industry • Topics in Process and System Engineering • Topics in Inorgarnic Material and Semiconductor Process • Topics in Fine Chemicals and Polymeric Materials • Topics in Biological and Environmental Engineering • Graduate Seminar for Chemical Engineers • Graduate Seminar • Reading and Research

* Core subjects

Career Path

Upon graduation, students from the School of Chemical and Biological Engineering enter many important sectors in academia, government and industry, playing leading roles in each sector.

2014-2016
Career path of Undergraduates

Classification	Industry	Graduate School	Others	Total
(%)	23%	43%	34%	100%
Number	68	127	99	294

2014-2016
Career path of Master`s Program graduates

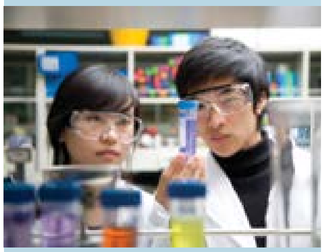
Classification	Industry	Public Offices	Graduate School	Others	Total
(%)	21%	2%	28%	49%	100%
Number	34	3	46	79	162

2014-2016
Career path of Doctoral Program graduate

Classification	Industry	Public Offices	Graduate School	Others	Total
(%)	33%	10%	11%	46%	100%
Number	50	14	17	70	151

Scholarships

The CBE offers a variety of scholarships to students. Approximately 70% of undergraduate students receive partial or full scholarships. SNU scholarship programs are mostly merit-based, but the university applies more generous criteria for international students. Almost all graduate students receive financial assistance from the BK 21 Plus Program.



Number of Scholarships Awarded

	Internal Scholarship (include National Grant type1,2)	External Scholarship
Fall 2014	152	124
Spring 2015	135	124
Fall 2015	126	118
Spring 2016	132	101

[unit: person]

Amount of Scholarship

	Internal Scholarship (include National Grant type1,2)	External Scholarship
Fall 2014	339,306	403,400
Spring 2015	273,361	428,937
Fall 2015	305,296	421,940
Spring 2016	274,132	354,744

[unit: thousand KRW]

Research Areas

From the premier national university in Korea to the world-class university, the efforts of SNU towards global prestigious school are already acknowledged by the world. Like generating the bright light in the darkness, the unceasing research and efforts towards the truth let SNU stand in line with the world top-class universities and now SNU's number of SCI article publications and the citation number are among the highest. In the research laboratories where light doesn't go off 24 hours, the world standard of knowledge is being rebuilt.

Process Development

Inorganic Nanomaterials

Flow Control

Catalysts

Semiconductor & Electrochemistry

Biotechnology

Environmental Technology

Organic Synthesis & Fine Chemicals

Polymers

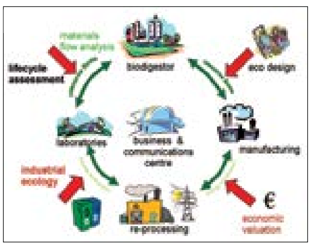
Process Development

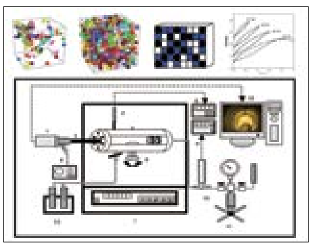
Research summary

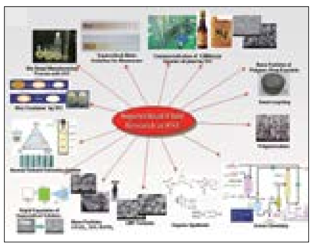
Researchers in the area of Process Development are focused on the analyses of complex process system involving unique reactions with diverse unit operations and processes as well as on the design, operation, and control of novel processes to reduce costs and improve efficiencies. In addition, technologies for renewable energy systems are under development to address the energy resources and environmental issues. Environmental process design and control for carbon capture and storage and engine exhaust after-treatment systems are under development for low and clean emissions.

Research topics

- Design, operation and control of chemical and energy processes
- Design, operation and control of next-generation secondary battery and fuel cells
- Design, operation and control of eco-industrial complexes
- Design, operation and control of batch processes
- Modeling and control of engine exhaust aftertreatment system
- Polymerization using supercritical fluids and application of supercritical fluid to fuel cell
- Development of Green Chemical Process using Supercritical Fluids
- Design of Nanoparticles/Nanocomposites using Supercritical Fluids
- Molecular dynamic simulations for thermodynamic property prediction







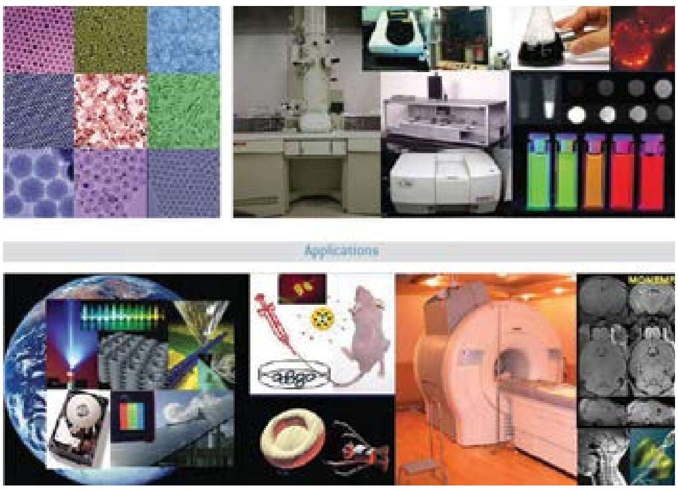
Inorganic Nanomaterials

Research summary

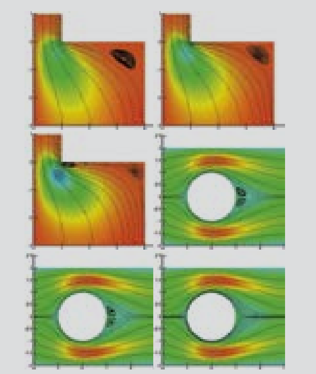
We synthesize new inorganic and inorganic/organic hybrid materials and develop new synthetic methodologies to discover novel materials. Our synthesis mainly focuses on complex metal chalcogenide and halide compounds. Our main interest at present is development of environmentally friendly and inexpensive photovoltaic and thermoelectric materials and their device fabrications. We are also interested in electronic and catalytic applications of our materials.

Research topics

- Development of energy generation materials for solar and thermoelectric applications
  - Design and synthesis of new inorganic and inorganic/organic hybrid materials
  - Device fabrications
- Development of new materials for electronic applications
- Solid state chemistry of complex inorganic solids
- Nonoxidic porous semiconductors
  - Photocatalysts/sensors
  - Nuclear waste/heavy metal remediation
  - Energy storage, gas separation/storage/conversion systems
- Nanochemistry of two-dimensional van der Waals materials
  - Design and synthesis of new heterostructured van der Waals materials
  - Electronics and optics



Flow Control

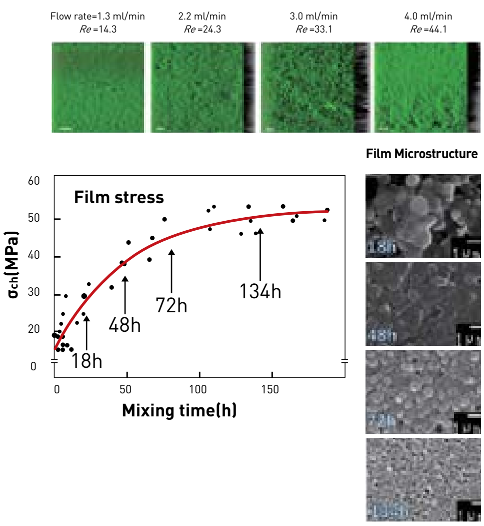


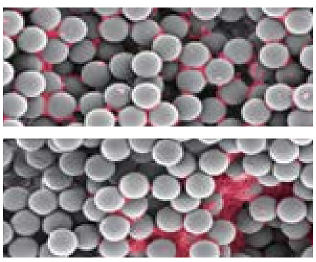
Research summary

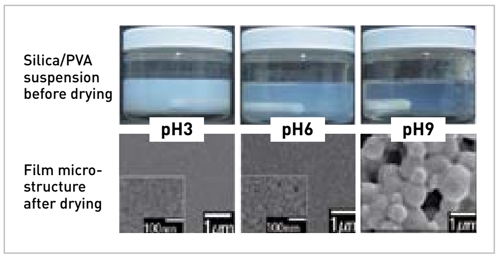
In this field, we investigate the viscoelastic flow properties of complex fluids, which appear in many manufacturing processes as well as in biological systems. We study how the complex fluids form the microstructure and how it is related with the performance of the final product. We also develop platforms for both material design and process control, which can be widely applied to diverse industries, including electronic materials, optical films, batteries, solar cells, plastics, cosmetics, pharmaceuticals, and so on.

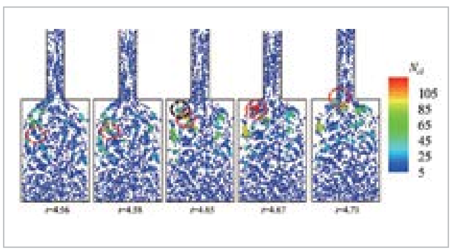
Research topics

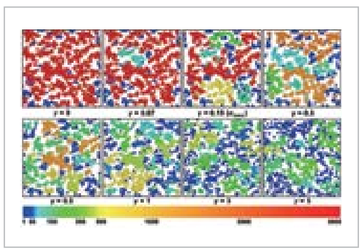
- Control of coating and printing process
- Flow control of biological systems
- Flow control of complex fluids in microchannel
- Development of organic/inorganic nanocomposites
- Analysis of polymer processing
- Molecular modeling of polymers and particulate suspensions
- Flow simulation of viscoelastic fluids











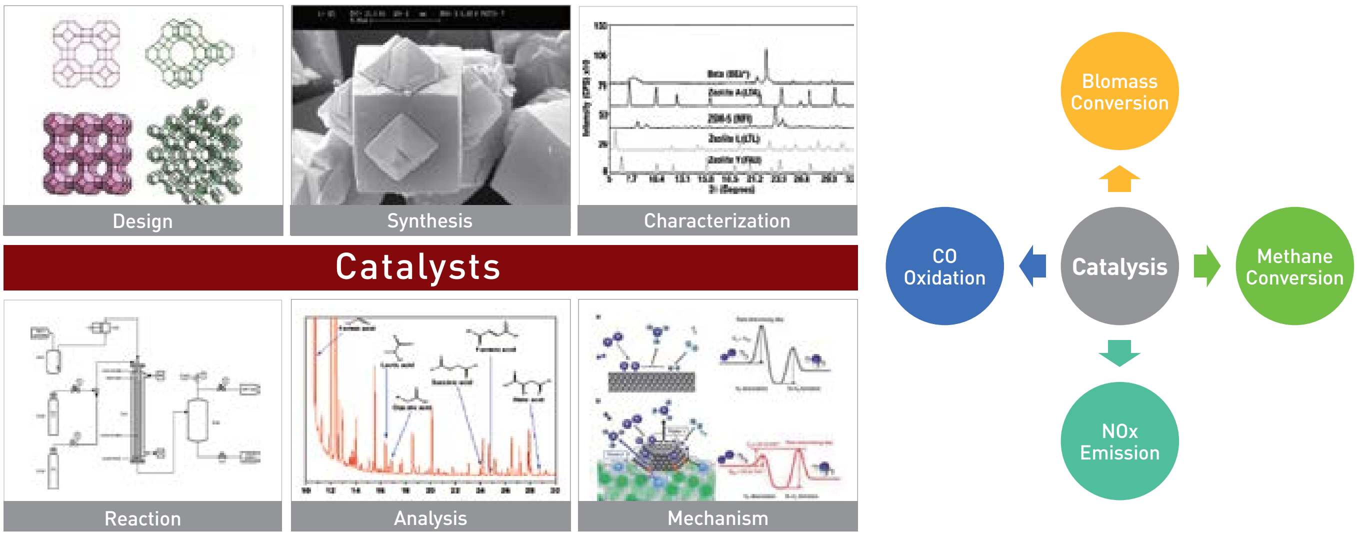
Catalysts

Research summary

Catalyst engineering is an important technology in chemical engineering, and has been widely employed in the field of petrochemical and energy industries. We work on the preparation, characterization, and application of various catalysts. We also focused on determination of reaction mechanism and active sites of the catalyst for the development of efficient catalytic processes. A goal of the research is to design novel catalyst for the important catalytic processes, and thus to establish a new paradigm and thus to establish a new paradigm for chemical industry.

Research topics

- **Synthesis and characterization of functional catalysts**
  (metals, metal oxides, carbons, polymers and acid-base catalysts)
- **Applications for various catalytic processes**
  (biomass conversion, CO oxidation, methane conversion and NOx emission control)
- **Design of catalytic reaction system**
  (packed bed reactor, high pressure batch reactor and semi-batch reactor)



RESEARCH AREAS

-
SEOUL NATIONAL UNIVERSITY
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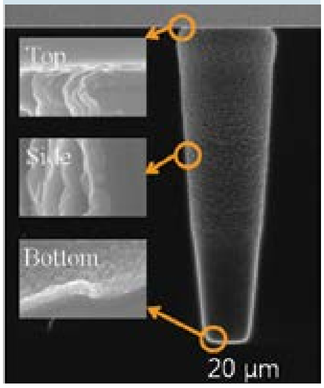


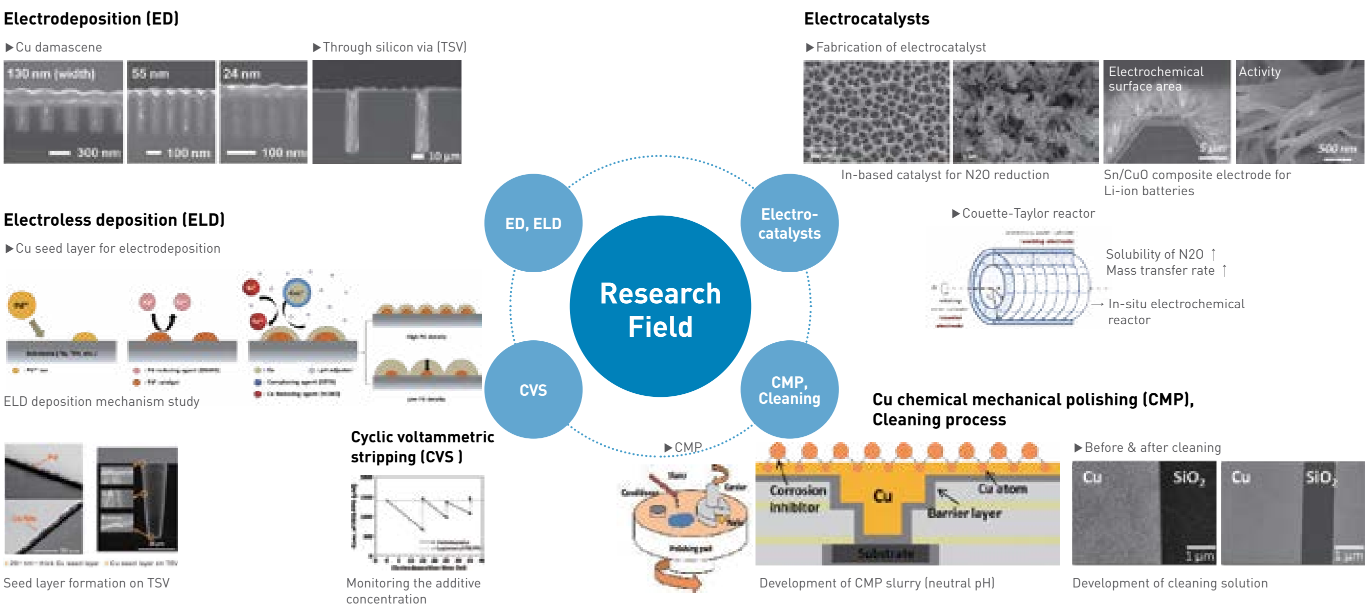
Semiconductor & Electrochemistry

Research summary

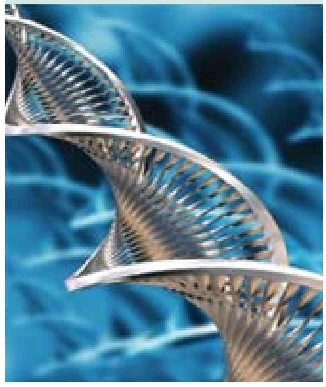
Of primary concern in semiconductor and electrochemistry areas are; (i) the semiconductor process using electrodeposition, electroless deposition, monitoring the additive concentration in electrolyte, Chemical Mechanical Polishing (CMP) slurries, cleaning solutions (ii) fabrication of electrocatalysts using electrochemical methods for gas reduction, Li-ion secondary batteries. The following research details are pursued to understand the fundamental phenomena involved in semiconductor processes and electrochemical systems, to develop experimental methodologies to characterize the parameters, finally, to improve present technologies and development of new materials, devices and processes.

Research topics

- Electrodeposition for fabrication of the interconnections
- Cu, Ag, Co electroless deposition
- High accuracy analysis of additives in acidic Cu electrodeposition bath
- Cu CMP slurry and post CMP cleaning
- Fabrication of electrocatalysts with electrochemical methods for gas reduction and Li-ion secondary batteries
- Systems for gas reduction (Couette-Taylor reactor)
- Fundamental studies on surface & interface science



Biotechnology

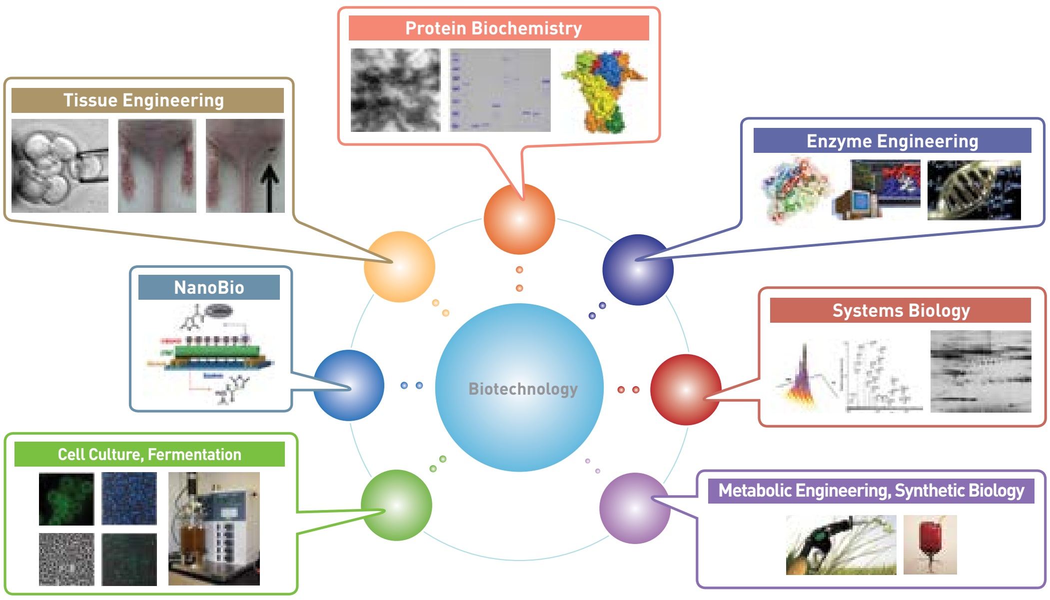


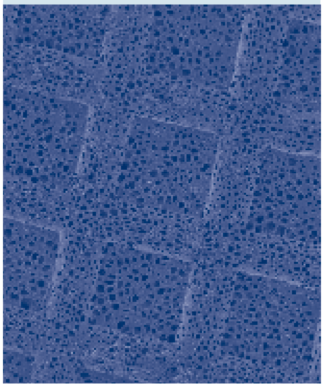
Research summary

Biotechnology (BT) is an astonishingly fast-growing key technology for the prosperity/affluent life of mankind. It focuses on the applications of living organisms, their products, and bio-processes for both the wellbeing of human and the conservation of environment. Biotechnology can be categorized into three main areas; 'Red BT' which is medical technology for the diagnostics and therapeutics of diseases, 'Green BT' which is applied for the production and security of agricultural resources, and 'White BT' which is environment-friendly industrial biotechnology utilizing enzymes. Furthermore, the BT field is still expanding its boundary by fusion with nanotechnology and electro/information technology. In our School of Chemical and Biological Engineering, the scope of research covers from the molecular level to systems level. The vast application area of BT includes chemical industries concomitant with bio-energy, tissue engineering, biosensors, and pharmaceutical development.

Research topics

- **Enzyme Engineering:** Screening and development of enzymes
- **Protein Biochemistry:** Protein folding, Protein assembly, Protein-based nanoarchitecture
- **Systems Biology:** Proteomics, Glycomics, Peptidomics
- **Metabolic Engineering and Synthetic Biology**
- **Fermentation Process:** Microbial fermentation, Animal cell culture, Production of bioproducts
- **Tissue Engineering:** Stem cell research, Applications of biomoleucular scaffolds
- **Nanobio:** Biosensor, Artificial nose





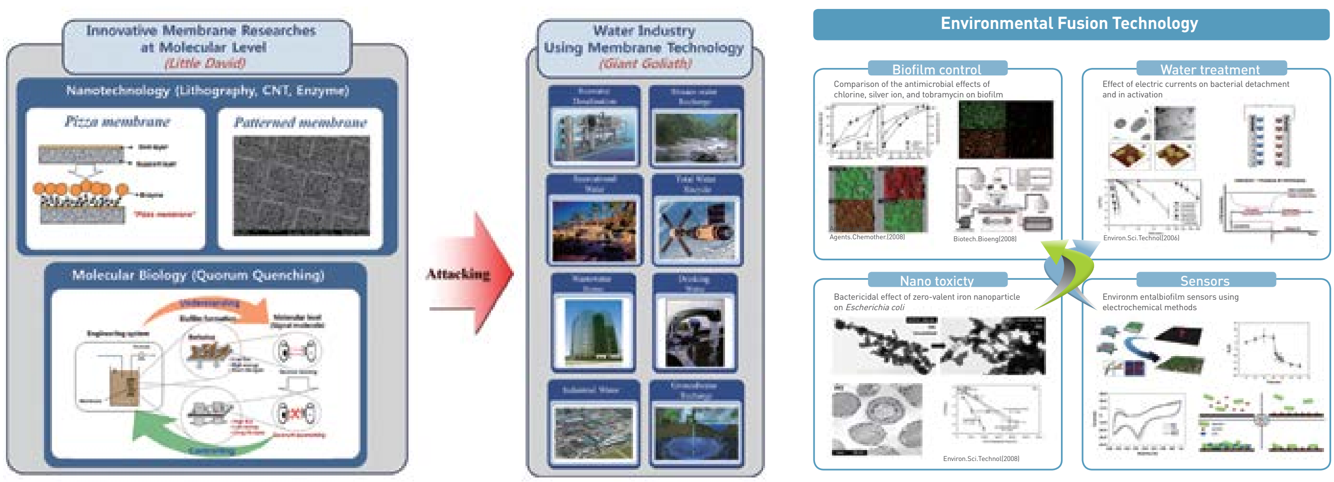
Environmental Technology

Research summary

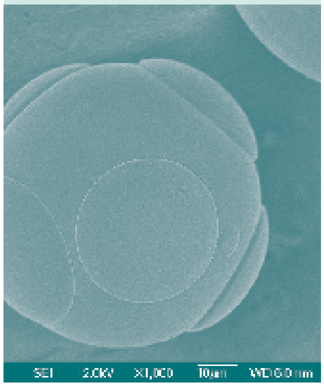
Environmental technology in the 21st century is focusing on the development of innovative technologies to face against climate change and energy crisis. To secure clean, safe water resource and to build clean air environment, it is important to eliminate toxic chemicals and pathogenic microorganisms. Currently, membrane technology, biofilm control and environmental-energy convergence study are the main areas in this field.

Research topics

- New membrane technology for seawater desalination, and wastewater reuse
- Analysis and control of biofilm in water and air environment
- Energy-saving environmental fusion technologies
- Developing the guidelines to assess toxicity of nanomaterials



Organic Synthesis
& Fine Chemicals

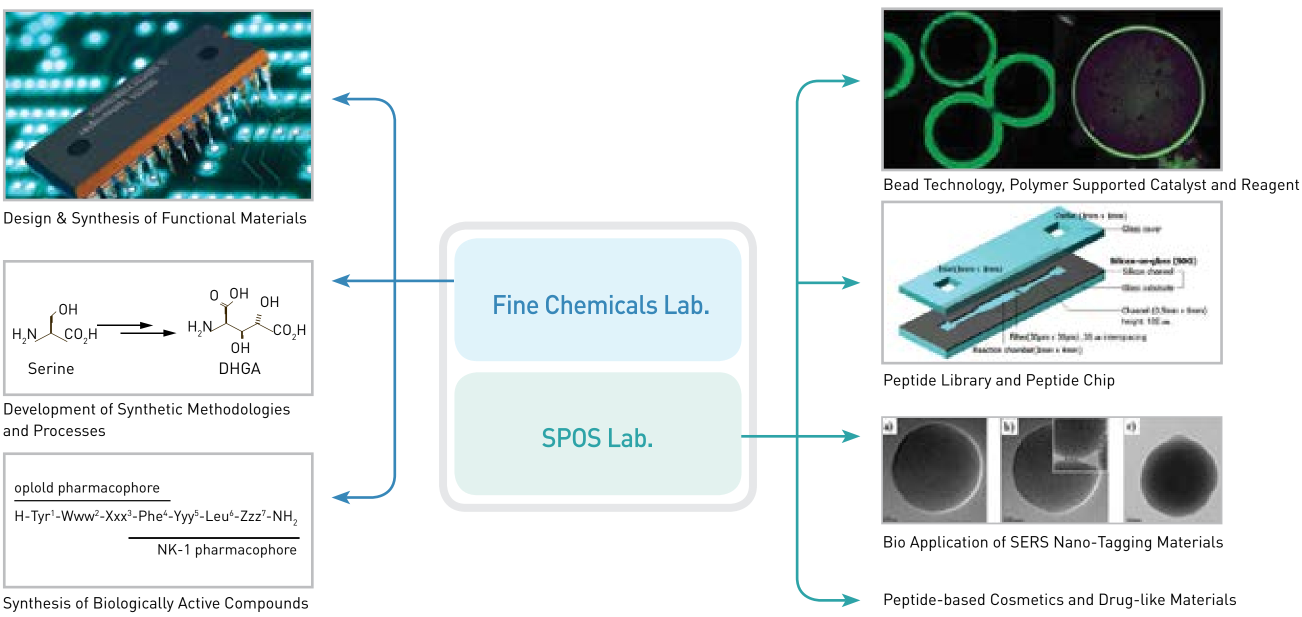


Research summary

Research of this area broadly addresses the important problems of current organic chemistry. Specific areas of research include polymer supported catalysts and reagents for organic synthesis, solid-phase peptide synthesis and peptide library design, biological application of SERS (surface-enhanced Raman scattering) nano-tagging materials (SERS dots™), the development of peptide-based cosmetic and drug-like materials, synthesis of high value fine chemicals such as pharmaceutical compounds, design of high performance molecules for electric and electronic devices, and invention of new stereoselective methods for asymmetric synthesis of a wide array of biologically important natural products. Members of the organic chemistry groups also work in collaboration with other departments, labs, and centers including the NANO Systems Institute, the Research Center for Energy Conversion and Storage.

Research topics

- Bead technology, polymer supported catalyst and reagent
- Peptide library and peptide chip
- Bio application of SERS nano-tagging materials (SERS dots™)
- Peptide-based cosmetic and drug-like materials
- Design and synthesis of functional materials
- Development of synthetic methodologies and processes
- Synthesis of biologically active compounds



RESEARCH AREAS

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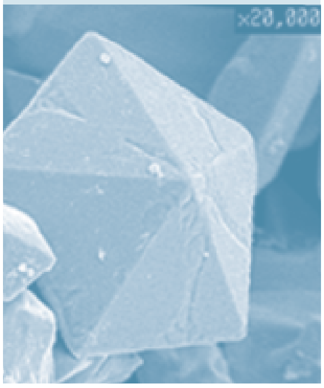


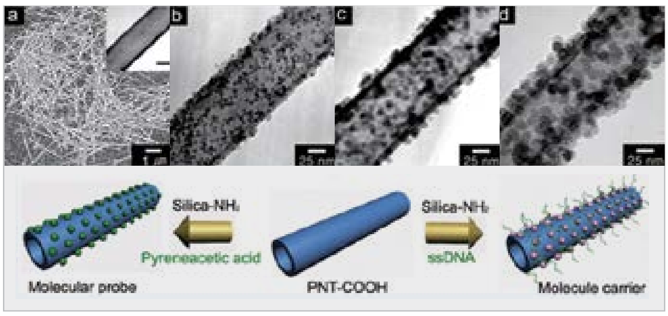
Polymers

Research summary

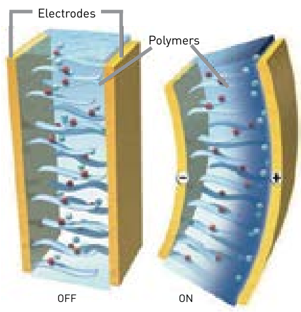
The major research areas of polymer groups are physical properties of polymeric materials and high performance composite materials, structure-property relationship in various polymeric materials, physics and physical chemistry of polymer and colloid systems, and synthesis of novel monomers and polymers. The recent focus of the research has been on the following topics:

Research topics

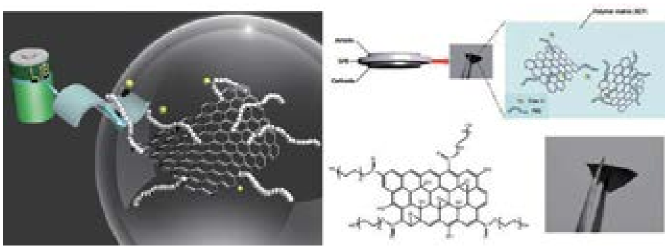
- Polymeric and conducting/magnetic nanomaterials
- Architecture-motion-property relations in polymers
- Functional polymer thin films
- Synthesis of polymers for electronic and nano/bio applications
- Nano-structured materials



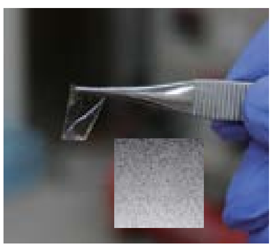
Fabrication of polypyrrole nanotube for molecular probe and DNA carrier applications



Polyelectrolytes for artificial muscle applications



Polymer composite electrolytes having functionalized graphene oxide filler



Sulfur containing block copolymer nanoparticle and their application for optical films

Research Laboratories

The School of Chemical and Biological Engineering has been giving impetus to the development of Korea from its early industrialism to its information-based society in the 21st century. Now it is playing a leading role in a further development of Korea such as successful globalization through a variety of researches done by expert professors.

Ahn, Kyung Hyun

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Our research effort is oriented toward the investigation of the flow properties of complex/microstructured materials and their flow behavior. We develop essential process technology for various industries like IT, BT, chemical, food, etc. Especially, investigation and control of particulate system, control of local heterogeneity, and developing new process by microrheological technique are studied.

Laboratory of Microrheology

Modeling of Particulate Systems

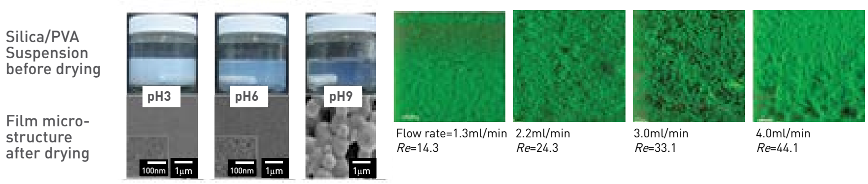
Most of electronic materials consist of various components which include inorganic particles and polymers, and their internal microstructure changes when they flow during processing. We like to understand the interaction between the particles and structural changes during processing. Dynamics of the particulates are probed by the newly developed simulation method which combines macroscopic flow analysis with microscopic molecular modeling. With this approach, heterogeneous local dynamics of particles are analyzed, and various complex fluid behaviors including shear banding are investigated numerically.

IT Rheology

There are many coating and printing processes widely used in the manufacturing of electronic materials such as display, battery and capacitor. We like to understand the various phenomena observed during their manufacturing process and to provide useful methodology to control them. We want to control the performance of the final products and to provide a platform to design the materials suitable for the corresponding processes. We also like to control the deformation and dynamics of the materials as well as heterogeneity and stress development during drying process.

Microfluidics and Microrheology

To study the dynamics of complex fluids on a micrometer scale, we use microfluidics and microrheological methodology as a tool. The dynamics of particulate suspensions in microchannel flow under electric field is studied. Also, the microrheological measurement is carried out for materials which are difficult to handle with the conventional rheometers. We study the rheological properties, local dynamics and heterogeneity by tracking the Brownian motion of probe particles in the medium. With these methodologies, we measure the local properties of biofilm, and evaluate the difference in properties in thickness direction of film during drying process.



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CRI Center for Intelligent Hybrids

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Research by our CRI (Creative Research Initiative) Center mainly focuses on the fundamental and applied aspects of thin films and nanopatterns involving macromolecules and functional nano-objects. The current emphasis of our research program is placed on the fabrication and characterization of block copolymer thin films, ultra thin functional multilayer films, nanoporous thin films, hybridization, and their applications to energy and environmental issues. Our research Center has already established synthetic schemes to prepare well-defined nanomaterials such as block copolymers, semiconducting nanocrystals, organosilicates, and hollow metal oxide nano-objects, sulfur-based materials with various functionalities. Furthermore, fundamental knowledge on the interfacial manipulation at the molecular level accumulated in this research Center can be directly applied to realize integrated devices or hierarchical structures with unique functions.

Self-Assembly of Block Copolymer Thin Films and Its Applications

Self-assembled block copolymers (BCP) are expected to serve as useful soft nanotemplates for a host of potential applications by adjusting chemical and physical structures of BCPs at the molecular level. To control the specific orientation of BCP microdomains in thin films, our research Center has actively been engaged in developing several surface engineering techniques based on the characterization and manipulation of surfaces and interfaces of BCP films. In addition, the defect minimization in large area for practical applications is ultimately required to realize high performance devices such as next generation terabit memory devices and revolutionary fabrication methods for the defect minimization of self-assembled domains are currently being developed in our laboratory.

Functional Thin Films Based on Layer-by-Layer Deposition

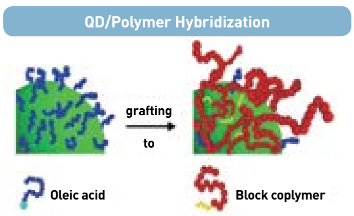
The Layer-by-Layer (LbL) deposition has received intensive attention in the past decade due to its simple fabrication procedure and yet broad potential applications such as functional ultra thin multilayer films, surface modification of substrates, and hybridization of functional nanomaterials. Our research Cneter has the reputation in the development of new classes of LbL deposition based on the spin assembly process, which is much simpler and faster than the conventional dip-based deposition method, and multistacking deposition with porous membranes for biomedical applications. This fabrication method results in the highly ordered internal structure suitable for high performance devices and platforms such as ultra thin capacitors, bio- and environmental sensors, and stem cell differentiation. In addition, our research group has recently extended the LbL deposition involving various functional nano-objects such as nanoparticles, nanowires, and micelles, to further improve the functions embedded in thin films to the next dimension.

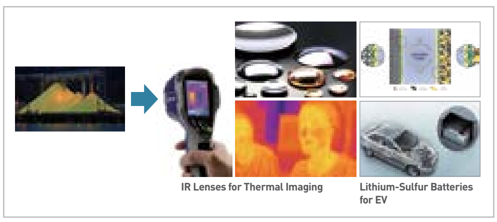
Nanoporous Materials for Optoelectronic Applications

Nanoporous organic and/or inorganic thin films provide a variety of potential applications such as intermetallic dielectric materials, optical components, sensor elements, and substrates for biological applications. Nanoporous structure can generally be created by the introduction of pore-generating materials (porogens) to thin films followed by the selective removal of such porogens by post treatments such as solvent etching, UV-, thermal-, acid-, or salt-treatment. Our research Center has reported the world-best nanoporous thin films with balanced mechanical and low dielectric properties for the next generation semiconductor devices, based on judiciously designed organosilicates and norbornene copolymers. In addition, our laboratory has recently worked out a strategy to prepare well-defined hollow inorganic nanospheres, which can be applied to areas such as solid-state lighting and photocatalysts.

Sustainable Growth in Chemical Industry: Sulfur Utilization

Excess amount of sulfur, microcrystalline yellow powders, is currently being produced worldwide after desulfurization of crude oil and other unconventional oil sources. In order to take a full advantage of such industrial waste of excess sulfur, our research Center is currently working on the processing of sulfur for high value-added products such as nex-gen Li-sulfur batteries, high refractive index materials, and thermal imaging. New additives to change the physical properties of sulfur are designed and synthesized along with the development of new processing techniques such as melt processing, interfacial polymerization, and in situ nanoparticlization based on sulfur-containing monomers.





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Our lab is aimed at designing and synthesizing new inorganic and organic/inorganic hybrid materials and developing their device fabrication processes. We specialize in metal chalcogenide and halide compounds. In particular, we focus on discovery of new materials that can contribute to solving energy, environmental, and fundamental problems of condensed matter physics.

Our representative research topics are as follows:
i) highly performing, environmentally friendly new thermoelectric materials and devices
ii) Next generation solar energy harvesting materials and their devices
iii) Visible/near infrared-responsive porous semiconductors for photocatalysis, nuclear waste/heavy metal remediation, and selective capture, storage, and conversion for gases.
We are also developing core processing technologies to commercialize our new materials based on our deep understanding and insights on synthesis of inorganic materials.

Energy Materials Laboratory

Photovoltaics

Rather than old school technology such as Si, CdTe and CIGS ($CuIn_{1-x}Ga_xSe_2$), we develop next generation technology such as perovskite solar cells. We are synthesizing new perovskite-type materials and developing their photovoltaic devices. They are also applicable to many important technologies such as displays, pho- todetectors, field effect transistors (FET), and conductors.

Thermoelectrics

Thermoelectric materials enable direct conversion between thermal energy and electrical energy, thereby providing an alternative route for power generation and cooling. We develop new high performance, next generation thermoelectric materials. Rather than conventional materials like PbTe, we focus on new systems that are made of earth-abundant and environmentally friendly elements for commercialization. We also work on low cost processes of materials preparation and device fabrication.

Synthesis of New Inorganic Compounds with Extraordinary Properties

We synthesize new inorganic compounds that have complex chemical compositions and crystal structures and show extraordinary properties. To achieve this, we utilize any element in the periodic table employing novel synthetic methodologies such as flux, hydro(solvo)thermal and ionic liquid reaction. Through better understanding of the close relationship of synthesis/crystal structure and crystal structure/properties, we seek to "design" specific compounds that have desirable structure and properties.

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Biomolecular Engineering Laboratory

Stress-Responsive Signal Transduction Networks in Yeast

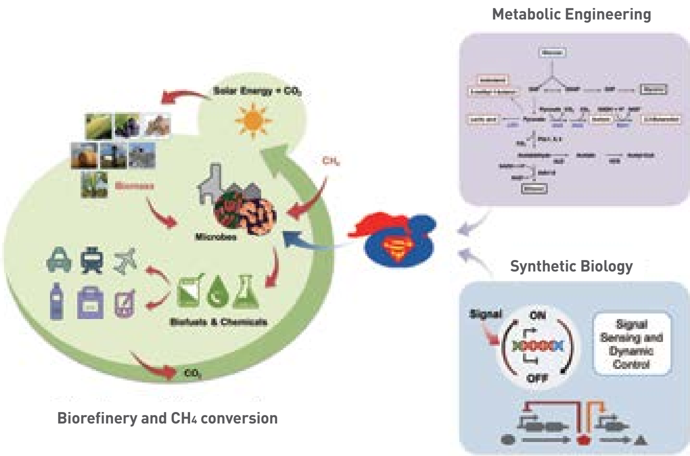
Yeast has been widely used as a eukaryotic model system to elucidate fundamental biological processes. In addition, because of its ethanol production capacity and high stress resistance, yeast is considered as an ideal industrial strain. Our research focuses on understanding yeast cellular homeostasis in response to various environmental conditions, and developing robust industrial strains. We are studying signal transduction pathways to regulate stress responses and cellular metabolism in response to nutrient starvation and other stress conditions such as heat shock, osmotic stress, pH stress, oxidative stress, and ethanol stress.

Biorefinery

Biorefinery is a concept of producing fuels and various chemicals from biomass, which can replace the petroleum-based refinery. The components of biomass (lignins, carbohydrates, proteins, and lipids) can be converted to fuels and various high-valued compounds by chemical/biological processes. We are interested in developing yeast strains to produce fuels and chemicals based on metabolic engineering and synthesis biology. Currently, we are developing yeast strains producing lactic acid, isobutanol, 2,3-butanediol, acetoin, various isoprenoid compounds, and other useful chemicals.

Bioconversion of Methane

Methane is an abundant carbon source existing in natural gas and bio gas. We are interested in utilizing methanotrophs, which can use methane as carbon and energy source, to produce useful chemicals from methane. Our research focuses on understanding metabolic regulatory networks, developing metabolic engineering tools, and finally developing engineered methanotroph strains producing useful chemicals.



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Our research focuses on understanding and redesigning cellular regulatory networks. We are interested in elucidating signal transduction pathways in cellular adaptation to various environmental stress conditions. In addition, we are applying metabolic engineering and synthetic biology tools to develop robust microbial strains for the production of chemicals and biofuels from biomass.

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Our group has researched industrial technology to design, operate, and assess chemical, energy and environmental processes economically and safely using the intelligent system technique with EDRC(Engineering Development Research Center). Since the main issues on energy and environmental problems and safety are correlated each other to several fields, convergence of multiple research areas is required considering the entire system. This lab has been the center of energy and environment fields performing comprehensive studies of energy and environment with intelligent systems technology. In addition, it makes a different with other labs that research results are applied to practical processes based on many government and corporation projects. Obtaining practically applicable research results, researchers of our lab are the first target of many companies, and are recognized for outstanding business performance. As energy and environment issues will be more and more important in the future, researchers from this lab will exercise greater influence in the industry.

The key elements of lab technologies are modeling and simulation skills for process and product design, monitoring & fault diagnosis techniques to identify and prevent potential accidents in the process. Also, real-time optimization of the plants by controlling the variables that maximize the efficiency is our another main technology. Prof. Han was awarded official commendation by Ministry of Knowledge Economy on account of his contribution to environmental industrial complex via hydrogen network optimization in 2009. In 2015, he got Industrial Service Medal from Korean government with a remarkable contribution to make the basic plan for the safety management of gas industry.

Intelligent Process Systems Laboratory / Engineering Development Research Center

Process and Product Design for Energy & Environment

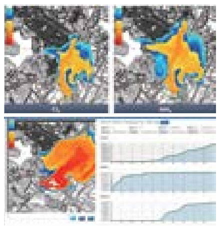
Energy depletion and environmental pollution issues that have a massive impact on humans are emerging as the most pressing challenges. This lab has given successfully many practical results based on process systems technologies. We have been solving energy and environmental issues of refinery, petrochemical, LNG, bio-diesel, compact GTL, Carbon capture utilization and storage (CCUS) technology, and power generation effectively. In the future, we will reduce energy consumption by using process and product unit design, modeling & simulation, control & optimization, monitoring & fault diagnosis, economic analysis for target processes, and contribute to environment by minimization of pollutants emission.

Process Optimization and Control

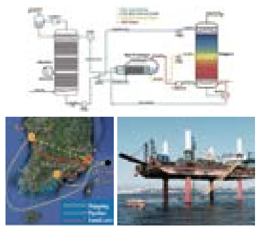
Due to the depletion of fossil fuels, research on new energy sources to replace traditional fossil energy is needed. The lab has conducted research on storage & conversion of energy. We have studied energy systems by performing systems design, modeling & simulation, control & optimization, monitoring & fault diagnosis, economic analysis for the processes including secondary battery, micro GTL, CO2 storage utilization, power generation, plasma etching and fuel cell. In the future, we will perform economic analysis for new systems, and carry out research and development on innovative system design for energy conversion & storage, in addition to optimal control methods.

Monitoring and Safety Management

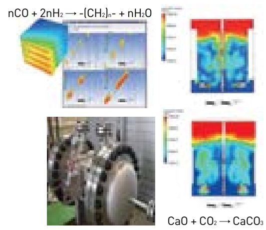
Unexpected releases of flammable, toxic chemicals from process have increased for many years as growing the chemical industry. Though the process is running with no troubles, there is a potential of accidental release any time. In order to prevent disasters, safety issues must be considered during both process design, operation, and even ongoing accident. This lab focuses on management and analysis of safety issues in the phase of process design, operation. All the design candidates are to be evaluated by conservative safety assessment. Real time monitoring technology has been developed to diagnose unexpected alarms to draw right decision. Effective training system with virtual reality is being built by this group. Our results help Korean safety rule and laws to be updated with the rapid changes in the world industry.



Toxic Gas Risk Analysis



Carbon Capture & Transportation & Storage



Reactor Design – Micro FT / Carbon Utilization

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1. Seongho Park, Ikhwan Jung, Yongkyu Lee, Krishnadash S Kshetrimayum, Jonggeol Na, Seongeon Park, Seolin Shin, Daegeun Ha, Yeongbeom Lee, Jongtae Chung, Chul-Jin Lee, Chonghun Han, **2016**, Design of microchannel fischer–tropsch reactor using cell-coupling method: Effect of flow configurations and distribution, *Chemical Engineering Science*, **143**, 63-75.

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Biomimetic Materials and Stem Cell Engineering Laboratory

Stem Cell Engineering

Lineage conversion from one somatic cell type to another is an attractive approach for deriving specific therapeutic cell generation. Our laboratory is currently developing a direct conversion methodology in which cells are transdifferentiated through a plastic intermediate state induced by exposure to non-integrative minicircle DNA (MCDNA)-based reprogramming factors, followed by differentiation other cell types. This non-viral methodology for direct lineage conversion may represents a novel process to convert somatic cells to another lineage.

In Situ Crosslinkable Hydrogels

Recently, various functional moieties have been incorporated into biomaterials for improved tissue regeneration. In particular, photo-mediated materials present significant advantages in controlling the crosslinking or cleavage by in which photons from light gets absorbed by the chemical and react instantly. Whether the material produces radicals, cleaves, or changes conformation upon light irradiation, spatial and temporal control of these reactions can shine a light on tissue engineering and also in clinical application. Our laboratory is currently developing a variety of photo-responsive biomaterials for application in musculoskeltal tissue engineering. Photopolymerization may provide optimal cell encapsulation system. Additionally, photodegradable units may allow controlled cellular microenvironment. Systematically controlling the crosslinking and degradation by light-based system may provide a platform to accurately control and monitor the tissue regeneration.

Origami-based Tissue Engineering

Our laboratory has developed a method for assembling biofunctionalized paper into a multiform structured scaffold system for reliable tissue regeneration using an origami-based approach. In this platform, a paper is conformally modified with a poly(styrene-co-maleic anhydride) layer via initiated chemical vapor deposition followed by the immobilization of poly-l-lysine (PLL) and deposition of Ca(2+). This procedure ensures the formation of alginate hydrogel on the paper due to Ca(2+) diffusion. Furthermore, strong adhesion of the alginate hydrogel on the paper onto the paper substrate can be achieved due to an electrostatic interaction between the alginate and PLL. The developed scaffold system was versatile and allowed area-selective cell seeding. Also, the hydrogel-laden paper could be folded freely into 3D tissue-like structures using a simple origami-based method.

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The overall goal of biomimetic materials and stem cell engineering laboratory is combine engineering principles and basic science with developmental biology to understand mechanisms of tissue regeneration in novel biomaterial systems.

Biomaterial scaffold may provide a vehicle to differentiate stem cells by controlled exposure to proteins, adhesion peptides, and growth factors in a three-dimensional matrix. Our laboratory is currently working toward the fabrication of bio-synthetic microenvironments conducive to stem cell differentiation by manipulating scaffold properties and incorporating the desired biological signals. In addition, our laboratory is developing non-viral strategies for a direct conversion stem cell technologies. In contrast to traditional viral transduction method, non-viral delivery of conversion factors has the merit of lowering immune responses and provides safer genetic manipulation, thus revolutionizing the generation of directly converted cells and its application in therapeutics.

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Our research has been focused on the large-scale synthesis of uniform-sized nanoparticles, their designed assembly, and medical & energy applications.

Nanomaterials Laboratory

Large-scale Synthesis of Uniform Nanoparticles

Over the last 10 years, our laboratory has focused on the designed chemical synthesis, assembly and applications of uniform-sized nanocrystals. In particular, we developed a novel generalized procedure called as the "heat-up process" for the direct synthesis of uniform-sized nanocrystals of many metals, oxides, and chalcogenides. The synthesized nanocrystals include metals (Fe, Cr, Cu, Ni, and Pd), and metal oxides (γ-Fe_2O_3, Fe_3O_4, $CoFe_2O_4$, $MnFe_2O_4$, NiO, and MnO) and MnS). We report the ultra-large-scale (10s of grams) synthesis of monodisperse nanocrystals of magnetite and MnO from the thermolysis of metal-oleate complexes (Nature Mater. 2004, 3, 891). We synthesized uniform-sized nanocrystals of various oxides of ZnO, TiO_2, CeO_2, Sm_2O_3 and FeOOH via non-hydrolytic sol-gel reactions.

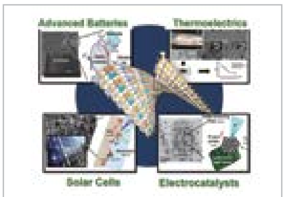
Medical Applications

Recently our group has been focused on medical applications of various uniform-sized nanoparticles. Using 3 nm-sized iron oxide nanoparticles, new non-toxic MRI contrast agent was realized for high resolution MRI of blood vessels down to 0.2 mm. We fabricated tumor pH-sensitive magnetic nanogrenades composed of self-assembled iron oxide nanoparticles and pH-responsive ligands for theranostic application, enabling the visualization of small tumors of < 3 mm via pH-responsive T1 MRI and fluorescence imaging and superior photodynamic therapeutic efficacy in highly drug-resistant heterogeneous tumors.

Hyeon Research

Chemical Synthesis of Uniform-sized Nanocrystals

Providing New Medical Diagnosis Tools and Therapeutic Methods using Nano



Nano for Energy

Energy Applications

We reported large-scale synthesis of magnetite nanocrystals imbedded in a carbon matrix. We demonstrated galvanic replacement reactions in metal oxide nanocrystals. When Mn_3O_4 nanocrystals were reacted with iron(II) perchlorate, hollow box-shaped nanocrystals of Mn_3O_4/γ-Fe_2O_3 were produced. These iron oxide-based nanomaterials exhibited very high specific capacity and good cyclability for lithium ion battery anodes. We report a simple synthetic method of carbon-based hybrid cellular nanosheets loaded with SnO_2 nanoparticles. The resulting SnO_2-carbon nanosheets exhibit specific capacity of 914 mAh g^{-1} with the retention of 97.0% during 300 cycles, and the reversible capacity is decreased by only 20% as the current density is increased from 200 mA g^{-1} to 3000 mA g^{-1}.

We present a synthesis of highly durable and active intermetallic ordered face-centered tetragonal (fct)-PtFe nanoparticles (NPs) coated with "dual purpose" N-doped carbon shell. Our ordered fct-PtFe/C nanocatalyst coated with N-doped carbon shell shows 11.4 times-higher mass activity and 10.5 times-higher specific activity than commercial Pt/C catalyst. Moreover, we accomplished the long-term stability in membrane electrode assembly (MEA) for 100 hr without significant activity loss.

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1. Multifunctional Tumor pH-Sensitive Self-Assembled Nanoparticles for Bimodal Imaging and Treatment of Resistant Heterogeneous Tumors, *J. Am. Chem. Soc.* **2014**, 136, 5647.

2. High-Resolution 3-Photon Biomedical Imaging using Doped ZnS Nanocrystals, *Nature Mater.* **2013**, 12, 359.

3. Galvanic Replacement Reactions in Metal Oxide Nanocrystals, *Science* **2013**, 340, 964.

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Polymer Nanomaterials Laboratory

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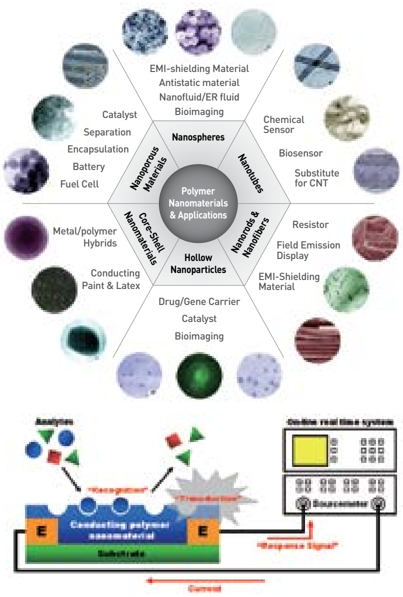
Our research area can be divided as the fabrication of polymer nanomaterials and the environmentally-friend applications such as chemical sensor, biosensor, catalyst, heavy metal removal, antimicrobial reaction and so on. For the fabrication of nanomaterials, we have many experiences and techniques such as soft-templated polymerization, vapor deposition polymerization, interfacial polymerization, dispersion polymerization and electro-spinning method. Especially, our group possesses the excellent ability to synthesis of conducting polymer nanomaterials with the various morphologies. In addition, they are superior to the surface modification of these nanomaterials for the environmentally-friend applications using chemical treatments.

Conducting Polymers

Over the last several decades, conducting polymers have received much attention from the viewpoint of both fundamental and applied studies by virtue of the exclusive features originating from their unique π-conjugated system. Since the initial discovery of polyacetylene, various kinds of conducting polymers have been extensively investigated. We are developing various fabrication methods for conducting polymer nanomaterials, consisting of polypyrrole (PPy), polyaniline (PANI), polythiophene (PT), and poly(3,4-ethylenedioxythio-phene) (PEDOT). We have also offered tremendous opportunities for advanced applications in the fields of electronics, optics, catalysis, energy storage, and biological systems.

Surface Modification

With the possibility of nanomaterials for versatile applications, surface modification is a key factor to allow the high performance and practical use. In our laboratory, vapor deposition polymerization, low-temperature plasma treatment, and silane modification have been extensively served as tools for surface modification of polymeric and inorganic nanomaterials. Interestingly, the controlled properties are readily obtained by the modulation on degree of surface modification. These introduced and controlled specific functions from surface modification might be anticipated to provide the adsorbents with superior adsorption for heavy metal ions, highly sensitive sensor platforms, and electrochemical electrodes with excellent capacity.



Inorganic Nanomaterials

Various inorganic nanomaterials have been widely used for their potential applications such as antimicrobial agents, mesoporous nanofibers, and templates for unique nanostructures. In our work, poly(methyl methacrylate) (PMMA) nanofiber containing silver nanoparticles was synthesized by radical-mediated dispersion polymerization and applied to an antibacterial agent. Silica nanoparticles have been adopted as templates to generate core-shell nanomaterials containing antimicrobial ability and biocompatibility. Moreover, polymer hollow structures can be produced by etching inorganic core. Silica nanofibers with highly ordered mesostructures were fabricated using AAO membranes by vapor deposition hydrolysis.

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Polymer Structures Laboratory

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Our research activities focus on understanding the relationships between molecular structure and physical properties in polymeric materials and the utilization of this knowledge to engineer polymeric materials on microscopic and macroscopic levels for use in functional and high-performance engineering applications. The polymeric system we are investigating includes new engineering plastics, polymer blends, and nanocomposites: The properties we concern for applications range from bioactive, conducting to thermomechanical properties.

High-Performance Polymer Blends

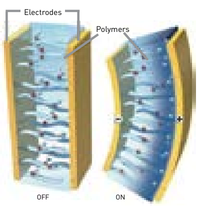
Although the field of polymer blends has been one of the most extensively and unceasingly studied in the last few decades, designing a new polymer blend for a certain purpose is a new task. We design, prepare, and test performances of the polymer blends for various polymers and for variety of applications. The polymers we deal with ranges from commodity polyolefin like polypropylene to specialty engineering polymers like aliphatic and aromatic polyketones. The purpose for which the blends are designed include thermal. mechanical, bioactive, and/or barrier property of the blends.

Polymeric Materials for Fuel Cells and Solar Cells

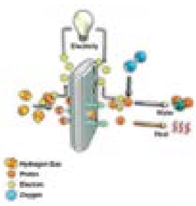
Polymer electrolyte is an important component material of fuel cells, solar cells, and secondary batteries in virtue of its ion conductivity, mechanical property, and stability. To enhance the energy conversion efficiency of fuel cell and solar cell systems, we develop polymer electrolytes with improved and balanced properties by designing and preparing new solid polymer electrolytes or modifying the existing polymer electrolytes in the form of nanocomposite, gel, or hybrid.

High-Performance Nanocomposites

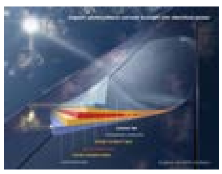
Nanocomposite is a new class of filled materials with ultrafine dimensions. Polymers filled with graphene or carbon nanotube are nanocomposites with superior physical properties to conventional composites. We develop nanocomposites for the application to automotive parts that can contribute to the reduction of total weight of automobile without sacrificing the performance. We also develop polymer nanocomposites for orthopedic prosthesis materials for high mechanical and bioactive properties.



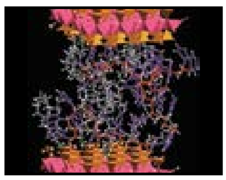
IPMC Actuator



Polymeric Fuel Cell Membrane



Organic Solar Cell



Polymer/Clay Nanocompaosite

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Molecular Biotechnology and Biomaterials Laboratory

Biocatalysis and Establishment of Biorefinery

Our lab produces high-value added physiologically active hydroxylated compounds, glycosylated compounds, decarboxylated compounds, and cell metabolites, which are applicable to functional foods, cosmetics, and pharmaceutical fields and chemical industry. To achieve such goals, we investigate and establish screening systems (classical microorganism screening and bioinformatics screening) of biocatalysts, and subsequently study enzyme reaction engineering in order to efficiently produce useful materials like the compounds mentioned above. The enzymes we are currently studying are as elaborated below:

1) Oxidoreductase: Cytochrome P450, tyrosinase, daidzein reductase, laccase, peroxidase
- Production of hydroxylated (iso)flavone, (S)-equol, long/short chain ω-hydroxy fatty acids, fatty acid esters
- Production of polyurethane from biomass
- Functional gelatin and hydrogel production

2) Metabolic and functional enzymes: transaminase, decarboxylase, transglutaminase
- Construction of bio-refinery systems from bio-mass using microbial cell factories
- Production of various monomers(ex: cadaverine) from amino acids or sugars for polymer synthesis
- Production of hydroxyl-styrene/hydroxyl-benzoic acid/phenol from lignin degradation products

3) Glycosyltransferase and glycosidase
- Sialyl/fuco oligosaccharides, NDP-sugar synthesis, glycoconjugates
- Ginsenoside glycoside / production of aglycon from saponin

Systems and Synthetic Metabolic Engineering

Our study for developing optimized cell factory for the production of valuable bioactive compounds requires better understanding of gene expression and metabolic activity in the cell through the systematic analysis of acquired transcriptomic, proteomic, and metabolomics data, which allow us to analyze our target cell as a whole system rather than to analyze a few suspected target mutants. In order to increase the yield and productivity of high value secondary metabolites such as antibiotics, anticancer, and immunosuppressants produced by Streptomyces, 1) identification of master transcription factors, 2) evaluation of overproducing strains through the transcriptomic, proteomic, and metabolomics approaches, 3) strains design using in silico metabolic model, 4) optimization of genetics part using synthetic biology were performed. As well as, our lab focuses on the development of cell factories to produce a variety of target products including hydroxy fatty acids. The following analytic tools are used for this research:

1) Analysis of transcriptome and ribosome profiles, and transcriptional regulatory factors,
using RNA seq, Ribo seq, and ChIP-seq techniques of next generation sequencing

2) Qualitative and quantitative analysis of proteome and metabolome
using mass spectrometer (LC-MS(LCQ ion trap, TSQ), GC-MS)

3) Interpretation of transcriptomic and proteomic data and design of strains
based on in silico metabolic model.

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Our lab is interested in the development of new functional bio-materials (natural product, peptides, oligosaccharides, chiral compounds, functional foods), one-pot enzyme reaction to construct biorefinery or even multi-steps reaction bio system, using various cells and enzymes. We are also investigating on a large scale production of the above in vitro or in vivo system. To solve such problems, our approaches touch upon various aspects of analysis with engineering concepts and tools (reactor control, analysis of reactive factors, separation and purification process development, activity and stability of enzymes/catalysts, quantitative analysis of metabolic pathways, omics data analysis and etc). Then, to maximize yields and productivity of targeted substances, researches on process optimization or development of new enzyme reactions/metabolic pathways are undertaken using diverse analytical methods. We often use new techniques such as in vitro evolution, protein engineering, computer modeling, bioinformatics, synthetic biology and etc., for designing novel enzymes as well as developing mutants by changing the properties of targeted enzymes. In the case of microbial metabolic pathways, we attempt to maximize yields and productivity of targeted substances through quantitative analysis of metabolism by applying metabolic engineering techniques, precise understanding of transcriptional regulatory factors, mRNA expression level analysis by DNA array, proteomics, and system biological tools.

Stem Cells and Tissue Engineering Laboratory

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The research of this laboratory focuses on regeneration of human tissues or organs with stem cells and tissue engineering techniques.
To enhance the regenerative potential of stem cells, the concepts of gene or growth factor delivery and biomaterials are applied to this approach.

Stem Cells

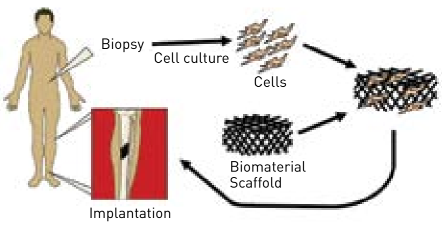
Stem cells have the potential to develop into many different cell types in the body. Due to their unique regenerative abilities, stem cells offer new potentials for treating various diseases. This laboratory is developing technologies to treat bone, cartilage, and heart disease using stem cells.

Tissue Engineering

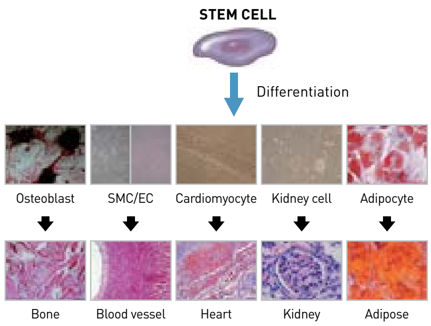
Tissue engineering offers the possibility of regenerating human tissues and so replacing lost or malfunctioning organs or tissues. Biomaterials are used to modulate stem cell behaviors and direct stem cell fate both in vitro and in vivo by displaying stem cell-regulatory signals in a precise fashion.

Drug Delivery

Local delivery of therapeutic proteins or genes to tissue or organ defect sites could induce regeneration of functional tissue, which could be applied to treat various diseases. This laboratory is developing systems to delivery proteins or genes locally in controlled manner.



Tissue Engineering



Stem Cells

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Translational Flextronics Laboratory

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Our group focuses on developing high performance wearable electronic devices which are integrated with diverse nanomaterials with target-specific functionalities. In specific, we aim to develop technologies for high performance flexible and stretchable electronic devices by using high quality nano-scale materials, which enable new biomedical and energy systems with novel/multiple functions. The technologies will provide soft, conformable devices that can establish intimate contacts to curvilinear surfaces of native tissues in vivo, without causing any damage or alteration in the tissue, with important, clinically relevant modes of use. These advanced technologies will improve current surgical capabilities and/or invent new and unprecedented medical systems, which are important tools in clinical procedures and surgeries, for the suffering patients. Furthermore, these technologies are also to create a low cost energy harvesting and light emitting devices using nanostructured electronic materials and unconventional processing technologies with hopes to generate electricity with easy accessibility for all the people in the world, especially for the developing world.

Epidermal and Wearable Electronic Devices

The measurement of physiological data from human skin using wearable devices have been of interest for more than several decades. However, the conventional wearable devices still rely on traditional rigid device layouts, making it difficult to make conformal contact on soft and curvilinear skin. This in turn results in poor signals from the body. To overcome the drawbacks of using the conventional rigid wearable devices, we are developing a new concept of "epidermal" electronic devices. The devices are made of ultrathin, low-modulus, lightweight, stretchable "skin-like" membranes that can be conformally laminated onto the skin. This epidermal electronic devices showed tremendous opportunities for realizing mechanically invisible wearable devices which can precisely measure the physiological data.

Electrochemical Sensors

Biochemical analysis enables the detection of important biomarkers including glucose, proteins, and ions for accurate disease diagnosis and feedback therapy. In our group, flexible and stretchable electrochemical sensors and actuators have been extensively researched for development of new classes of minimally invasive surgical tools and wearable devices. Our group utilizes heterogeneously integrated nanomaterials and modulates their functionalities via material synthesis and surface functionalization for biomedical applications. Also, the monolithic integration of electrochemical devices with the electrical and physiological devices enhances the accuracy of the disease detection and compensates potential errors from the environmental effects. These approaches can broaden the scope of flexible and stretchable electronics to unconventional medical applications by adding unique properties and high performances to conventional biomedical devices/surgical tools.

High-Performance Optoelectronic Devices

In our group, various colloidal nanoparticles and inorganic nanomaterials have been widely employed for the optoelectronic devices such as quantum dot light emitting diodes, MoS_2 photodetectors, and perovskite photodetector/solar cells. By using distinctive nanomaterials, we have been able to make high performance optoelectronic devices with unique optical characteristics. For instance, 2.6 μm thick ultrathin and wearable CdSe/ZnS quantum dot LEDs were manufactured with high electroluminescence (14,000 cd m^{-2}) and excellent deformability (~1,000 cycles of 20% stretching test). We also demonstrated a novel transfer printing technique named intaglio transfer printing, which allows to align red-green-blue quantum dot pixels with ultrahigh resolution up to 2,460 pixels per inch.

Advanced Energy Devices

For a comfortable, portable, and easy-to-use system platform in wearable electronic devices, it is necessary to replace the conventional bulky and rigid energy devices with thin and deformable ones with the capability of long-term energy supply. In our group, we are developing deformable energy devices which can be used in the flexible, stretchable electronic devices as the electrical power suppliers. Previously, we demonstrated a wearable fall detection system composed of a wristband-type deformable triboelectric generator and lithium ion battery in conjunction with integrated sensors, controllers, and wireless units. A stretchable conductive nylon is used as electrodes of the triboelectric generator and the interconnection between battery cells. The integrated energy supply system runs the 3-axis accelerometer and related electronics that record human body motions and send the data wirelessly.

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Our main research interests lie in the area of heterogeneous catalysis and reaction engineering, especially for the sustainable energy (chemicals/fuel) production and the environment protection. Catalytic reaction plays a major role in most environmentally friendly, energy- and material-efficient chemical processes. To meet the challenges of continuously changing nature of feedstocks and demand, new processes must be developed, and existing processes must be improved toward the direction of the cleaner environment and the higher energy efficiency. The desired innovation can be assisted significantly by an adequate understanding of catalytic reactions and an ability to design catalytic centers. Therefore, our research goal is to search for and develop the underlying chemical and engineering rules governing catalysis, especially regarding the relationship between the active sites and product activity/selectivity. Afterward, the obtained fundamental knowledge about catalyst can be utilized to design novel and efficient catalytic processes for the practical application.

Laboratory for Energy and Environmental Catalysis

◉ Catalysis for Energy (fuel and chemicals) Production

The challenge to develop the catalyst for sustainable chemicals/fuel is motivated by the progressive shift from the depleting petroleum to alternative feedstocks such as biomass, natural gas and coal. Currently, synthesis gas (CO/H_2), methanol, ethanol, carbohydrates, CH_4 and CO_2 are widely researched as a major candidate intermediate or starting feedstocks to the fuels and the chemicals. In order to develop the energy-efficient chemical process based on these intermediates, the optimum catalyst with high activity and selectivity should be found. Hence, the extensive study about the relationship between the active sites and product selectivity/activity must be performed initially. Then, a novel catalyst must be designed to improve the overall yield of the desirable product. The interesting reactions are the utilization of methane in addition to the production of the value-added products starting from the renewable biomass feedstocks.

◉ Catalysis for Environmental Protection

The catalytic removal of harmful gases from the vehicle is an urgent task to solve the environmental and energy problems we are facing. For example, U.S. government mandates an increase major improvement in vehicle fuel efficiency to 35 miles per gallon by 2016, which needs the use of high efficiency engine concepts such as diesel and lean burn engine technologies. Especially, these technologies rely on a new generation of NOx reduction (DeNOx) and hydrocarbon oxidation catalysts in order to comply with stringent emission standards that are set to meet air quality goals. Therefore, the fundamental and applied researches are necessary to discover and develop new and improved catalyst materials for the future vehicle. The interesting catalytic systems are DOC (diesel oxidation catalyst), SCR (selective catalytic reduction) and NSR (NOx storage-reduction) catalysts to remove CO, hydrocarbon, soot and NOx emitted from internal combustion engines.

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Electronics Processing Research Laboratory

Kim, Jae Jeong

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Electronics processing research laboratory was established in 1999. Since then, 160 SCI papers, 93 patents and 199 conference presentations have been accomplished. Research area can be classified as the metallization in semiconductor process, chemical mechanical polishing (CMP), and electrochemically synthesized catalysts used for gas reduction or lithium secondary batteries. As the dimension of semiconductor is shrinking, the nano filling capability of the trench and via becomes very critical issue in metallization fabrication. As a research area of our laboratory in semiconductor process, the Cu deposition and filling by using electrodeposition and electroless deposition are focused. In particular, filling of through silicon via (TSV) is investigated as a promising technology for next-generation 3D interconnections. The electrolytes used in the filling are monitored by cyclic voltammetric stripping (CVS) method. CVS method is also developed to confirm the changes in the composition of organic additives. As a subsequent metallization process, the removal of over-deposited Cu is another research field, that is, CMP. Moreover, the electrocatalysts for gas reduction and Li-secondary batteries are investigated to increase the catalytic activity by using electrochemical methods. In the area of gas reduction, the gas reduction system is being manufactured by Couette-Taylor vortex flow, which demonstrates the higher performance compared to the conventional batch reactor by considering high reduction reaction rate.

Cu Electrodeposition

Cu deposition, the method of reducing Cu ion in solution by external electrical energy, is widely used in Cu metallization. We have studied the effect of organic additives such as superconformal deposition which fills trenches with Cu from the bottom of trenches, the mechanism of electrodeposition, film property changes by Cu electrodeposition, etc.

Cu Electroless Deposition

Cu electroless deposition, reducing Cu ion in solution by the oxidation of reducing agent, is one of the most promising techniques for the deposition of Cu seed layer in the next generation. As the size of the metal line has dwindled, depositing Cu seed layer for Cu electrodeposition has become very critical due to its high step coverage. Therefore, the formation of Cu seed layer and superconformal deposition by using additives have been extensively studied in our group.

Cyclic Voltammetric Stripping (CVS) Method

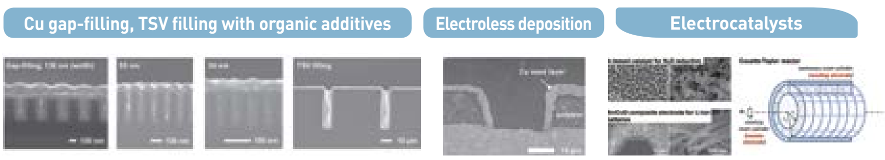
Organic additives are used for void-free filling in metallization. Since additives are decomposed and incorporated during Cu electrodeposition, the performance of electrolytes gradually degrades during the continuous electrodeposition. The changes of additive concentration are analyzed by monitoring the concentration of additives (e.g. SPS, PEG-PPG) based on CVS measurements.

Chemical Mechanical Polishing (CMP)

Cu CMP process is classified as a planarization method for removing over deposited Cu and separation of Cu line and dielectric material. In our laboratory, Cu CMP module process is investigated such as Cu CMP slurry in neutral pH, the effect of functional groups in complexing agent of Cu CMP slurry, and post Cu CMP cleaning solution.

Electrocatalysts

The electrocatalyst which is fabricated by electrochemical process such as electrodeposition (In, Au, Ag, Sn, Cu), electroless deposition and galvanic displacement (Pd), have high catalytic activity and stability. The gas reduction system is devised using Couette-Taylor vortex flow which shows rapid dissolution of gas and high reduction reaction rate.



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Our lab has been focusing on research and development of high value-added fine chemicals such as pharmaceutically important compounds, high performance molecules for electric and electronic devices, cosmetic ingredients, high explosive materials and other functionally specified target compounds based on the organic synthetic methodology and technology. Another area of interest in our lab is development of novel stereoselective methods for asymmetric synthesis of organic compounds with biologically activity as well as chirality. It is our strength that we can design and prepare the target compounds with various functionalities based on better understanding of fundamental principles and knowledge on chemical reactivity and selectivity of molecules.

Fine Chemicals Laboratory

Design & Synthesis of Functional Materials

Ionic Liquids and Carbonates for Batteries: Ionic liquids have unique properties such as high ionic conductivity, wide voltage window, non-volatility and non-flammability. We have developed novel ionic liquids as electrolytes in lithium-ion battery applications to overcome some drawbacks with conventional organic electrolytes. Development of high performance carbonate electrolytes with superior safety and handling characteristics is another topic of interest.

Materials for Electroplating: Organic additives in the electrolytes for electrochemical deposition processes are important for defect-free filling of microvias or Through Silicon Vias. We have been developing new types of organic additives for high density interconnect boards such as PCBs.

Other High Performance Molecules: Another area of our continuing interest has been the synthesis of high performance molecules such as 2,6-dimethylnaphthalene (2,6-DMN) that is a key starting material for the next-generation engineering polyester PEN, and polynitro-substituted strained compounds that are expected to be high explosives with superb safety characteristics.

Development of Synthetic Methodologies & Processes

Stereoselective Dihydroxylations: Stereoselective OsO_4-catalyzed dihydroxylations of various allylic amino olefins have been achieved by efficient control of their acyclic conformations. Bioactive molecules with a vicinal amino diol moiety such as a callipeltin D subunit, isostatine and phytosphingosine have been synthesized through the methodology.

Intramolecular Stereoselective Additions: Our research interest in an efficient asymmetric synthesis of bioactive molecules with an amino alcohol unit has resulted in the stereoselective introduction of functional groups from internal nucleophiles that are linked to the stereogenic centers in the starting material. Stereoselective intramolecular 1,4-addition reaction and epoxidation have been developed to produce statine and its nitrogen analogue, DHGA, HGA, and AHPPA derivatives.

Synthesis of Biologically Active Compounds

Total synthesis of natural or unnatural products: Some natural or unnatural products with beneficial biological activity could be applied to cure several diseases such as cancer, inflammation, hypertension, etc. We have synthesized pareitropone and its analogs as potential anticancer agents, and several known and new dipeptides with antibacterial and antihypertension activity.

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Water Environmental and Membrane Technology Laboratory

The membrane market in the area of water environment is rapidly growing worldwide due to climate change. Therefore, development of innovative membranes and membrane processes are obvious to win at the highly competitive water markets. Considering nearly 50 years of membrane history, our goal is to deviate from conventional technology, but to approach from the molecular biological level (little David) to conquer the rapid growing water industry (giant Goliath).

Molecular Biology (Quorum Sensing) for Innovative Membrane Processes Against Global water Shortage

Bacteria perceive the cell population density using small signaling molecules called autoinducers and regulate their group behaviors such as biofilm formation as a response (Quorum Sensing, QS). This means that blockage of cell to cell communication at the molecular level can inhibit the intrinsic problem of biofilm growth on the membrane.

Based on this QS concept, we have developed new biofouling control techniques, using enzymatic or bacterial quorum quenching (QQ) to uproot intrinsic membrane biofouling in membrane processes at engineering scale for water & wastewater treatment.

Preparation of Quorum Quenching Bacteria Entrapping Media

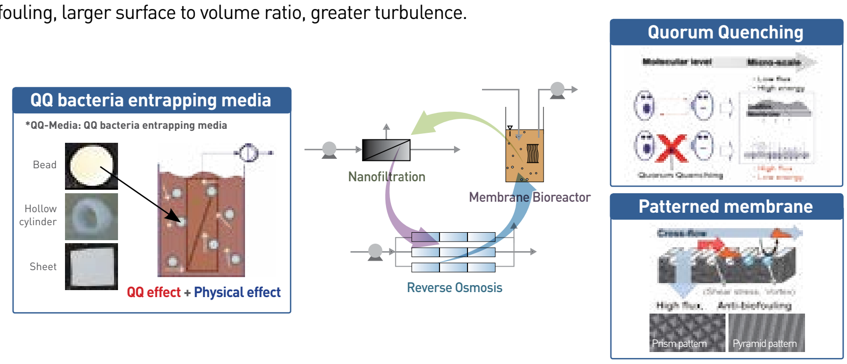
Various QQ-bacteria entrapping media (QQ-media) have been developed to protect QQ-bacteria against other microorganisms living together in the same reactor as well as to enhance physical washing effect.

Diverse shapes and sizes of QQ-media such as bead, cylinder, hollow cylinder, and sheet were prepared and applied to different membrane processes, taking into account types of membrane modules like flat-sheet or hollow-fiber modules.

Preparation of Patterned Membranes

In order to cope with problems of current commercial membranes (lower flux, higher energy consumption, fouling) used in water treatment, Patterned and Pizza membranes are being developed.

Using nanotechnology, especially lithography, various surface structures (pyramid, embossing, prism, etc) are imparted to conventional membranes to make patterned membrane having advantages such as lower fouling, larger surface to volume ratio, greater turbulence.



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We in the 21st century, have to take action seriously against the climate change followed by global water problem on which global concerns are focusing more and more. On the other hand, this issue of water shortage precipitates the growth of giant water industry worldwide. Membrane technology has been recognized as one of the solutions to aforementioned issue because it can be applied in broad spectrum of water area and play a key role in i)production of drinking and industrial waters of high-quality, ii) treatment and re-use of wastewater and iii) development of zero-discharge system in various industrial sectors and more.

We have done research on membrane technology for more than twenty years. Currently, we are preparing Patterned Membranes which have advantages such as higher flux, less energy consumption, longer lifespan, but work well against membrane fouling. We are also studying deeply Quorum Sensing (QS) and Quorum Quenching (QQ) mechanisms in mixed microbial communities in order to uproot biofouling problem confronted in any membrane process.

The ultimate goal of our lab is to develop innovative membranes and membrane processes of highly competitive in the world water markets, combining IT & NT (Patterned Membranes) and BT (QS/ QQ at molecular biological level).

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Polymer Chemistry Laboratory

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Polymer Chemistry Lab is devoted to synthesis, characterization of novel polymers and understanding polymer chemistry. Our efforts are aimed at applying these technologies for many possible applications, such as biological, environmental technologies, fuel cell, redox flow batteries, lithium ion batteries, and high performance polymers. A variety of new polymers, their derivatives, and new polymer composite materials, for example, liquid crystalline polyoxyethylenes, antimicrobial polymers having acrylate backbone structures, polymer electrolytes for lithium ion batteries containing PEG or organic/inorganic hybrid moieties, polythiophene-based conducting and light emitting polymers, polybenzimidazole and poly(arylene ether sulfone) derivatives for fuel cell membranes, fluorinated and zwitterionic polymers having antifouling properties, and high performance nanocomposites containing carbon nanomaterials including graphene moieties, were prepared through various synthetic and processing approaches. Through these studies on chemistry, synthesis, and applications of polymers, we would like to contribute to the advances in the science and technologies in the chemical engineering society.

Polymers for Biological and Environmental applications

Various copolymers containing a renewable cardanol moiety were prepared via radial polymerization for surface coating applications. Cardanol has antibacterial property originated from its phenol group. Fluorinated monomer or dopamine-based monomer was used as a comonomer to impart antifouling property to the film surfaces. With these polymers, multi-functional coating surface could be prepared. For example, water treatment membranes with antifouling and antibacterial properties were obtained by simple coating of these polymers. In addition, membranes based on such polymers were prepared. For example, interfacially-synthesized polyamide membranes with carbon nanomaterials exhibited high water permeability with high salt rejection value, and cellulose-based, stimuli-responsive ionic/hydrophilic polymer membranes improved FO system performances due to less severe internal concentration polarization.

A nanocomposite reverse osmosis membrane containing carbon nanotubes (CNTs) and graphene oxide (GO) exhibits a superior performance through a synergistic combination of CNTs and GO.

Polymers for Fuel Cells and Redox Flow Batteries

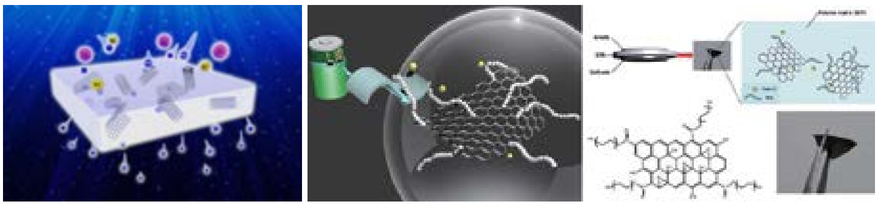
Polymers for the fuel cell and redox flow battery applications have been synthesized. Especially hydrocarbon based polymers and their cross-linked structures were prepared for the mid temperature fuel cell applications. The polymer membranes showed high proton conductivity and physicochemical stability. The membrane electrode assemblies prepared from these polymer membranes showed outstanding fuel cell performance with long-term stability even at harsh operating conditions. Also, the designing of hydrocarbon based polymers for redox flow battery applications are focused on increasing chemical stability and ion selectivity in highly acidic environment.

Polymers for Lithium Ion Batteries

Ion-conducting polymers based on poly(ethylene glycol) methyl ether methacrylate were synthesized and used as solid polymer electrolytes for lithium ion batteries. Solid polymer electrolytes resolve safety issues of conventional liquid electrolyte system such as explosion and leakage. Various components such as organic/inorganic hybrid POSS, functionalized graphene oxide, core-shell silica having boron moieties were incorporated to enhance mechanical/electrochemical properties of electrolytes. Our solid polymer electrolytes show excellent cycle performance even at elevated temperature.

High Performance Polymers

Polymer nanocomposites with improved physical properties for various applications were prepared using graphene derivatives as fillers. Various approaches to prepare graphene-derivatives modified with various kinds of chemical moieties including polymers were introduced because the modification of graphene is strongly needed to increase the miscibility with the polymer for practical applications of the polymer nanocomposites. The physical properties of polymers including mechanical strength, thermal properties, and electrical properties were much improved by using such graphene derivatives as the fillers of polymer nanocomposites.



Polymer composite membranes and electrolytes having functionalized graphene oxide filler

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Energy Process Engineering Laboratory

Modeling and Optimal Control of Nonconventional Processes

Dynamic modelling and control of car after treatment system is conducted for reducing pollutants from vehicle with high fuel efficiency. This system is affected by fast and unpredictable disturbances. Model based control with reinforcement learning can provide robust optimal control.

We also develop a model predictive control (MPC) technique combined with iterative learning control (ILC), called the iterative learning model predictive control (ILMPC), for constrained multivariable control of batch processes. It can easily handle various issues for which the general MPC is suitable, such as constraints, time-varying systems, disturbances, and stochastic characteristics.

Microalgae Culturing System for Biodiesel and Value-added Products

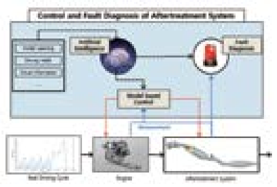
Current production of biofuel and value-added products using microalgae is still at laboratory scale phase because of its economical inefficiency. To overcome this limitation, various researches have been developed in our group. First, soft sensor based on Raman spectroscopy and filtering techniques are developed to predict and monitor the culture condition in real time. Second, model approach which integrates intracellular metabolic information and macro-scale cell growth model is proposed. Finally, model based optimization and control schemes for improving productivity of high value added materials are developed with experimental verification. And currently, our research area is expanded to high added value product such as pigments for health food from microalgae culturing system.

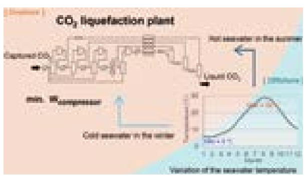
Carbon Capture and Storage (CCS) Technology, Plant Operation and Maintenance

We have develped several simulation based optimization and control schemes for the integrated plant including Carbon Capture and Sequestration (CCS) chain and Plant Operation & Maintenance (O&M) within virtual plant environment. For example, we developed the optimal design and operating conditions of the CO2 liquefaction process with considering variation in cooling water temperature. The variations in the operational energy and other operational issues are investigated and the optimal discharge pressure of the final stage compressor before the Joule–Thomson (J-T) expansion and the optimal pressure ratio of multistage compressors are proposed to minimize the total compressor power consumption. In addition, a dynamic model of the pre-cooling process of cryogenic CO_2 tanks is also developed. Then through the linearized MPC module, optimal control input sequences which are affected by the value of the terminal penalties are obtained.

Asset Management using Dynamic Optimization and Fault Detection and Diagnosis

In order to manage complex water pipe line network efficiently, integrated supervisory system and effective leak detection methods are essential. We developed a management platform for water pipe line network which can make decision based on statistical model and cost model. Also we developed an improved leak detection of water pipe line network system based on signal processing, and scheduling technique of water supply system which is based on mixed integer nonlinear optimization.





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Energy Process Engineering Laboratory are focused on development and application of modeling, control, monitoring, and optimization techniques not only for the existing fossil fuel based energy production and chemical processes, but also for the nonconventional processes such as semiconductor production, bioreactor, and engine exhaust aftertreatment system to enhance their efficiencies with environmental consideration. The main projects are development of plant operation and maintenance system within virtual plant framework, model predictive control and monitoring of automotive engine exhaust aftertreatment system, optimization of value-added product using microalgae, run-to-run control of batch processes including semiconductor production system and polymerization reactor, development of the whole process model of carbon capture and storage, development of energy planning approach based on dynamic optimization technique. In addition, we have also conducted research on optimal design of cooling processes using rigorous 3-D CFD simulation and continuous process for producing specialty chemicals. Our lab has built a microalgae culture system with monitoring and real-time control function for commercialization of microalge based biodiesel and value-added products.

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Our research area is electrochemical engineering related to the development of electrochemical energy storage devices including Li-ion batteries, Na-ion batteries, Li metal batteries (Li-S, Li-air), Mg batteries, and Redox flow batteries.

Our research activities are centered on i) understanding fundamental electrochemical behaviors of intercalation and conversion materials, such as reaction and failure mechanisms, with emphasis on interfacial chemistry regarding ionic transport between solid (electrode) and liquid (electrolyte), ii) searching for new charge storage materials focusing on the relationship between crystal structure and conduction mechanism, and iii) applying fundamental understanding to design new materials and electrochemical systems showing excellent performance.

The ultimate goal of our research is the development of new innovative electrochemical energy storage systems with high energy density pursuing for a safe, clean, and more efficient energy system as one of the grand challenges facing humanity.

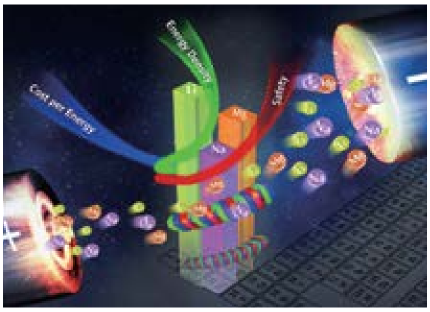
Electrochemical Energy Sytems Laboratory

◉ Na-ion Batteries

To meet the high demand for energy storage systems such as smart grid and electric vehicle applications, the next generation of secondary batteries is urgently required. Among the various post rechargeable battery systems, Na-ion batteries are one of the promising choices because of the natural abundance, non-toxicity, and chemical similarity of sodium ions with lithium ions. Since sodium positions just below lithium in Group 1A of the periodic table, the heavily studied synthetic protocols, characterization methods, industrial techniques, and scientific equipment/facilities of Li-ion batteries can be efficiently applied for Na-ion batteries. Sodium-ions with a large ionic size, however, can derive different kinetic and thermodynamic properties. Therefore, the deliberate design of materials and electrochemical systems is required to improve electrochemical performance. Our group has developed several promising electrode materials such as phosphorus, Sn_4P_3, SnSe, $Na_{0.7}MnO_2$, and $Na_{4-a}M_{2+a/2}(P_2O_7)_2$.

◉ Li Metal Batteries

Many aspects of a failure mechanism in Li metal anode are still not fully understood, and therefore, in-depth studies on these issues are demanded to improve the electrochemical performance of Li metal batteries including Li-air and Li-S batteries. In particular, the interface chemistry between Li metal and electrolytes is still not well characterized, although it is known that the electrochemical performance of Li metal anode is strongly dependent on the interface chemistry such as the formation of solid electrolyte interphase (SEI) layers. Therefore, our group focuses more on the improvement of surface properties through intensive studies on protective layers preventing Li dendrite growth and irreversible electrolyte decomposition. In addition to Li metal anode, we develop cathode materials for Li-air and Li-S batteries.



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Laboratory for Rheology and Processing of Microstructured Materials

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Our research is oriented toward the investigation of the complex flows of viscoelastic fluids. As most materials used in many industries are viscoelastic, it is important to understand the complex behavior of viscoelastic fluids under the flow field to achieve high performance and high productivity. For this purpose, we develop and apply numerial algorithms to simulate complex flow behavior of viscoelastic fluids in diverse process conditions. In addition, we develop new rheometric platforms and investigate the rheological properties of nano-based composite materials.

Modeling and Simulation

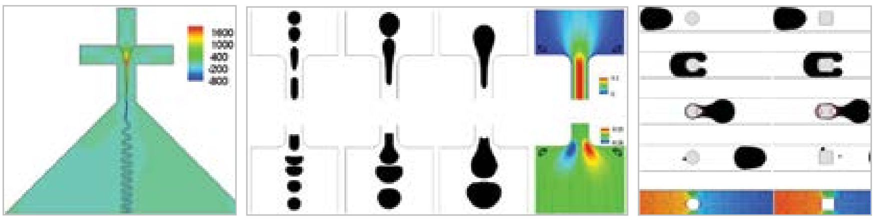
As most materials used in industy are viscoelastic, they show different behavior compared to the conventional Newtonian fluids. Understanding the flow behavior of these viscoelastic fluids is important to control the actual process. We use supercomputer to perform the flow analysis of viscoelastic fluids and develop numerical analysis platform to analyze primary unit processes appeared in many industries, for instance, multi-phase flow of viscoelastic fluids in addition to the flow analysis of basic processes like extrusion, injection molding, coating, etc.

Non-linear Rheology

Conventional rheometers provide the information about the responses of fluids in well-defined simple flow field, but in actual processes deformation is much larger and the flow field is very complex. To bridge the gap between them, we study the non-linear behavior of complex fluids and rheological properties under oscillatory squeezing and mixed flow. Flow behavior in a more complicated geometry such as contraction and expansion are also investigated both experimentally and numerically. We are trying to find out the relationship between the non-linear rheological properties and microstructural changes of complex fluids from these researches.

Nano Rheology

We are interested in application of nano particles. We develop manufacturing technology of polymer nanocomposites by applying electric fields, investigate the mechanism of nano particle localization in polymer blends, and study the interrelationship among the transport properties, microstructure, interfacial characteristics, and processing of polymer blends/composites.



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Our research is to understand structure-interaction property relations and its resulting microscopic or macroscopic behavior. To this end, We've developed theories, numerical methods and employed numerical simulations to study molecular phenomena and evaluate properties of various systems like polymers, lipids or colloids, both qualitatively and quantitatively. We've used statistical mechanics to understand how molecular parameters translate into equilibrium and non-equilibrium thermodynamic behaviors. These researches provide predictive tools for both static and dynamic properties.

Theoretical and Computational Soft Matters Laboratory

Theoretical Modeling of Block Copolymers using Self-consistent Field Theory

Motivated by recent experiments of directed self-assembly of AB diblock copolymer thin film induced from patterned substrates, we employ self-consistent field theory (SCFT) which is well known for studying inhomogeneous polymeric materials, especially block copolymers. We investigated the effect of each roughness factor, such as period and depth of eroded line patterns. The higher-order accurate and stable pseudo-spectral method is adopted to numerically solve the SCFT equations. Appropriate cavity function is also employed to represent the square wave patterns. There is some correspondence between the orientation of BCP micro-domain and roughness factors. We can examine the critical condition where inversion occurs between parallel and perpendicular orientation of BCP on patterned substrates.

The Experimental and Theoretical Study on Wrinkle to Fold Transition

In Mother Nature, there exist buckling/folding structures in diverse scales, from human lung to geological stratum. Inspired by those phenomena, study on buckling/folding has been continued for societal benefit, therefore, formation and control of buckling/folding structure is a very important issue in science and engineering. Buckling/folding structures introduced by metal/polymer bilayer system are experimentally and theoretically analyzed. Researches on applications such as superhydrophobic surfaces, stretchable conductor and other energy devices are also conducted.

Molecular Dynamic Study on Inhomogeneous Polymeric Materials and Interfacial Properties

Various equilibrated phase structures - including S (spherical), H (hexagonal), G (gyroid), and L (Lamellar) phases - are obtained by our approach. To verify our method, various properties of the lamellar phase are examined and compared with previous results reported earlier. We are planning to extend our approach to 3D structures. In addition, the effect of structural differences of copolymers on the interfacial behaviors at the immiscible polymer blend is studied using molecular dynamics simulations.

Density Functional and Boltzmann Transport Study on Thermoelectric Materials

The thermoelectric effect is electron transfer induced by temperature gradient in metals and semiconductors, and vice versa. In this research, behaviors of electrons and phonons are investigated to calculate electronic and thermal properties like electronic and thermal conductivities, Seebeck coefficient, and figure of merit using DFT, BTE and molecular dynamic simulations.

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Organic Synthesis Laboratory

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Our group has focused on bead technology, which plays a key role in the field of solid-phase organic chemistry. We reported a variety of catalyst /reagent-immobilized resin beads for efficient organic synthesis, core-shell type resin bead for solid-phase peptide synthesis, and affinity beads for harvesting protein. Also, we have developed various kinds of biocompatible surface-enhanced Raman scattering (SERS) nano-materials (SERS Dots™) for encoding compound libraries and diagnostic application. In addition, we have constructed peptide library system based on bead and microarray technologies to find out and analyze specific ligands which has specific relationships between the peptides and target enzymes/proteins. Finally, we have modified bio-active molecules with peptides to modulate the properties of bio-active molecules, such as anti-oxidants and whitening agents, which can be applied in cosmeceutical industries.

◉ Bead Technology, Polymer Supported Catalyst and Reagent

Bead technology is important to obtain the best synthetic performance in the field of solid-phase peptide synthesis (SPPS). Various core-shell type resin beads have been developed in our lab in order to improve the synthetic efficiency of peptides. also, Polymer-supported catalysts and reagents have gained a great deal of interest in the area of organic chemistry due to many advantages such as easy work-up, simple isolation of the product and reusability. For these purpose, we have developed polymer-supported metal catalyst and polymer-supported IBX reagent for numerous organic reactions. Furthermore, affinity bead which is enable to separation, purification and concentration of protein was developed.

◉ Peptide Library and Peptide Chip

Many critical diseases, such as cancer and Alzheimer disease, are concerned with kinase activity. Thus, we have constructed peptide library on solid support to discover the kinase substrates and inhibitors with one-bead one-compound (OBOC) method. When the different peptide sequences were randomly synthesized on the each polymer supports by using split and mix method, we analyze enzyme specificity or activity from the results. Also, we established various peptide microarray techniques for bioassay. For example, we developed spot synthesis, which is parallel peptide synthesis on a glass chip by using surface modification, and micromirror array (MMA), which can assemble biological molecules by using selective illumination.

◉ Bio Application of SERS Nano-Tagging Materials (SERS dots™)

SERS (surface-enhanced Raman scattering) has broadened the applications of Raman spectroscopy in biology and biomedicine because of high sensitivity, selectivity and multiplexing capacity. In addition, SERS tagging materials have many advantages, such as the lack of photobleaching, narrow peak band widths, and single laser excitation for detection of multiple tagging. We have developed biocompatible SERS tagging materials (SERS dots™) and demonstrated their feasibility for intracellular cancer targeting and imaging. Recently, we focused on preparation of multi-functional SERS dots™ by utilizing fluorescence dye for effective analysis, and magnetic nanoparticles for separation of cancer stem cell.

◉ Peptide-based Cosmetic and Druglike Materials

The use of biologically-active natural product is limited in industry due to its instability for manufacturing process, short-half life and low permeability in human body, and insufficient activity. Thus, we have modified a variety of natural compounds; ascorbic acid, kojic acid, hydroxycinnamic acid, with peptide to improve their properties such as stability, biological activity and cell permeability. In addition, activity of the synthetic compounds is evaluated by various assay system. in particular, since we have focused on depigmentation and anti-aging, structure and activity relationship (SAR) study are performed with major target enzyme in cosmetic & pharmaceutical industries such as matrix metalloproteinase and tyrosinase.

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Supercritical Fluid Process Laboratory

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We are exploring the use of supercritical fluids as green solvents for developing clean technology or green products. We have extensive capabilities and experience in working with high pressure and/or high temperature. At SNU, there are various facilities available for bench- to pilot-scale studies of supercritical fluids. The current research areas are numerous and include particle design, material processing, chemical reactions, bio-refinery, polymerization, extraction, fractionation, and waste-refinery. Our research results have been actively transferred to the industries so that a number of commercial plants have been successfully operated. We also have been joining the international network to build a better understanding of supercritical fluids and other researchers in the world through the student and academic exchange program.

Nano-Particulate and Composite Design using Supercritical Fluids

- Recrystallization and micronization of drug particles (Aspirin, Ibuprofen, Itraconazole, Cefpodoxime Proxetil, Varsatan)
- Nano particulates of high energy materials with/without surface modification (HMX, RDX, HNIW)
- Synthesis of metal oxide particles with/without surface modification (CeO_2, $LiCoO_2$, $LiFePO_4$, ZnO-CeO_2, $Ce_xZr_{1-x}O_2$, Fe_2O_3, ZnO, $BaTiO_3$)
- Formation of drug complex (β-CD, PVP)

Green Chemistry using Supercritical Fluids

- Biodiesel synthesis with in-situ formed nano catalysts
- Upgrading of super-heavy oil using supercritical fluids
- Decross-linking of XLPE/XLPP using supercritical methanol
- TPA synthesis from p-xylene using subcritical water and supercritical CO_2
- Polymerization in supercritical fluids
- Biomass pre-treatment using subcritical water
- Removal of residual solvent from food and drugs using supercritical CO_2

Food Processing using Supercritical Fluids

- SFE of sesame oil (Commercialization of 2,000 ton/yr plant)
- Supercritical CO_2 processing of brown rice
- Coldbrew coffee/tea/herb production
- Extraction of PL-PUFA from krill using supercritical CO_2 and ethanol

Waste-Refinery using Supercritical Fluids

- SCWO for wastewater from TPA manufacturing plant
- SCWO for organic and inorganic blended wastewater
- Hybrid process for synthesis of metal oxide particles during SCWO

Restoration of Joseon Dynasty Annals using Supercritical Fluids

- Extraction of beeswax using supercritical fluids
- Supercritical drying for microstructure
- Impregnation of beeswax using supercritical fluids

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Electrochemical Energy Conversion & Storage Laboratory

Fundamental Phenomena Involved in Batteries and Capacitors

Batteries and capacitors are often described as a virtually living system since their electrochemistry, phase transitions and transport properties continuously vary not only during cycling but also throughout their lifetime. A fundamental understanding of the mechanisms and kinetics prevailing in these complex systems, in particular at the electrode-electrolyte interfaces, is needed to characterize and improve the performances of the present battery and capacitor technologies.

Experimental Methodologies

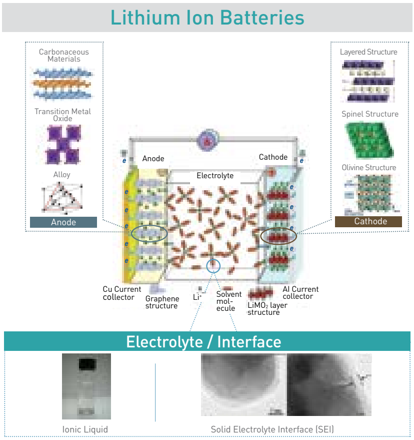
In-situ analytical tools can provide more reliable and accurate data than that obtained by ex-situ ones in the characterization of batteries and capacitors. In-situ DEMS (differential electrochemical mass spectrometry), Raman, dilatometry, XPS (x-ray photoelectron spectroscopy), IR (infrared spectroscopy) are utilized. AC impedance spectroscopy is also used to differentiate the electrochemical processes that occur with different rate characteristics (for instance, complex capacitance analysis).

Failure Modes

Safety and cell life are the most stringent issues, among others, to realize electric vehicles and electricity storage systems in the near future. Safety and cell life of batteries and capacitors are deeply associated with the thermal and electrochemical stability of the constituent materials. The thermal and electrochemical stability of SEI (solid electrolyte interphase), electrodes, electrolytes, and ionic liquids are studied.

New Materials and Processes

The performance of batteries and capacitors is commonly limited by the performance of the constituent materials, such that the improvements in materials' technologies and their preparation processes are desperately needed to meet the tomorrow's market. Recent discovery of nano-structured materials with many unique thermodynamic and kinetic characteristics has open opportunities to develop novel tailored electrodes/electrolytes. Also studied are the amorphous electrodes materials that carry high rate capability, the expanded graphites for capacitors, and the oxide materials that are lithiated by conversion reaction.



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Electrochemical phenomena play a fundamental role in providing essential materials and devices for modern society. For instance, the electrochemical energy conversion and storage devices such as batteries and electrochemical capacitors power the wireless revolution in mobile phones and notebook computers, and now enable the electric vehicles and electricity storage generated from renewable sources. Of primary concern in this laboratory is; first, understanding of the fundamental phenomena involved in these electrochemical systems; second, development of experimental methodologies to characterize them; third, unraveling the failure modes responsible for the safety and life problems; finally, improvement of the present technologies and development of new materials, processes, and devices.

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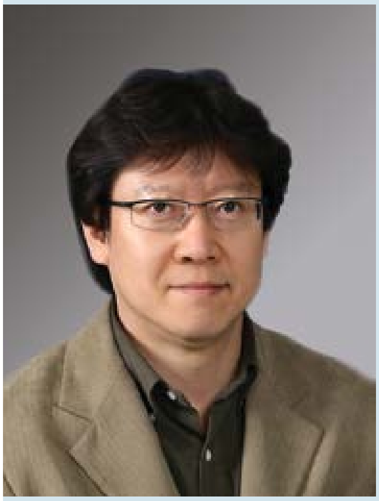

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All the molecular mechanisms operating inside living organisms have been optimized during evolution. In particular, proteins, an essential biological element for the survival of life, have also been optimized for their functions. These proteins, however, have never encountered the nanomaterials, a well-established and flourished product of recent nanotechnology, during the evolutionary process. Fusion between proteins and nanomaterials existing at the same size-scale, therefore, could optimize/compromise their functions into novel materials with unique properties which have never been witnessed in the history of evolution. In our lab., multifunctional and multidimensional protein-based hybrid materials have been prepared by employing various nanoparticles and allosteric/self-assembly proteins capable of responding external stimuli. Ultimately, we try to develop biocompatible nanomaterials or devices useful for monitoring and controlling human's physiological activities by integrating and synchronizing the multifunctional protein-based bio-nano fusion materials. Eventually, the resulting biocompatible sensing materials/devices will be applied at human-machine interface not only to improve human's sensing power but also to catch a minute change in signals of human physiology. In particular, α-synuclein (αS), an amyloidogenic protein pathologically related to Parkinson's disease, has been employed to fabricate gold-nanoparticles (AuNP) multi-dimensional structures by taking advantage of the unique self-assembly and surface adsorption properties of the αS-AuNP conjugates.

Advanced Protein Materials Laboratory

Fabrication of Hierarchical 1D, 2D, 3D Structures of AuNPs and Their Applications for Biosensor Development

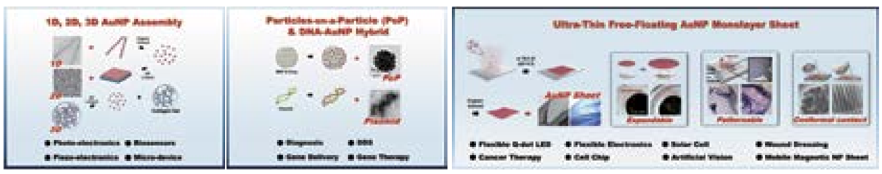
- Fabrication of AuNPs into multi-dimensional structures of 1D chains, 2D arrays/films, 3D microcapsules
- Functionalization of the multi-dimensional products with other NPs (Q-dots & magnetic NP) and αS-interactive compounds
- Preparation of free-floating AuNP monolayer film patterned in multi-island clusters of AuNPs
- Detection Systems for external physical signals (light, pressure, heat, sound)

Preparation of the αS-AuNP Complex with MSN (Mesoporous Silica Nanoparticle) or Nucleic Acids for Intracellular Drug or gene Delivery and their Applications for Theranostics

- αS ligand-mediated selective drug release from PoPs (Particles-on-a-particle) and development of high efficiency DDS
- Intracellular delivery of DNA or siRNA to control gene expression and applications in the areas of molecular biology and biotechnology
- Fabrication of theranostic PoP nanocomposites prepared with various NPs and αS-interactive biological materials

Large scale Preparation of free-floating AuNP Monolayer Film and its Applications in Nanotechnology and Bioengineering

- Photonic and electronic materials applications;
  1. Applications to non-volatile memory device, solar cell, fuel cell, and flexible electronics
  2. Multi-functional films with various NPs and αS-interactive compounds for Q-dot LED, mobile sheet with magnetic NP, membrane sensors
- Applications in biotechnology and biomedical engineering;
  1. Skin patch for drug-delivery and wound treatment, light-responsive artificial retina
  2. Cancer therapy with photodynamic effect



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2. Jee Eun Yang, Jae Sung Park, Eunae Cho, Seunho Jung, and Seung R. Paik, **2015**, Robust Polydiacetylene-based Colorimetric Sensing Material Developed with Amyloid Fibrils of α-Synuclein, *Langmuir*, **31**(5), pp 1802-1810.

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Cell and Microbial Engineering Laboratory

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Research objectives of our laboratory are the application of biotechnology and nanotechnology to microbial and animal cell systems for the production of useful biomaterials and for the development of useful bio-based systems.

Development of Artificial Olfactory System and Biosensor

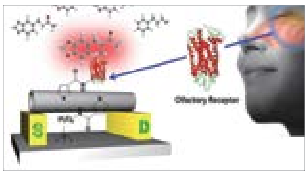
The research objective is to develop a human-like artificial olfactory system and smell/taste sensing biosensors. Human olfactory receptor genes are collected and cloned into bacterial or human cells to express the olfactory receptor proteins. The specific bindings between the olfactory receptors and odorant molecules are detected using cell-based, nanovesicle-based, protein-based, and peptide-based systems. The artificial olfactory system (bioelectronics nose) is expected to replace the sensory evaluation method, and then can be used for standardization and visualization of smell. For the development of biosensors, the biological elements containing olfactory receptors are combined with various nanomaterials such as carbon nanotubes, conducting polymer nanotubes and graphene. The olfactory biosensors can be applied to various fields such as disease diagnosis, food quality assessment, monitoring of environments and processes, and smell industries.

Nano Biotechnology and Stem Cell Research

We are developing the methods for the control of cellular behavior using nanomaterials such as nanoparticles and nanotubes. Aligned multi-walled carbon nanotube sheets are used to differentiate human mesenchymal stem cells to neural cells. We also investigate the properties of the bacterial nanoparticles and the dynamic behavior of the magnetic nanoparticle-incorporated cells. Cellular behavior of the magnetic nanoparticle-incorporated cells can be controlled or manipulated in the magnetic field. 3-D spheroids can be efficiently generated through the focused magnetic force using a magnetic pin. This system ensured not only reproducible and size-controlled generation of spheroids but also versatile types of spheroids such as random mixed, core-shell, and fused spheroids, providing a very useful tool for various biological applications. These techniques are used for the guidance of stem cell differentiation and cancer cell research.

Cellular Engineering and Protein Delivery

In our lab, we found that 30K proteins originating from silkworm hemolymph have very interesting properties. The 30K proteins (30Kc6, 30Kc12, 30Kc19, 30Kc21 and 30Kc23) have molecular weights of around 30 kDa. The 30Kc6 protein inhibits apoptosis and consequently enhances the production of recombinant proteins, such as erythropoietin, interferon-b, and monoclonal antibody, in mammalian cell systems. The 30Kc19 can penetrate cell membrane as well as stabilizing cargo proteins. Cell-penetrating peptide derived from the 30Kc19 protein was also identified. We are investigating these 30K proteins and their corresponding genes for anti-apoptosis engineering and protein delivery. These approaches can be applied to the production of biopharmaceuticals, delivery of therapeutic proteins, and cell reprogramming for stem cell research.



Bioelectronic Nose

Bioelectronic Tongue

SELECTED PUBLICATIONS

1. J. H. Lim, E. H. Oh, J. Park, S. Hong, & T. H. Park, **2015**, Ion-channel-coupled receptor-based platform for a real time measurement of G-protein-coupled receptor activities, *ACS Nano*, **9**, 1699–1706.

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Systems and Synthetic Biology Laboratory

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The ultimate research goals of our lab are **1)** understanding biological systems better by elucidating complex regulatory networks with high-throughput methods, **2)** expanding design methods by development of biophysical models and molecular toolboxes for efficient genome/genetic engineering, and **3)** designing optimal artificial cells based on this information so that cells can dynamically respond to environmental and/or intracellular metabolite changes by various sensors in a programmable manner for biochemical and biomedical applications. In order to achieve these goals, iterative rounds of systems/synthetic biology and evolutionary approaches would be needed. First, using systems biology approaches, complex biological regulatory networks need to be elucidated in order for us to efficiently identify engineering targets. Second, several key molecular tools for synthetic biology should also be developed for efficient engineering and/or design of biological systems. With these tools, biological systems should be engineered to **1)** efficiently utilize renewable biomasses and **2)** specifically sense various environmental changes to produce target products. Then, the engineered systems can be further evolved to meet the required **1)** ranges of sensing and actuating capacities and **2)** productivity and yield of target products. We can also profile what's going on inside the cell with genome-scale analysis and re-utilize the information for further enhancement.

Meta-structure Reconstruction

Knowing what we are dealing with is the most important strategy to successfully engineer our targets. Although it had been several decades to study E. coli, there are still plenty of unknown regulatory mechanisms, networks, and interaction between them beyond the genomic sequence. Owing to the development of innovative high-throughput technologies, we can now have potentials to fully reconstruct meta-structure of bacterial regulatory networks beyond E. coli. We use the cutting-edge high-throughput genome-scale experimental methods such as ChIP-exo, RNA-seq, TSS-seq, and Ribo-seq to build a comprehensive regulatory network of bacterial genome. Comprehensive understanding of the meta-structure of bacteria will continue to enable applications in metabolic engineering, microbial engineering for energy, materials, and human health.

Synthetic Molecular Tools

Building a synthetic metabolic pathway requires molecular tools to design DNA sequence to achieve a specific expression level (static control) and a dynamic response of expression (dynamic control). We develop various molecular tools that can control multiple layers of regulation such as transcription, translation, and post-translation processes. Furthermore, we examine various approaches that can generate phenotypic diversity to evolve the engineered system to meet the expected performance.

Programming Cells

With various molecular tools, we program cells to solve issues in energy, environment, healthcare applications. For example, we design and construct de novo metabolic pathways to produce chemicals and fuels from renewable biomasses. Iteration of evolutionary approaches and genome-scale comprehensive analysis of the system would generate an economically feasible bioprocess. We also integrate multiple environmental signals and implement synthetic control over biological processes for various types of environmental and biomedical applications.

SELECTED PUBLICATIONS

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Molecular Catalysis and Reaction Engineering Laboratory

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Our research is focused on determination of reaction mechanisms and active sites in surface catalysis by metals, metal oxides, metal-oxygen clusters, and olefin polymerization catalysts. Characterization and manipulation of catalyst surfaces by scanning tunneling microscopy (STM), and energy & environmental catalysts are also our major research concerns. The goal of our research is to demonstrate the design of new materials and of new catalysts starting from the discovery of novel surface reactions, and thus to establish a new paradigm for the development of catalytic science and technology.

Molecular Catalysis by Metals, Metal Oxides, Metal-Oxygen Clusters, and Olefin Polymerization Catalysts

This research includes (i) chemistry and catalysis of various polyoxometalate structural classes, (ii) selective partial oxidation, (iii) acid-base catalysis, (iv) fine chemical synthesis, (v) catalytic membrane reactor, (vi) polymer-supported catalysts, and (vii) catalyst design by molecular imprinting technique.

Characterization and Manipulation of Catalyst Surfaces by Scanning Tunneling Microscopy

Our STM studies of heteropolyacids (HPAs) span a wide range of issues in catalysis and surface science. These examples include (i) determination of redox and acid properties of bulk HPA catalysts from surface properties of nanostructured HPA monolayers, (ii) probing molecular shape, orientation, and packing of self-assembled HPA arrays, (iii) identification of individual molecules in the mixed HPA catalysts, and (iv) fabrication of atomically sharp and stable STM probe utilizing HPA single molecule.

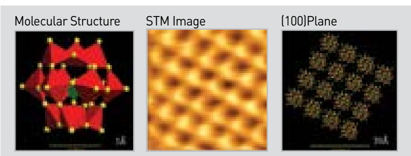
Energy & Environmental Catalysts

Our research areas related to energy and environmental catalysts are (i) hydrogen production for fuel cell, (ii) production of high-valued chemicals from bio-based chemicals, (iii) purification of automotive exhaust gas.

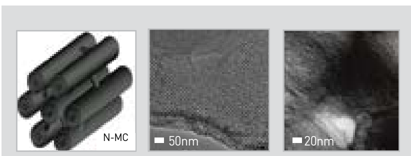
Catalyst Development for Petrochemical Industries

We are developing molecular catalysts for petrochemical industries. We are conducting following researches.

1. Chemical immobilization and molecular catalysis of polyoxometalate catalysts
2. Hydrogen production by steam reforming of LNG and ethanol
3. Epoxidation of propylene to propylene oxide
4. Oxidative dehydrogenation of propane to propylene
5. Direct synthesis of hydrogen peroxide from hydrogen and oxygen
6. Ammoxidation of propane to acrylonitrile
7. Direct synthesis of methane to BTX
8. Alkylation of isobutane with 2-butene
9. Hydrogenation of bio-based C4 chemical (succinic acid)



Characterization and manipulation of heteropolyacid catalyst



Chemical immobilization of heteropolyacid catalyst on mesoporous material

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Photo & Electrochemical Energy Laboratory

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Our group research is focused on the application of electrochemical methods with (opto)electronic and ionic materials and the realization of devices and systems. We perform research on fuel cells, batteries, and photoelectrochemical cells. Our goal is to develop high performance electrochemical technologies that are miniaturized, low cost, long durable and environmentally safe. Fundamental studies of the solid/liquid interface, in-situ analysis, and electrochemical nanotechnology are also carried out.

Fuel Cells

Fuel cell is an electrochemical system which converts directly chemical energy to electric energy with high efficiency. Scientific and industrials impacts of fuel cell could be enormous in the areas of stationary, electric vehicle, residential, portable electronics like a notebook computer and cellular phone. Our research has focused on high efficient new electrode nanomaterials, nanostructures, and electrode-electrolyte assembly for polymer electrolyte fuel cell and direct methanol fuel cell.

Photoelectrochemical Cells

We are working on the development of semiconductor electrodes for photoelectrochemical cells. Nanostructured oxide semiconductors such as TiO_2, Fe_2O_3, and WO_3 are being investigated as photoelectrodes in sensitized solar cells and photoelectrochemical hydrogen production. Our research works cover maximization of surface area for photon absorption and structural engineering of nano-oxides for efficient charge collection.

Advanced Batteries

Recently, small or micro size power source is very necessary to realize small size electronic device, it has great potential for use in areas, such as MEMS, smart card, on-chip power sources and portable electronic devices. Therefore micro- or thin-film battery is a promising candidate for a micropower source, which is fabricated all solid state, which we are pursuing. We are also developing new nanomaterials for novel battery materials. In-situ analyses using XRD, FTIR and electrochemical XPS are performed to understand electrode materials and electrode/electrolyte interface.

SELECTED PUBLICATIONS

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6. W. J. Chung, J. J. Griebel, E. T. Kim, H. Yoon, A. G. Simmonds, H. J. Ji, P. T. Dirlam, R. S. Glass, J. J. Wie, N. A. Nguyen, B. W. Guralnick, J. Park, A. Somogyi, P. Theato, M. E. Mackay, Y.-E. Sung*, K. Char* & J. Pyun*, **2013**, The use of elemental sulfur as an alternative feedstock for polymeric materials, *Nat. Chem.*, **5**, 518-524.

Environmental Materials & Process Laboratory

Advanced Materials for Clean Environment and Energy

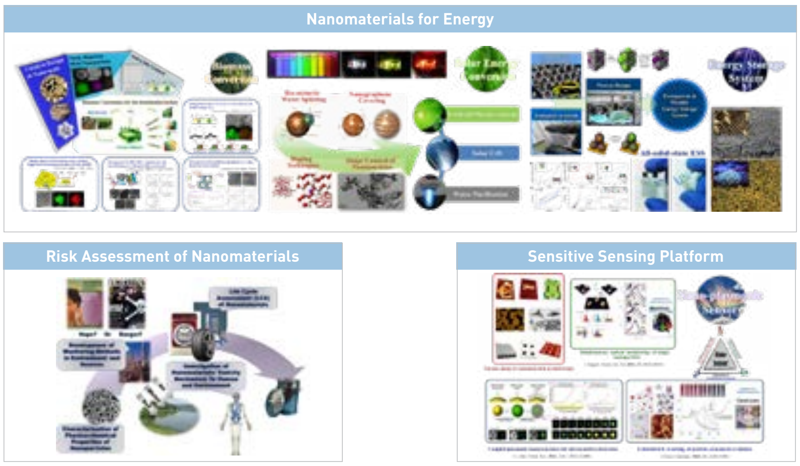
The fabrication of advanced (nano/mesostructured) materials has been an important issue in terms of both their functionalized structures and applications to adsorbents, electrochemical materials or catalysts whose surface area or shape need to be controlled. Mesoporous materials (silica, alumina, aluminosilicate, titania, and carbon) having uniform-pores and hollow spheres have been prepared and studied via advanced preparation methods and appropriate characterizations. These materials could be easily used for the various applications by surface modification with functional groups. In addition, resulting materials could be used to prepare the catalysts, photocatalysts (activated under visible light), and artificial photosynthesis system.

Highly Sensitive Novel Sensing Platforms

The development of highly sensitive and selective detection methods is quite important to measure surface-generated signals for biosensing and environmental monitoring. In our group, a variety of surface-fabrication methods (i.e., micro/nanolithography, physicochemical modification of surface) and analyzing methods (i.e., atomic force microscopy, surface plasmon resonance spectroscopy, and dark field microscopy), have been applied to the effective detection of biologically and environmentally relevant issues. Recently, we have been focusing on the development of more powerful sensing platforms, which allow highly-sensitive, selective, label-free, real-time and multiplexed detection methods, combining with nano-biotechnology.

Human and Environmental Risk Assessment of Nanomaterials

Nanotechnology has been developed dramatically and their numbers of products have increased in the markets. However, potential toxic effects of nanomaterials on human and environmental concerns have been still wrapped on veil. In our group, we pursuit to develop an assessment technology for EHS (environmental, health and safety) risks of nanomaterials, such as determination on the exposure source and route, development of nanomaterials' LCA (life cycle assessment), characterization of physicochemical properties, and development/standardization of monitoring methodology for nanomaterials. From this study, we have possessed competitive technology for the evaluation of nanotoxicity and their guideline, which was served as references for policy decision and screening tools for following research.



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We pursue a converging of nanotechnology (NT), environmental technology (ET), and biotechnology (BT). We expect our results to be effectively utilized for an improvement of human life. The research areas are classified as i) Advanced Materials for Clean Environments and Energy, ii) Highly Sensitive Novel Sensing Platforms, and iii) Human and Environmental Risk Assessment. Our research group has performed these studies with a strong basis of chemical engineering. In addition, we have applied the fundamental studies with new concepts to ET as well as recent attractive NT including in situ sensors, nanobiochips, memory device, fuel cell, nano/micro reactive systems, adsorbents and catalysts. Currently, we are aiming at developing practical processes based on the results.

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The research area of this labotratory is enzyme engineering, especially computational design of enzyme, cofactor regeneration and cofactor-mediated enzymatic synthesis of chemicals, and environmental biotechnology using biocatalysts.

We aim to become a world class laboratory, with profound researches on theories and applications of enzymes for industrial applications. We believe a good research comes from a creative thinking.

Enzyme and Environmemtal Biotechnology Laboratory

◉ Computational Design of Enzyme

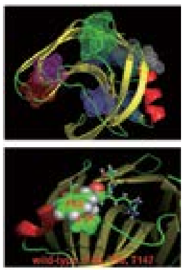
There are several important factors to be considered when applying enzymes and proteins in industries. We are interested in computational design of thermostability, activity, stability in organic solvent, substrate specificity, and optimum pH of enzymes. Based on analysis of the factors that affect proteins significantly, strategy to design cavity and packing of enzyme was established. And we proposed a spring model to explain enzyme functions, by which, a strategy to increase the enzyme activity was developed.

◉ Novel Approaches for Cofactor-Dependent Enzyme Reaction

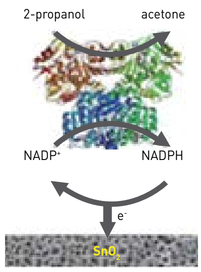
Oxidoreductases are very attractive enzymes to synthesize high value-added compounds, and these enzymes require cofactor for the reaction. However, cofactors have to be regenerated for economically efficient enzyme process because it is too expensive to stoichiometric use. We developed a novel mediator-free cofactor regeneration system using novel metal oxide electrode. Using this mediator-free system, various enzyme reactions are being performed to produce chemicals. Researches for the fabrication of enzyme-based biosensor using nanoparticles are also being conducted.

◉ Environmental Biotechnology

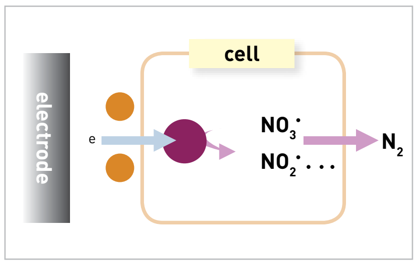
Nitrate and ammonia ions are one of the water pollutants from wastewater. Intermediates from these pollutants cause eutrophication and threats to human health. The nitrate removal process contains 4 enzymatic reactions and ammonia removal process contains 3 enzymatic reactions. We developed a novel bioelectrochemical nitrogen removal technology that simplified the complicate biological process.



Enzime Design



Confactor Regeneration



Environmental Biotechnology

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Water Environment & Energy Laboratory

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In these days, the word 'convergence' is widely used in various research areas and the 'converged' researches are contributing tremendously to enhancements in our society. Our research group focus on convergence of science and engineering studies in water treatment and environment research fields. In this perspective, we focus on four topics: desalination, application of electrochemistry for water treatment, and precious metal recovery using battery technology.
The research on desalination divides into capacitive deionization process and membrane process. In these processes, energy consideration is essential so that energy recovery is simultaneously pursued. The study on safe water engages electrochemical reaction for oxidant generation in order to disinfect water and this approach contains the fabrication of new electrode material. In addition, this research focuses on safe water production with the "New Appropriate Technology" development for the developing or underdeveloped countries. The resource recovery intends to recover valuable metals from brine, sea, or wastewater. New paradigm embracing battery technology combined with water treatment is vigorously studied in developing this technology. Overall, we aim to enhance the quality of human life with future-oriented convergence technology.

Capacitive Deionization (CDI)

Capacitive deionization (CDI), which is viewed as an alternative or competing technology for RO technology, has been getting academic and industrial attention as a novel desalination process. Resembling supercapacitor, the principle of electrical double layer capacitance (EDLC) is used for deionization. CDI removes ionic species in saline water by applying an electric potential to porous electrodes. Here, we are trying to improve the CDI system by understanding operation mechanisms, employing novel materials for CDI electrode, developing innovative system design, and optimizing the energy consumption by incorporating energy recovery system.

Resource Recovery

We developed novel lithium recovery process successfully by convergence technology blending separation and battery technology together. It is much faster recovery process than the conventional process which goes through evaporation process longer than a year. This technology is representative technology which successfully demonstrates convergence of energy and environment through combining battery technology with resource recovery technology. Now, we are trying to enhance the efficiency of the electrodes and design to optimize process.

Electrochemical Oxidation

Various oxidants (hydroxyl radical (•OH), ozone (O3) and hydrogen peroxide (H2O2), chlorine (Cl2) and chlorine derivatives (e.g., •Cl, ClO2)) generated on the electrode surface during electrolysis play a critical role for the water treatment. These reactive oxygen species (ROS) are produced by water splitting while Cl2 and chlorine derivatives are formed from the dissolved chloride ion. The species and yield of the produced oxidants are strongly affected by several reaction factors including electrode material, electrolyte composition, applied current (or voltage), pH, temperature and type of electrolysis.
For scientific and technological success of electrochemical water treatment, we focus on the development of novel electrode materials and the reactor design to provide effective oxidant production based on understanding surface chemistry and process engineering.

Membrane

Membrane is a selective barrier with ability to transport one component more readily than others due to differences in physical and/or chemical properties across the membrane and the permeating components. We aim to develop not only high performance reverse osmosis (RO) technology but also new membrane technologies such as forward osmosis (FO), and pressure retarded osmosis (PRO).

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Chemical Convergence for Energy & Environment

WCU Program

World Class University

WCU Program

- A higher education subsidy program of the Korean government, funded by the Ministry of Education, Science and Technology
- Launched 2009, to transform Korean universities into world-class research institutions by inviting international scholars who possess advanced research capabilities
- Inter-disciplinary studies for higher educational and industrial competitiveness

C_2E_2 Chemical Convergence for Energy & Environment

http://c2e2.snu.ac.kr

The C_2E_2 major funded by the WCU Program is a graduate course at the School of Chemical and Biological Engineering, SNU.

- Energy & Environment applications through Chemical Convergence (Nanoscale Toolbox, Processing & Hybridization of Organic / Inorganic Nanomaterials)
- World-Class Faculty : 11 accomplished professors including 4 foreign scholars
- Research Funds : 10 million USD for 5 years
- **Course Curricula**

Field	Chemical Convergence Materials	Nanocomposite Processes	Energy & Environmental Applications
Course	Characterization of Nanomaterials	Physics of Solid Polymers Solid State Physical Chemistry	Materials & Structure of Chemical Convergence for Energy & Environment
	Modern Techniques in Polymerization	Introduction to Surface/ Interface Chemistry	Introduction to Chemical Convergence for Energy & Environment
	Functional Polymer Nanomaterials	Nanocomposite Materials for Energy Storage & Conversion	Energy Storage Materials & System
	Synthesis of Organic Nanomaterials	Special Topics to Chemical Convergence for Energy & Environment 1	Advanced Environmental Chemistry
	Characterization & Properties of Self-Assembled Materials	Special Topics to Chemical Convergence for Energy & Environment 2	Electrochemical Energy Engineering
	Functional Inorganic Nanomaterials	Seminar of Chemical Convergence for Energy & Environment	Environmental Process Engineering

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The Theato research group focuses on the synthesis of functional polymers. Over the last years we have developed an expertise to prepare highly functionalized polymers and block copolymers with a precisely defined architecture. Based on the synthesis of functional polymers our primary interests are devoted to the development of novel multi-responsive polymers, e.g. polymers that respond to different stimuli such as temperature or light, as well as the behavior of functional polymers on surfaces and/ or at interfaces. Further interests of the group are functional nanoparticles of organic or inorganic nature. But also novel polymeric materials for electronic applications (OLEDs, photovoltaics, batteries or sensors) are developed in our group.

Laboratory of Functional Polymer Surfaces

Synthesis of Well-Defined Reactive Polymers

Investigation of the controlled polymerization (ATRP, RAFT, NMP, ROMP, ROP, ADMET, etc.) of reactive monomers represents a very challenging synthetic task. Established methods of controlled polymerizations enabled the polymerization of a series of classical monomers with a striking precision. Precise architectural control of homopolymers and block copolymers are the reasons for the huge success of all controlled polymerization techniques. As the direct synthesis of highly functionalized polymers by controlled polymerization techniques has not been possible for a long time, we have developed an indirect synthesis of functional polymers with unprecedented precision in two sequential steps, resulting in an extremely variable synthetic scheme.

Functional Polymer Films

The behavior of ultra-thin polymer films on surfaces and the respective influence on surface properties can be understood and controlled in a very elegant manner using specifically designed hybrid polymers. Accordingly we have expanded into different research areas: i) immobilization of biological complexes on surfaces, ii) hybrid polymer coatings for controlled wettability, iii) stimuli-responsive surfaces, iv) biosensors, v) patterning of block copolymer thin films for information storage, or vi) processable hole- and electron injection layers.

Organic or Inorganic Functional Nanoobjects

To establish nanomaterials in nanotechnolgical applications the understanding and the control of the self-assembly process of nanoobjects is of great importance. Polymers play a dominating role in nanochemistry and thus, functional polymer architectures have been used for the modification of inorganic nanoparticles. With such precisely surface modified nanoparticles a direct assembly has been realized. But also the development of functionalized nanoparticles to flexibly graft polymers from or onto has been achieved. Additionally, with our concept of reactive polymers, we have the chance to prepare functional nanomaterials as thin films (2D), nanowires, nanorods, and nanorings (1D) or nanoparticles (0D).

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Laboratory for Nanocomposites and Polymeric Materials

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Our research interests are focused on the synthesis, characterization and processing of polymeric and nanocomposite materials possessing enhanced properties for potential applications in artificial muscles, information storage and energy, with an emphasis on the control of nanoscale structure. Recent developments in polymer and colloid chemistry offer the synthetic chemist a wide range of tools to prepare well-defined, highly functional building blocks. We seek to synthesize complex materials from a "bottom up" approach via the organization of molecules, polymers and nanoparticles into ordered assemblies. Control of structure on the molecular, nano- and macroscopic regimes offers the possibility of designing specific properties into materials that are otherwise inaccessible. We are particularly interested in compatibilizing interfaces between organic and inorganic matter as a route to combine the advantageousproperties of both components. This research is highly interdisciplinary bridging the areas of physics, engineering and materials science with creative synthetic chemistry.

Magnetic Mesoscopic Polymers: Field Induced Assembly of Functional Nanoparticles

We are pursuing a modular synthesis of nanocomposite chains composed of ferromagnetic colloids and functional block copolymers. Controlled and living polymerizations allow the organic chemist to prepare of a wide range of functional block copolymers which will be used as polymeric surfactants in the formation of magnetic colloidal dispersions. In the presence of a magnetic field, these core-shell magnetic nanoparticles align into polymeric chains. The assembled chain can then be locked in by crosslinking of reactive groups attached to the block copolymer surfactant. It is anticipated that the hybridization of these components on the nanoscale will synergistically combine the beneficial film forming properties of organic polymers with the magnetic character of the inorganic colloid. We have developed new synthetic methods using polymeric surfactants to prepare well-defined ferromagnetic nanoparticles and demonstrated that dispersed colloids can be magnetically assembled into mesoscopic 1-D nanoparticle chains, which we refer to as mesoscopic polymer chains, or "meso-polymers." Functionalization and controlled assembly of these novel building blocks are currently being pursued.

Nanostructured Materials for Energy

We are investigating the preparation of novel nanostructured semiconductor materials and conjugated polymer composites for solar cells and energy storage in the form of batteries and supercapacitors. We have developed synthetic methods to functionalize CdSe quantum dots that will enable electro-copolymerization with thiophene monomers to prepare covalently linked, electroactive materials. In particular, we are investigating the direct modification of transparent conductive oxide materials via electro-polymerization to prepare electrochemically "wired" thin films of polymer-semiconductor hybrids with anodic electrodes. We have also developed synthetic methods to prepare well-defined cobalt oxide nanowires for evaluation in solar cells and Li-batteries. This interdisciplinary project combines synthetic organic chemistry, polymers, colloid science, optical spectroscopy, thin film/surface characterization and device fabrication.

Nanostructured Composite Thin Fims for Magnetic Tape

We are investigating the preparation of nanostructured thin films of organic polymers and magnetic nanoparticles as novel binder materials for magnetic tape. This technology is critical for long term archival storage, which is still the most reliable and cost-effective media for this application. New synthetic methods to functionalize and protect high moment and coercivity ferromagnetic nanoparticles against corrosion and sintering are being developed using organic polymers and polymeric precursors.

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Laboratory of Engineering Enzyme Reactivity for Biocatalysis

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Nature uses enzymes to catalyze a wide range of synthetic reactions. Biocatalysis adapts nature's enzymes for synthesis of drugs, chemical intermediates & biofuels. Using biocatalysis in place of chemical methods minimizes pollution and the use of toxic and non-selective chemical reagents. To adapt nature's enzymes for chemical synthesis we change the selectivity of enzymes and even change the type of reaction that they catalyze. We change the structure of natural enzymes using either computer analysis to design changes or limited random mutagenesis when we are not sure what the best change would be. Our current focus is extending the catalytic range of serine hydrolases to perhydrolysis, acyl transfer in water, and carbon-carbon bond formation.

Perhydrolysis

Many serine hydrolases catalyze perhydrolysis-formation of peroxycarboxylic acids from carboxylic acids and hydrogen peroxide-likely using an esterase-like mechanism. However, some hydrolases are more effective catalysts than others. Our goal has been to identify molecular mechanisms that enhance perhydrolyis over hydrolysis. So far we have identified two strategies, both involving a loop in the active site near the binding site for water or hydrogen peroxide. One strategy is to move this loop closer to the active site so that hydrogen peroxide fits perfectly. A second strategy is to turn the loop around so that it reduces the reactivity of water, but not hydrogen peroxide. These perhydrolases are being further engineered to remove lignin from biomass.

Acyltransferases

Both esterases/lipases and some acyltransferases transfer acyl groups using a Ser-His-Asp catalytic triad and use similar mechanisms. Acyltransferases transfer the acyl group to an acceptor alcohol, while esterases/lipases transfer the acyl group to water. Comparison of the x-ray structures of structurally related esterases/lipases with acyltransferases reveals a different conformation of the oxyanion loop within the active site. We hypothesize the different conformation in acyltransferases reduces the reactivity of water. We are currently engineering acyltransferase ability into hydrolases to apply them to synthesis of antibiotic and biodegradable polyesters.

Carbon-Carbon Bond Formation

Some serine hydrolases - hydroxynitrile lyases (HNL's) - catalyze formation of a carboncarbon bond - the addition of cyanide to aldehydes. Carbon-carbon bond formation is the key reaction to organic synthesis. Our goal is to expand the range of carbon carbon bond formations catalyzed by HNL's to nucleophiles beyond cyanide. First we engineered a serine hydrolase into a HNL to identify the essential elements for this new reaction. We identified a key amino acid substitution that shifts the orientation of the substrate to change the type of reaction. Next we are engineering enzymes that accept other nucleophiles to create new enzymes for organic synthesis.

SELECTED PUBLICATIONS

1. T. Devamani; A. M. Rauwerdink; M. Lunzer; B. J. Jones; J. L. Mooney; M. A. O. Tan; Z. J. Zhang; J. H. Xu; A. M. Dean; R. J. Kazlauskas, **2016**, Catalytic Promiscuity of Ancestral Esterases and Hydroxynitrile Lyases. *J. Am. Chem. Soc.* **138**, 1046-1056.

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Institute of Chemical Processes (ICP)

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ICP is one of the 13 research institutes belonging to College of Engineering in Seoul National University. Thanks to the donation from SK corporation in 1995 toward research institute building (about 4,000 m3) with a main focus on chemical processes, ICP was founded in 1996 with Prof. Hyun-Ku Rhee appointed as the first director.

ICP is dedicated to conducting and disseminating high-impact and industry-oriented research, training world-leading researchers and engineers, and supporting activities that will advance the research and industry related to chemical processes. ICP has five research divisions in the following areas: process development, semiconductor and electrochemistry, organic materials and polymers, nano/inorganic materials and catalytic processes, and biological/ environmental engineering. Most of the faculty members in School of Chemical & Biological Engineering participate in one of the divisions.
ICP has pioneered research and training collaborations between academia, industry and government. It harbors nine research centers and institutes funded by the government, and among them are Engineering Development Research Center, IBS Center for Nanoparticle Research, The National Creative Research Initiative Center for Intelligent Hybrids, and World Class University. In order to promote active collaborative research with industry, ICP recruited five visiting professors who are current or former CEOs of major chemical companies in Korea. Due to these efforts, ICP has developed tens of industry-sponsored research projects where faculty members in other universities as well as SNU are involved. It also has offered several short courses for practitioners and engineers in industry. With these ongoing efforts and achievements, Seoul National University ranked ICP as the best research institute on campus in science and technology in 2015.

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