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<td>09  Location</td>
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</tbody>
</table>
The Department of Chemical and Biomolecular Engineering at KAIST has just completed its 40th year and is entering the fifth decade of its history. In the course of the 40 years, it has successfully transformed itself into one of the best chemical and biomolecular engineering programs, not only in Korea but also in the world. Currently, it is thriving with one of the largest undergraduate and graduate student bodies of its discipline, 25 full-time faculty members who are recognized as international leaders in their respective fields, and facilities/equipment that provide opportunities to conduct research at the forefront of science and technology.

The discipline of chemical and biomolecular engineering has continually evolved over the years. During the last few decades, we saw the emergence of biotechnology and nanotechnology, which have now become integral components of the discipline. The rapid changes in the field have brought opportunities for significant innovations: The discipline is now at the center of science and technology, positioned to play a major role in addressing some of the most pressing issues for the humanity, such as the energy shortage, global warming, and better healthcare. The fast pace of change has also made it a real challenge to keep its curricula coherent and focused. They left us with the problem to redefine the ways we educate our students, from curricula to methods.

With the rising competition and fast evolving R&D landscape, the next decade will prove to be a challenge for us, but we are confident that we will continue to grow and improve to be recognized internationally for its pursuit of innovation and excellence. We envisage that some of the most innovative ideas on education and research will be generated and tested here. This will be made possible by the unswerving dedications by our faculty and staff, and the inflow of top-class talents who are continuing to be attracted by the intellectually rich and open atmosphere of KAIST. Your continued interest and support as well as constructive criticisms are most welcome.
Overview of Chemical and Biomolecular Engineering

The Department of Chemical and Biomolecular Engineering at KAIST focuses on a new engineering discipline that combines life science and nano science with traditional chemical engineering principles. The main concern of the discipline is to use new scientific discoveries and these principles to design novel and innovative chemical and biological products and processes that improve the environment and the quality of living in a sustainable manner.

The department began with just a graduate program in chemical engineering in 1973. An undergraduate program was added in 1989 as the KAIST and KIT merged. KIT had been established by the government in 1986 as an undergraduate program specializing in science and technology. Following the merger, the department started a new era at the newly constructed Daejeon campus in 1990, with both undergraduate and graduate programs.

To reflect the rapid expansion of the departmental faculty’s research activities into biochemical/biological engineering and nanochemical engineering domains during the 90’s, the name of the department was changed to the Department of Chemical and Biomolecular Engineering in the beginning of 2002.
Currently, the department is thriving with 25 full-time faculty members, 596 undergraduate students, 112 MS students, and 202 PhD students. Over the years the number of BS graduates has grown to 445, MS graduates to 1,360 and PhD graduates to 710. These graduates are now playing key roles in research and development in major companies and research institutes as well as in universities.

The educational goal of the department is to produce leaders who are well versed in the fundamentals of chemical and biomolecular engineering principles and possess the research, leadership and entrepreneurial skills to shape the course of future technology and to help meet this century’s major societal challenges in areas such as energy, environment, and healthcare.

An excellent research infrastructure has now been established in the department. Six engineering research centers for bioprocesses, bioinformatics, energy and environment, systems and synthetic biotechnology, integrated optofluidic systems and advanced biomass are currently active.

**KAIST CBE’s Vision**

KAIST CBE Department will become an exemplary model for future Chemical and Biomolecular Engineering programs through innovative education and research programs. KAIST will be a global trend-setter, influencing how the discipline of Chemical and Biomolecular Engineering will evolve and contribute to solving major societal challenges.

**KAIST CBE’s Mission**

<table>
<thead>
<tr>
<th>Goal 1</th>
<th>Goal 2</th>
<th>Goal 3</th>
<th>Goal 4</th>
<th>Goal 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students are taught scientific phenomena at all length scales and engineering skills to integrate them into innovative product and process designs.</td>
<td>Faculty members cooperate to address major societal problems (e.g., energy, environment, and health) through interdisciplinary research.</td>
<td>Innovation and entrepreneurial spirit are key characteristics of our faculty and students.</td>
<td>International visibility and global footprint are vastly improved.</td>
<td>All employees seek continuous improvement at all times.</td>
</tr>
</tbody>
</table>

- **Educate** engineers who understand science of chemistry, molecular biology and economy of process and products.
- **Serve** the industry, society and nation through innovation of technology and advancement of knowledge.
Status

Faculty
25 professors, 8 emeritus professors, 1 visiting professor, 7 adjunct professors, 7 research professors

Staff
11 post-doctorate research fellows, 6 administrative and technical staff members

Student Enrollment (1, April / excl. students in LOA)

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
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<td>56</td>
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<td>110</td>
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<td>M.S.</td>
<td>87</td>
<td>88</td>
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<td>Ph.D.</td>
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<td>166</td>
<td>162</td>
<td>149</td>
<td>149</td>
<td>149</td>
<td>172</td>
</tr>
</tbody>
</table>

Foreign students: 23 March, 2013

Career Paths of the Graduates (2008.2-2012.1)

Bachelor’s Degree Recipients
- Industries
- Graduate / Professional Schools
- Military Service
- Others

Master’s Degree Recipients
- Industries
- Academic Institutes
- Research Institutes
- Ph.D. Programs
- Others

Doctoral Degree Recipients
- Industries
- Academic Institutes
- Research Institutes
- Others
Education

Overview of the Curriculum

The education at KAIST focuses on cultivating creative problem defining/solving skills and independent research abilities in addition to the traditional education by lectures. The curriculum is designed to lead from the bachelor’s to the master’s to the PhD course. There is flexibility that allows us to recognize advanced courses taken from earlier degree programs or from other institutions.

Undergraduate Program

The department offers a four-year undergraduate program leading to the academic degree, Bachelor of Science. The curriculum is designed to provide the students with a rigorous regimen for learning the basic chemical and biomolecular engineering principles, while maintaining the flexibility to pursue a wide variety of intellectual explorations. In addition to the course work, our students are encouraged to participate in internships, overseas exchange programs, and undergraduate research programs, in order to diversify their knowledge/skill sets and prepare themselves for graduate schools or research-oriented careers.

Degree Requirements

A. Total Required Credits: At least 130 credits in total
B. General Courses: At least 27 credits and 9AU
   - Mandatory General Course: 6 credits and 9AU
   - Elective General Course in Humanities & Social Science: at least 21 credits
C. Basic Courses: at least 32 credits
   - Mandatory Basic Courses: 23 credits
   - Elective Basic Courses: at least 9 credits
D. Major Courses: At least 41 credits
   - Mandatory Major Courses: 18 credits (Molecular Engineering Laboratory, Chemical and Biomolecular Engineering Laboratory, Introduction to Chemical and Biomolecular Engineering, Industrial Organic Chemistry, Chemical Engineering Analysis, Molecular Thermodynamics and Energy Systems)
   - Elective Major Courses: At least 23 credits
E. Elective Courses

F. Research Courses: at least 4 credits
   - Graduation Research: 3 credits (required)
   - Department Seminar: 1 credit (required in senior year)
   - Individual Study: 2 credits at most

G. English Proficiency Requirements
   - Prior to graduation, our students must demonstrate a high level of English proficiency by scoring higher than 83 points on the TOEFL iBT or by earning an equivalent score on other exams.

H. Graduation Requirements for Foreign Students: TOPIK (Test of Proficiency in Korean)
   - Undergraduate foreign students are required to obtain level 2 or higher score in TOPIK before entering or during studying at KAIST.

※ General and basic course requirement for our undergraduate program vary with year of the admission; therefore, students entering KAIST before 2011 should refer to the Course Completion Requirements by Year of Admission.

Course List

<table>
<thead>
<tr>
<th>Classification</th>
<th>Course Code</th>
<th>Course Title</th>
<th>Lecture:Exp: Credit(HW)</th>
<th>Term</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandatory</td>
<td>CBE 201</td>
<td>Molecular Engineering Laboratory</td>
<td>1:4:3(6)</td>
<td>Fall</td>
<td></td>
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<tr>
<td>Major Course</td>
<td>CBE 202</td>
<td>Introduction to Chemical and Biomolecular Engineering</td>
<td>3:0:3(3)</td>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CBE 203</td>
<td>Industrial Organic Chemistry</td>
<td>3:0:3(3)</td>
<td>Spring or Fall</td>
<td>*CBE221</td>
</tr>
<tr>
<td></td>
<td>CBE 205</td>
<td>Chemical and Biomolecular Engineering Analysis</td>
<td>3:0:3</td>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CBE 221</td>
<td>Molecular Thermochemistry and Energy System</td>
<td>3:0:3(3)</td>
<td>Fall</td>
<td></td>
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<tr>
<td></td>
<td>CBE 301</td>
<td>Chemical and Biomolecular Engineering Laboratory</td>
<td>1:4:3(6)</td>
<td>Spring</td>
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<tr>
<td>Elective</td>
<td>CBE 260</td>
<td>Biomolecular Engineering</td>
<td>3:0:3(3)</td>
<td>Spring</td>
<td>*BS209</td>
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<tr>
<td>Major Course</td>
<td>CBE 261</td>
<td>Biochemical Engineering</td>
<td>3:0:3(3)</td>
<td>Fall</td>
<td></td>
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<td></td>
<td>CBE 303</td>
<td>Physical Chemistry for Chemical and Biomolecular Engineers I</td>
<td>3:0:3(3)</td>
<td>Fall</td>
<td></td>
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<td></td>
<td>CBE 311</td>
<td>Molecular Reaction Engineering</td>
<td>3:0:3(3)</td>
<td>Spring</td>
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<tr>
<td></td>
<td>CBE 321</td>
<td>Separation Processes</td>
<td>3:0:3(3)</td>
<td>Fall</td>
<td></td>
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<td></td>
<td>CBE 331</td>
<td>Fluid Mechanics for Chemical Engineering</td>
<td>3:0:3(3)</td>
<td>Spring</td>
<td></td>
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<tr>
<td></td>
<td>CBE 332</td>
<td>Heat and Molecular Transfer</td>
<td>3:0:3(3)</td>
<td>Spring</td>
<td></td>
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<tr>
<td></td>
<td>CBE 341</td>
<td>Process Simulation and Control</td>
<td>3:1:3(3)</td>
<td>Fall</td>
<td></td>
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<tr>
<td></td>
<td>CBE 351</td>
<td>Introduction to Macromolecular Engineering</td>
<td>3:0:3(3)</td>
<td>Spring or Fall</td>
<td></td>
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<tr>
<td></td>
<td>CBE 362</td>
<td>Biosensors</td>
<td>3:0:3(3)</td>
<td>Fall</td>
<td>*BS432</td>
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<tr>
<td></td>
<td>CBE 404</td>
<td>Physical Chemistry for Chemical and Biomolecular Engineers II</td>
<td>3:0:3(3)</td>
<td>Spring or Fall</td>
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<tr>
<td></td>
<td>CBE 441</td>
<td>Chemical and Biological Product Design</td>
<td>3:0:3(3)</td>
<td>Spring</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>CBE 442</td>
<td>Optimal Design and Economics</td>
<td>3:0:3(3)</td>
<td>Fall</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>CBE 443</td>
<td>Chemical and Biological Product Design Laboratory</td>
<td>1:6:3(6)</td>
<td>Spring or Fall</td>
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<tr>
<td></td>
<td>CBE 455</td>
<td>Nanochemical Technology</td>
<td>3:0:3(3)</td>
<td>Spring or Fall</td>
<td>**</td>
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<tr>
<td></td>
<td>CBE 461</td>
<td>Biorefineries for fuels and chemicals</td>
<td>3:0:3</td>
<td>Spring or Fall</td>
<td>**</td>
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<tr>
<td></td>
<td>CBE 462</td>
<td>Bioseparation Engineering</td>
<td>3:0:3</td>
<td>Spring or Fall</td>
<td>**</td>
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<td></td>
<td>CBE 471</td>
<td>Introduction to Environmental Engineering</td>
<td>3:0:3(3)</td>
<td>Spring or Fall</td>
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<tr>
<td></td>
<td>CBE 473</td>
<td>Microelectronics Processes</td>
<td>3:0:3(3)</td>
<td>Spring or Fall</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>CBE 474</td>
<td>Instrumental Analysis for Chemical Engineers</td>
<td>3:0:3</td>
<td>Spring or Fall</td>
<td>**</td>
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</tbody>
</table>
### Graduate Program

The Department of Chemical and Biomolecular Engineering at KAIST aspires to develop one of the world’s best research programs. A prerequisite to achieving the goal is a strong graduate program. The various labs in the department are equipped with excellent equipment and facilities that provide the students with the means to conduct top-class research in a wide spectrum of fields ranging from traditional chemical engineering to materials and bio. Every graduate student in the department is expected to acquire in-depth knowledge and skills to develop and to transmit new knowledge in a specialized area of chemical and biomolecular engineering. Possible research areas include biotechnology, nanomaterials, catalysis, soft materials, and energy/environment/systems. Each of the research areas is described in detail in the “Research” tab.

The department offers a number of degree programs that should meet each student’s needs, including the Master of Science (MS) and Doctor of Philosophy (PhD) degree programs. In both cases, they are asked to undergo formal coursework and perform thesis research. Course requirements for the MS and PhD degrees have evolved with time; therefore, the students are advised to consult with their advisors. All students are asked to select a thesis advisor from the Chemical and Biomolecular Engineering faculty and must submit a thesis dissertation in order to receive the degree.

### Degree Requirements

- **Master’s Program**
  - A. Total Required Credits: at least 33 credits
  - B. Mandatory General Courses: 3 credits and 1AU
    - Choose one of the following: Scientific Writing, Introduction to Computer Application, Probability and Statistics, Introduction to Materials and Engineering, Engineering Economy and

<table>
<thead>
<tr>
<th>Classification</th>
<th>Course Code</th>
<th>Course Title</th>
<th>Lecture:Exp: Credit(HW)</th>
<th>Term</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elective Major Course</td>
<td>CBE 481</td>
<td>Special Topics in Chemical and Biomolecular Engineering</td>
<td>3.0:0:3(3)</td>
<td>Spring or Fall</td>
<td><strong>(Subtitle is assigned)</strong></td>
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<tr>
<td></td>
<td>CBE 483</td>
<td>Engineering Principles of Human Physiology</td>
<td>3.0:0:3(3)</td>
<td>Spring</td>
<td>**BS463, **</td>
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<tr>
<td></td>
<td>CBE 491</td>
<td>Special Topics in Chemical and Biomolecular Engineering II</td>
<td>2.0:2:2(2)</td>
<td>Spring or Fall</td>
<td><strong>(Subtitle is assigned)</strong></td>
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<td></td>
<td>CBE 492</td>
<td>Special Topics in Chemical and Biomolecular Engineering III</td>
<td>1.0:1:1(1)</td>
<td>Spring or Fall</td>
<td><strong>(Subtitle is assigned)</strong></td>
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<tr>
<td>Research</td>
<td>CBE 490</td>
<td>Undergraduate Research</td>
<td>0.6:3</td>
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<td></td>
<td>CBE 495</td>
<td>Individual Study</td>
<td>0.6:1</td>
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<tr>
<td></td>
<td>CBE 496</td>
<td>Seminar for Undergraduate Students</td>
<td>1.0:1</td>
<td></td>
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</tr>
</tbody>
</table>
- CC010 Special Lecture on Leadership (non-credit, general scholarship students, foreign students are excluded)
- CC020 Ethics and Safety I (1AU)

C. Mandatory Major Course: 6 credits

D. Elective Course: at least 12 credits (It is required, at least, to take 9 credits from the lectures offered by the department. Lectures offered in Graduate School of EEWS by the professors of CBE department are considered as lectures offered by CBE department.)

E. Research Credits: at least 12 credits (Including 3 credits from Seminar. Seminar credits may be substituted by the number of semester taking ‘Introductory Korean for Foreigners’ or performing internship required by Interdisciplinary program. Students entering the integrated master’s and doctoral degree program in 2009 and onward are required to take 2 credits of seminar.)

- Doctoral Program
A. Total Required Credits: at least 60 credits
B. Mandatory General Course: 3 credits and 1AU
C. Mandatory Major Course: 6 credits
D. Elective Course: at least 21 credits (It is required, at least, to take 12 credits from the lectures offered by the department. Lectures offered in Graduate School of EEWS by the professors of CBE department are considered as lectures offered by CBE department.)
E. Research Credits: at least 30 credits

※ The course credits earned in the Master’s course work can be used towards the Doctoral degree (except research credits).

### Course List

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<thead>
<tr>
<th>Classification</th>
<th>Code</th>
<th>Course Title</th>
<th>Lecture:Exp: Credit(HW)</th>
<th>Term</th>
<th>Remark</th>
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<tbody>
<tr>
<td>Mandatory</td>
<td>CC010</td>
<td>Special Lecture on Leadership</td>
<td>1:0:0</td>
<td>Fall</td>
<td></td>
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<tr>
<td></td>
<td>CC020</td>
<td>Ethics and Safety I</td>
<td>1AU</td>
<td>Spring or Fall</td>
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<tr>
<td>Mandatory</td>
<td>CC500</td>
<td>Scientific Writing</td>
<td>3:0:3</td>
<td>Spring or Fall</td>
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<tr>
<td>General</td>
<td>CC510</td>
<td>Introduction to Computer Application</td>
<td>2:3:3</td>
<td>Spring or Fall</td>
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<tr>
<td>Choose 1</td>
<td>CC511</td>
<td>Probability and Statistics</td>
<td>2:3:3</td>
<td>Spring or Fall</td>
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<tr>
<td></td>
<td>CC512</td>
<td>Introduction to Materials and Engineering</td>
<td>3:0:3</td>
<td>Spring or Fall</td>
<td></td>
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<tr>
<td></td>
<td>CC513</td>
<td>Engineering Economy and Cost Analysis</td>
<td>3:0:3</td>
<td>Fall</td>
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<tr>
<td></td>
<td>CC522</td>
<td>Introduction to Instruments</td>
<td>2:3:3</td>
<td>Fall</td>
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<tr>
<td></td>
<td>CC530</td>
<td>Entrepreneurship and Business Strategies</td>
<td>3:0:3</td>
<td>Fall</td>
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<td>Classification</td>
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<td>Course Title</td>
<td>Lecture:Exp:Credit(HW)</td>
<td>Term</td>
<td>Remark</td>
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<td>Choose 1</td>
<td>CC531</td>
<td>Patent Analysis and Invention Disclosure</td>
<td>3:0:3</td>
<td>Spring or Fall</td>
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<td></td>
<td>CC532</td>
<td>Collaborative System Design and Engineering</td>
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<td>Fall</td>
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<tr>
<td>Mandatory Major Course</td>
<td>CBE 601</td>
<td>Research Methodology for Chemical &amp; Biomolecular Engineers</td>
<td>2:3:3(3)</td>
<td>Spring</td>
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<tr>
<td></td>
<td>CBE 602</td>
<td>Problem Solving in Chemical &amp; Biomolecular Engineering</td>
<td>3:0:3</td>
<td>Spring or Fall</td>
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<tr>
<td>Selective Major Course</td>
<td>CBE 502</td>
<td>Engineering Applied Mathematics</td>
<td>3:0:3(4)</td>
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<tr>
<td></td>
<td>CBE 503</td>
<td>Numerical Method for Chemical Process</td>
<td>3:0:3(4)</td>
<td>Spring</td>
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<tr>
<td></td>
<td>CBE 505</td>
<td>Chemical Process and Product Design</td>
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<td>Fall</td>
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<td></td>
<td>CBE 511</td>
<td>Design of Reaction System</td>
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<td></td>
<td>CBE 512</td>
<td>Introduction to Catalysis Engineering</td>
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<td></td>
<td>CBE 513</td>
<td>Catalysis for Renewables</td>
<td>3:0:3</td>
<td>Spring</td>
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<td>CBE 522</td>
<td>Introduction to Interfacial Engineering</td>
<td>3:0:3(3)</td>
<td>Spring</td>
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<td>Rate-controlled Separation Process</td>
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<td></td>
<td>CBE 525</td>
<td>Molecular Electronics</td>
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<tr>
<td></td>
<td>CBE 531</td>
<td>Multiphase Reactor Engineering</td>
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<td>Spring or Fall</td>
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<td>CBE 542</td>
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<td>CBE 551</td>
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<td>Spring or Fall</td>
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<td>CBE 552</td>
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<td>CBE 554</td>
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<td>CBE 556</td>
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<td>CBE 644</td>
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<td>CBE 731</td>
<td>Polymer Fluid Dynamics</td>
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<td>Spring or Fall</td>
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</table>
INDUSTRY-SPONSORED EDUCATIONAL PROGRAM

- **CEPP (Customized Educational Polymer Program of Catalyst, Process and Polymeric Materials)**
  Educational Program supported by LG Chemical to educate graduate students in the areas of catalyst, process and polymeric materials.

- **EPLL (Educational Program for LG Innotek LED)**
  Educational Program supported by LG Innotek to educate graduate students in the area of LED technology. [http://epll.kaist.ac.kr]

- **EPSS (Educational Program for Samsung Semiconductor)**
  Educational program supported by Samsung Electronics to educate graduate students in the area of semiconductor processing. [http://epss.kaist.ac.kr]

- **KEPSI (KAIST Educational Program for Semiconductor Industry)**
  Educational Program supported by HYNICS Semiconductor Co. to educate graduate students in the areas of memory, semiconductor element and processing technology. [http://kepsi.kaist.ac.kr]

- **LGenius (LG Display educational program)**
  Educational Program supported by LG Display to educate graduate students in the areas of LCDs, LEDs, OLEDs, flexible displays, etc. [http://lgenius.kaist.ac.kr]
Student Life / Activities

Events

- **Spring - Sports Event / Fall - Excursion**
  A sports meeting for undergraduate students is held at the beginning of the spring semester. During the event, students participate in a variety of physical activities and games. These activities are often done to help freshmen make friends at their new institution and to bond with each other and the upperclassmen, as well as with professors. The CBE department arranges Fall Excursions each year to one of the most important places in the country, such as Mungyeongsaejae Provincial Park and Gyeryongsan National Park. Excursions are a great way to meet and get to know other students and faculty in the department, providing opportunities for students to create a sense of community and foster an appreciation and respect for nature at the same time.

- **Industry Visit**
  Students obtain insight into how companies work and also acquire useful information on industrial practice by visiting industrial sites. Starting in the spring of 2011, the CBE department has been arranging annual industrial site visits with the help of the OCI Company Ltd., one of the leading chemical companies in Korea. During the two-day tour, participants visit the OCI R&D center in Seongnam and the training center in Pocheon, or its plants located in Gunsan, Iksan or other areas.

- **Graduate Student Symposium**
  The KAIST CBE Graduate Student Symposium was inaugurated in 2011 and entered its third year in 2013. The symposium is aimed at providing a forum for publicizing and receiving feedback on the ongoing research activities of our graduate students, and developing personal networks and acquaintances between our students and local industry and company representatives. It is intended to be a student-driven event, to be organized and run by the students with minimal input from the faculty and staff.

- **KAIST CBE Global Distinguished Lectureship**
  The KAIST CBE Global Distinguished Lectureship is an annual event in which an internationally
leading researcher in chemical and biomolecular engineering at a foreign institution is selected and invited to give a series of lectures. The lectures are open to our students and faculty as well as alumni and friends. The visiting lecturer, in addition to giving seminars on recent trends and advances in his/her field is asked to participate in informal discussions with KAIST faculty and students. The seminar series is already becoming a marquee event and a proud tradition in our department. The first three recipients of the lectureship were:
- Prof. William J. Koros, Georgia Institute of Technology (November 16-17, 2011)
- Prof. Gregory Stephanopoulos, Massachusetts Institute of Technology (September 25-26, 2012)
- Prof. Rakesh Agrawal, Purdue University (November 12-13, 2013)

• Town Hall Meetings

The CBE Town Hall Meetings provide a venue to meet with fellow students, professors and other members of the department in an open forum discussion environment. It is an informal gathering, giving all participants a chance to talk personally in a relaxed environment about various issues or problems that matter to them. It is a semi-annual event, occurring near the end of every Spring/Fall semester.

Facilities

• Undergraduate Student Lounge

The Undergraduate Student Lounge, newly renovated in December 2011, offers a common area equipped with four desktop computers, a printer, and a scanner, as well as a private group meeting room with a glass board.

• Floor Lounges

Students are encouraged to use the floor lounges, located at the end of every floor of building W1-3, for individual study and group meetings. These small lounges have chairs and a meeting table along with a glass board.

• Study Space

A study room for undergraduate students is located on the second floor of the building. It is designated as a silent study area, shared by students of the three departments in building W1, which are the Department of Materials Science and Engineering, the Department of Civil and Environmental Engineering, and the Department of Chemical and Biomolecular Engineering. The room provides 80 seats available for individual study.
Scholarships

- "Leaders Scholarship"

The Leaders Scholarship is awarded for academic excellence and is intended to provide support for those students experiencing financial hardship. The scholarships are made possible by the generous support of our donors, external agencies, and industrial partners.

Scholarships given during 2012

<table>
<thead>
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<th>Contributor</th>
<th>No. of Awardee</th>
<th>Amount (/person)</th>
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<td>Hyosung Co.</td>
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<td>Lotte Chemical Co.</td>
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<tr>
<td>GS Caltex Co.</td>
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Research Program

Innovative research programs in both the traditional and emerging areas of chemical and biomolecular engineering are being offered by our faculty members. Most of the research projects are carried out with the financial support from the government as well as industries. Our research and teaching programs challenge the students to strive for innovative and rigorous scientific and technological discoveries. The research experiences are supplemented by various seminars, internships, and course work. The results of the students’ research work are often published in top scientific journals and presented at various international and domestic conferences.

The past graduates from KAIST CBE are now playing leading roles in various international and domestic companies and institutes, contributing to the progress of science and technology in Korea and the world. Many graduates and faculty members have been recognized for their excellence with various prestigious national and international awards.

Current research topics covered by the department’s research programs are described in the following list. We recommend those interested to contact the individual faculty members for more detailed information concerning their research.

Aerosol processing / Air pollution control / Applied rheology / Biodegradable hydrogel / Bioinformatics / Biopharmaceuticals production / Biopolymer / Biosensor and nanobiomaterials / Carbon nanotube / Catalysis / Cell culture / Clean energy production / DNA, cell, protein chip / Drug delivery / Electrodes for battery / Energy systems / Environmental Biotechnology / Fuel Cell / Hydrogen storage / Mass transfer / Membrane separation process / Metabolic Engineering / Metabolism data mining / Microfluidic system / Molecular dynamics / Molecular self-assembly / Nanopatterning / Nano-structured materials / Optical data storage and display / Optical electronics / Photocatalytic reaction / Photonic crystals / Polymer nanocomposite / Processing control, modeling and optimization / Reactive separation / Remediation of Soil and Groundwater / Sol-gel processing / System identification
CBE Research Areas

**Soft Materials (Polymer)**
Polymer Nanomaterials, Organic Opto-Electronic Mat, Polymer Nano Electronics.

**Nanomaterials**
Molecular & Interface Engineering, Superlattice Nanomaterials, Microfluidic systems, Modeling and numerical analysis, Semiconductor and metal nanocrystals.

**Catalysis**

**Energy/Enviroment/Systems**
Bio energy, Batteries, Env, Remediation Eng, Green Eng, Process Systems.

**Biotechnology**
Metabolic Engineering, Systems Biotechnology, Synthetic Biotechnology, Biochips and Biodevice, Nano-Bio MEMS, Protein Engineering, Drug Delivery

KEY ACCOMPLISHMENTS

**Publications**

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<th>Year</th>
<th>Number of SCI papers per professor</th>
<th>Impact factors per professor</th>
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Research Areas

Biotechnology

Biotechnology seeks to apply chemical and biomolecular engineering principles to a broad range of scientific and technological applications using biological systems or bio-related materials in every area from molecules to production plants. In this sense, Biotechnology research is a cross-disciplinary field that allows creative and innovative collaboration within the Department or with researchers outside.

Essential efforts entail the application of traditional and emerging engineering knowledge to understanding fundamental and complex systems of living organisms, e.g., metabolic engineering, and to addressing societal challenges, as in biofuel and fine chemical production. The expansion of research capabilities to the nanoscale materials or biodevices such as DNA/protein chips has broadened the horizon of the Biotechnology research area.

• Research Areas
  - Synthetic/Systems biotechnology based on Omics study.
  - BioRefinery - Production of fine chemicals, biodegradable plastics and biofuels from renewable resources.
  - Nanobiotechnology through BINT convergence - development of Nano-bio devices including DNA/Protein Chip, MEMS, TAS etc.
  - Protein/antibody engineering and high level production in bacterial cultivation.
  - Gene therapy and vaccine delivery

• Professor
  - Metabolic Engineering, Systems Biotechnology, Synthetic Biotechnology [S. Y. Lee]
  - BioSystems [Y. K. Chang]
  - Biochips and Biodevice [H. G. Park]
  - Nano-Bio MEMS [T. S. Seo]
  - Protein Engineering [K. J. Jeong]
  - Drug Delivery [Y. C. Kim]
Nanomaterials

Nanotechnology is a multidisciplinary field that deals with materials and structures in nanometer scales. The combination of design, fabrication, and application of nanomaterials does not only satisfy our scientific curiosity, but it also significantly impacts our daily lives. The fundamental understanding of the relationships among physical properties, chemical compositions, and dimensional structures enables the miniaturization of current devices and creation of new nanomaterials. We know a few, but still many more interesting properties are unknown and unique phenomena are yet to be understood.

We are eagerly exploiting various aspects of nanomaterials, including self-assembly of organic and organometallic amphiphiles, developing functional nanomaterials by assembling nano building blocks into designed patterns, micro-/nano-fluidics and nano sensor systems, functional nano-coatings by chemical vapor deposition, and the design and synthesis of semiconductor and metal nanocrystals.

Research Areas
- Self-assembly of organic and organometallic amphiphiles.
- Functional nanomaterials by assembling nanobuilding blocks into designed patterns.
- Microfluidic systems, chemical and biological detections, and Systems biology.
- Functional nano-coatings using chemical vapor deposited polymeric films.
- The design and synthesis of semiconductor and metal nanocrystals

Professor
- Molecular & Interface Engineering (J. D. Kim)
- Superlattice Nanomaterials (S. M. Yang)
- Microfluidic systems, modeling and numerical analysis (D. H. Kim)
- Functional Nano-Coatings (S. G. Im)
- Semiconductor and metal nanocrystals (D. C. Lee)
Catalysis

Development of alternative energy sources and environmentally benign chemical processes are essential for sustainable development of human society. Catalysis is at the core of developing clean energy sources, including advanced petrochemistry, biorefinery, and hydrogen energy technologies such as fuel cells. Paralleling the efforts to develop new energy sources, catalysis also plays an important role in developing clean environment technologies. Green catalytic processes encourage the design of products and processes that minimize the use and generation of hazardous substances and improve energy and resource efficiency. In order to derive the required functions of catalysts in such processes, understanding the kinetics and mechanisms of the catalytic reaction and how the molecular structure of certain catalysts influence the reaction rate in different ways is necessary. In combination with such fundamental knowledge, cutting-edge nanotechnologies and high-throughput screening of catalysts can be used for designing advanced catalysts.

- Biomass conversion and biomass-derived fuel cell
- Catalyst development via high-throughput screening
- Heavy oil upgrading
- Photocatalytic water splitting
- Development of new nanofunctional materials for catalytic application

- Nano Catalysis & Materials (S. I. Woo)
- Chemical Product Design (S. B. Park)
- Energy & Green Catalysis (M. K. Choi)
Soft Materials (Polymer)

Impetus for the study of soft materials, specifically polymers, is derived from the active pursuit of flexible, lightweight, and inexpensive functional devices. Polymers have served as one of the main themes in chemical engineering and have become one of the key ingredients for industry. Polymers extend from conventional rubber and plastic to medical and electronic applications. Polymer groups in the CBE at KAIST are extensively researching batteries, polymer-based solar cells, fuel-cells, various nanostructures of polymers fabricated by top-down and bottom-up approaches, light-emitting diodes and so forth. Integration of polymer engineering and nanoscience takes us into a new sector in which a wide spectrum of research areas can extend their prospects in efforts to address various challenges, such as energy crisis and health care.

Research Areas
- Polymer Light-Emitting Diodes (LED)
- Secondary Battery
- Polymeric Nanocomposites with MWNT and Graphenes
- Organic Solar Cells
- Polymer-Nanoparticle/Nanorod Hybrid Materials for Sensors and Catalysts
- μ-Encapsulation and controlled Release

Professor
- Intelligent Soft Materials (S. H. Kim)
- Polymer Nanomaterials (O. O. Park)
- Polymer Materials (J. K. Park)
- Organic Opto-Electronic Materials (H. T. Jung)
- Polymer Nano Electronics (B. J. Kim)
**Energy/Environment/Systems**

The Energy/Environment/Systems research area addresses some of the most pressing challenges of our time: securing a stable base for the energy supply and halting the global warming trend. These challenges can be met by developing renewable energy sources and reducing carbon dioxide emission. No single approach is likely to suffice; an effective solution will require creative integration of several approaches including biofuel, photovoltaics, wind energy, and hydrogen, as well as improved use of traditional fossil fuel sources (e.g., coal gasification).

This is a truly interdisciplinary field of study, spanning a broad range from molecular to process to enterprise to earth/atmosphere, and demanding knowledge and expertise in materials, biotechnology, and system engineering. At the forefront of these activities are the chemical and biomolecular engineers whose training in both the basic science and systems engineering make them uniquely qualified to address problems spanning a diverse range.

KAIST's CBE research program in this area is both active and diverse and includes activities in nanomaterials and polymers for solar cells, batteries, and fuel cells; biofuel; hydrogen, storage; carbon capture and storage; and efficiency improvement through smart plant design, optimization, and control.

**Research Areas**
- Biodiesel production
- Microalgal cultivation
- Gas hydrates
- Reactive distillation
- Carbon capture and storage, utilization
- Model predictive control and dynamic programming
- Energy asset management
- Low energy nuclear reaction / cold fusion

**Professor**
- Energy and Environment Systems (H. Lee)
- Process / Materials Design (J. W. Lee)
- Environment Remediation Engineering (J. W. Yang)
- Energy Systems (J. H. Lee)
Research Centers

- BPERC (BioProcess Engineering Research Center)
- BiC (Bioinformatics Research Center)
- EERC (Energy & Environment Research Center)
- CSSB (Center for Systems and Synthetic Biotechnology)
- IOF (Center for Integrated Optofluidic Systems)
- ABC (Advanced Biomass Center)

1. BPERC (BioProcess Engineering Research Center)

Director: Prof. Sang Yup Lee

Introduction
The BPERC is a leading academic and industrial research center aimed at developing bioprocess technologies by integrating upstream to downstream processes. Professors at the Department of Chemical and Biomolecular Engineering are actively involved in developing bioprocesses that allow production of various bioproducts, including primary metabolites, secondary metabolites, biodegradable polymers and recombinant proteins. The BPERC operates a pilot plant, which allows active collaborations with industry companies and helps students to experience industrial bioprocess experiments. Major research facilities include stirred-tank bioreactors (5L, 50L, 300L), membrane bioreactor (100L), process mass spectrometer, process scale centrifuge, ultrafiltration system, GPC, HPLC, homogenizer, and oxygen generating system PSA.

Research Fields
- Systems Metabolic Engineering
  Metabolic engineering is the most active research topic at the BPERC. Systems metabolic engineering strategies aim to optimize the whole bioprocesses from upstream to downstream processes using a series of molecular and computational tools, thereby enhancing the production of bioproducts as well as for the development of new bioproducts.
• **Bioreactor Design**
  Research is dedicated to improving bioreactor productivity through high cell density continuous bioreaction systems. Research topics include membrane bioreactors, cell immobilization, fed-batch and extractive bioconversion systems, development of product-specific bioreactors, and scale-up of bioreactors.

• **Separation and Purification**
  Research is focused on reducing the number of purification steps and improving the recovery yield per step at costs less than conventional purification methods. Development of novel bioseparation processes is also an important topic being pursued.

• **Recombinant DNA Products Processing**
  Development of recombinant organisms, fermentation and bioreactor control optimization strategies, and purification of recombinant DNA products are pursued with midstream and downstream processes in mind.

• **Enzyme Engineering**
  Enzyme catalysis in organic solvents, biocatalysis of petrochemical products, and characteristics of engineered-enzymes are studied.

• **Biosensors**
  Biosensors for noninvasive measurement of human body metabolites and biosensors for bioprocess monitoring are also be developed.

• **Environmental Biotechnology**
  Some of specific research topics include production of biopolymers and biodegradable plastics, algal biomass production from carbon dioxide, anaerobic digestion of organic wastes, and microbial desulfurization of petroleum.
2. BiC (Bioinformatics Research Center)

Director: Prof. Sang Yup Lee

Introduction

The KAIST Bioinformatics Research Center (BiC) was established in 2003 with an aim to advance bioinformatics and related researches for the benefit of mankind. The main objective of the BiC is to conduct world-class academic and industrial researches through integrative approaches involving high-throughput experimental data and computations. The BiC coordinates active collaborations among biologists, computer scientists, biotechnologists, biochemical engineers, and other scientists and engineers for large-scale biological discoveries. This allows efficient implementation of bioinformatic findings from real biological and biotechnological systems. A number of professors at the Departments of Bio and Brain Engineering, Chemical and Biomolecular Engineering, Biological Sciences, Physics and other academic fields are participating in various center activities.

Research Fields

- Systems Biology/Biotechnology
  Systems Biotechnology is, according to the director of BiC Sang Yup Lee, defined to be “the application of science and technology at systems level to living organisms as well as parts, products and models thereof, for the production of knowledge, goods and services”. In practice, all the information and data available (and/or generated in house) from traditional and modern biological sciences, including genomics, transcriptomics, proteomics, metabolomics, and fluxomics, are all integrated at systems level for the development of bioprocesses as well as parts thereof.

- Bioinformatics and Biologically Inspired Computing
  Bio-Software Development
  Bio-Network Analysis
  Bio-Data Management
  Bio-Data Mining

- Large-scale biological networks
  High-throughput experimental technologies have generated huge amounts of data on molecular interactions within a living cell. These interaction data can be formulated as a biological network where each molecule is a node and the interaction between these nodes are considered as a link in the network. There are various types (levels) of biological networks including protein-protein interactions, signaling and transcription-regulatory networks, and metabolic networks. These networks are not independent of each other, but they are rather interrelated in a hierarchical way. Although the collected
data are believed to be incomplete and noisy, the availability of massive network data gives us a new insight for the systems-level understanding of biological systems. The large-scale organization principles and functional properties of the biological systems can be understood by studying the topological and dynamic properties of biological networks.

3. EERC (Energy & Environment Research Center)

Director: Jong Duk Kim

Introduction

The limitation in the global energy resources and the environmental problems associated with energy utilization have become today’s problems that science and technology must face. As the technology protection policies of developed countries and the worldwide competition to secure energy resources are tightening our less resourceful economy, our industrial products are losing competitiveness in the world market. In addition, the energy environmental problems due to rocketing increases in the energy consumption caused by increased domestic income and in the demand for better living circumstances are extending to social problems. Therefore, the Energy & Environment Research Center sets a goal in solving energy/environmental problems that are directly related to the national welfare, providing means of economical exploitation of energy resources, and in developing comprehensive and interdisciplinary programs for academic research collaboration.

• In order to accomplish this goal, our research center;

[1] Nurtures creative researchers in energy/environmental fields
   The development of a new energy technology begins with the nurturing of researchers with a sense of duty and innovative ideas. Our center encourages graduate students in the KAIST to actively take part in research projects in various major fields, thereby supplying experts in energy/environmental technology fields.

[2] Develops new as well as clean & recycled energy resources
   Aims to develop technologies related to effective exploitation of fossil energies and utilization of renewable such as solar and hydrogen energies.

[3] Develops environmental energy utilization systems
   To develop technologies related to economic energy utilization, minimization of environmental pollutant
4. CSSB (Center for Systems and Synthetic Biotechnology)

Director: Sang Yup Lee

Mission

The Center for Systems and Synthetic Biotechnology (CSSB) attempts to stimulate integral researches inside and outside the campus, and become an international hub of scientific collaborations in the field of systems and synthetic biotechnology, thereby achieving the world-top research capability in the field.

Background

In recent years, the disciplines of systems and synthetic biology have gained prominence as the embodiments of the future of biological sciences. The native cellular systems of biological and industrial interests need to be better characterized and accurately modeled at the systems level. These are the goals of systems biology and, its rapid development will lay a foundation for the successful establishment of synthetic biology.

Establishment objectives

The CSSB was established to lead research in the field of systems and synthetic biotechnology. The CSSB aims at elucidating biological phenomena of various organisms at systems-level by developing bioinformatic and analytical tools in order to transform them into industrially applicable organisms that efficiently produce a variety of value-added products. In the next few years, this objective will be critical in determining the competitiveness of the bio-industry. Recently, international research collaborations are actively being pursued as well. Examples of such scientific collaborations include the participations from the Technical University of Denmark (DTU) since 2011, and the University of Queensland, Australia, since 2007.
Goals of the participating researchers

A key for the success here is efficient collaborations among experts from various disciplines. Researchers at the CSSB have expertise in systems biotechnology, including acquisition and analysis of omics data, modeling and simulation of genome-scale biological networks, and biomolecular engineering experiments. They have world-class research capability for the construction and fermentations of recombinant microorganisms to produce value-added products, including primary metabolites, biodegradable biochemicals and heterogeneous proteins. More breakthroughs are to come in the next few years.

5. National Creative Research Initiative
   - Center for Integrated Optofluidic Systems

Director: Seung Man Yang

Introduction

Optofluidic devices use fluidics to manipulate photonics and the combination of fluidics with photonics can offer unmatched high-fidelity sensitivities and resolution by manipulating functional properties of photonic devices that can instantly and accurately process information. Potential functionalities can be classified into three categories; namely, fluidically tunable photonic devices; detection and manipulation of chemical or biological substances in fluidics; and delivery of optical gain media, nonlinear optics liquids or colloidal particles into arbitrary region of photonic structures with nanoscale precision fluidic addressability.

Research Fields

- Nanophotonics

Nanospheres which are all equal in size are self-organized from a suspension into hexagonally packed crystalline lattices in two or three dimensions, called colloidal crystals. These lattices can show unusual optical insulating behavior against light wave in certain range of wavelengths like semi-conductors in electronic microcircuit, which are called ‘photonic bandgap materials.’ Such behavior of photonic bandgap materials arises from cooperation of periodic scatters. In addition, laser holography lithography can simplify the fabrication process since existing photolithography-based MEMS technology can be used directly. It is expected that the number of defects will also
dramatically decrease compared to those in self-assembly technology.

**Microfluidics**
- Preparation of fluidic optical gain media to modulate optical properties
- Optimization of microfluidic devices by Stokesian simulations at extremely low Reynolds numbers
- Fabrication of microfluidic platform such as microscale mixers, valves, controllers and actuators for optofluidic devices
- Self-organization of colloidal particles inside microfluidic devices for fabrication of photonic balls with favorable photonic bandgap properties, which allow for application to reflection mode microdisplay

**Optofluidics**
We noticed that photonic bandgaps of photonic crystals change according to the refractive index of the substance that fills the space between particles which compose photonic crystal lattices. Based on this idea, we found that optofluidic devices can be realized by constructing active photonic structures in microfluidic devices, and their optical responsiveness of photonic bandgaps can be easily tuned by changing flows in the optofluidic devices. The flexibility and robustness of the proposed optofluidic systems are beneficial for optical switches, waveguides, photonic crystal lasers and high power beam delivery. In addition, the optofluidic devices will provide very powerful tools for drug discovery, chemical synthesis and characterization and high-sensitivity chemical and bio sensors.

6. World Class University (WCU) Project
   - Nanostructure based high performance bio-sensing device

**Director:** Hee-Tae Jung

**Korean Participants:** Sang Yup Lee, O Ok Park, Seung-Man Yang, Mohan Srinivasarao, Jay H. Lee

**Introduction**
Interest of sensing technology for low concentration chemical species has been dramatically increased for diagnosis, pharmaceutics and environmental analysis, especially for the bio-sensing application. Various type of
bio-sensor has already been developed, however none of those satisfied the requirement of next generation bio-sensor which are high sensitivity, selectivity and reliability. Bio-sensor can detect target materials using optical/electrical and chemical properties of sensing platform.

This research project aims for the development of high-performance nano-structure based bio-sensor with high selectivity and sensitivity. We have intensively developed new nano-pattering approaches such as secondary sputtering lithography. Also we investigated optical properties of nano-wire and nanoparticles for high performance of bio-sensing application. By molecular simulation via multi-scale approach, these are verified that the system enables us to estimate the performance of the device and optimize from the starting step.

Research scope

Developing new nano-structures is one of the key issues in the biotechnology, energy, environmental and opto-electronics. Therefore, optimizing nano-structures for high sensing ability is very meaningful to develop the future biosensor as well as advanced nano-electronic devices. This research will lead us to fabricate high performance biosensors, and make our potential and competition stronger to the best in the sensing area.

We developed two different approaches of highly effective nanostructures for achieving high performance of sensing ability: lithography and nano-particle/wires. A novel secondary sputtering lithography (SSL) was used to generate 1-dimensional (1D) nano-structure, and used it as a novel chemi-resistor with install of the gas flow system and resistance monitoring system. Similar studies were performed by using prism holography lithography. We showed the SERS effect of those nano-patterns with absorbed bio-materials at low concentration, proving a good bio-sensing ability.

Furthermore, we generated a sensing platform for pathogenic bacteria and hazard metal ions by using nano-particle and nano-wires, based on the amplification of specific DNA signal by SERS effect. We used various types of Au nanoparticles that were prepared by new chemical approaches. In addition, we performed computer simulation with multi-scale approach which can estimate and suggest the most stable nanostructures, in order to verify high performance of sensing ability using our new nanostructures.

In conclusion, the main goals of this project are:

i) Developing an optimum nanostructure for achieving high performance of bio-sensing ability.
   - Electrical and optical bio-sensors using lithography based nanostructures.
   - Optical bio-sensor on the basis of the nano-wire and particles.

ii) System identification and estimation using computer simulation with multi-scale approach.
Expected effect

By precise control of process condition of SSL, we expected to maximize efficiency of bio-sensor and detect raw chemicals from human breath as the results of mentioned works. The other suggested method is prism holography lithography. From this result, we made facile device which has highly amplified signals more than conventionally used devices. Moreover, if we apply metal nanostructure to the inside of micro-fluidic chip, real-time sensing of bio-sensing from SERS effect will be possible.

We also produced NW based bio-sensor by using SERS effect with high sensitivity. Using this sensor, we successfully detected target DNAs implying that the ability to be used for diagnosis including detection of pathogenic bacteria. For fabrication of gold (Au) nanoparticle (NP) based biosensor, we synthesized Au rhombic dodecahedron particles which is hard to synthesize with conventional method, by seeded growth method with DMF and tri-sodium citrate. Suggested method in this study is relatively simple and has wide range of controllability of size, high mono-dispersity and high productivity. Size and shape of nanoparticle directly related to its optical property, so that this study suggests stable way to study optical aspect of nanoparticle. This study provides effective way to ensure reliability to Au NP based bio-sensor by tuning optical property so that we can obtain accurate signal even in narrow wavelength range of the light.

In addition, we established simulation system for state estimation and control based on system identification about bio-sensing system. Simulation technology has been grown dramatically with growth of computer capacity, however still remains theoretical stage so that further practical application is required. Simulation technique in this study helps this problem as well as practical application of nano system, solving uncertainty problem. We connected the stochastic equation based macroscopic model and molecular simulation. Analysis from this accurate model helps improving nano system by suggesting the most effective way calculated by simulation. Thereafter if we focus on this field of research, we can have competitiveness in the field of developing the miniaturized and high performance nano-biosensor which is in the initial state of study in over the world.
7. Advanced Biomass Center

Executive Director: Prof. Ji-Won Yang

Key Participants: Sang Yup Lee, Jay H. Lee, Min Sung Park, Yong Keun Chang, Jae Woo Lee, Jong Duk Kim, Tae Seok Seo, Yeu Chun Kim, Sung Gap Im, Min Kee Choi, Ki Jun Jeong

Introduction

The Advanced Biomass R&D Center (ABC) is the largest and the most extensive University/National Laboratory Consortium in Korea, and its primary objective focuses on the development of technical, scientific, and engineering solutions in order to produce economically viable and environmentally sustainable biomass-derived biofuels, biochemical, and high value products. ABC project is one of the Global Frontier Projects funded by the Ministry of Science, ICT and Future Planning. This $120M US project (2010-2019) employs more than 300 researchers throughout the country who strives to find break-through solutions to make biomass-derived drop-in fuels economically competitive against petroleum-based transportation fuels. Their fields of studies involve identification and improvement of the quality and quality of aquatic and land biomass, genetic improvement of biomass species, pretreatment processes, microalgae cultivation, harvest, oil extraction, conversion, and sustainability. The unique strength of ABC which is the foundation of the fertile ground for new innovation and breakthroughs is the close collaboration among scientists and engineers from various backgrounds. The BioEnergy Engineering and Research Laboratory (BEER Lab) at KAIST is the flagship laboratory within ABC which conducts research and development in a broad spectrum of topics ranging from, but not limited to, 1) Microalgal strain development for biomass, oil, and high value products, 2) technology development for phototrophic, mixotrophic, and heterotrophic cultivation system for microalgae, 3) energy efficient microalgae harvest technology, 4) oil extraction from wet microalgal biomass, and 5) direct conversion of biomass to green crude or biodiesel. BEER Lab also puts major emphasis on recycling of waste resources such as organic wastes, municipal waste water, livestock wastes, and other materials to reduce the overall raw material costs that are associated with the production of biofuels and high value products while simultaneously achieving removal of waste materials from the environment. In addition, BEER Lab collaborates extensively with a large number of faculty members in the Department of Chemical and Biomolecular Engineering, KAIST in the areas of systems metabolic engineering of microalgae, new tools for DNA delivery, microfluidics and flow-cytometry-based rapid characterization microalgae for oil production, direct oil extraction from microalgae, the use of lipid-extracted algae for the production of volatile fatty acids or methane, and systems modeling. Furthermore, ABC works
concurrently with other laboratories around world such as Los Alamos National Laboratory, Pacific Northwest National Laboratory, Brooklyn College, UCSD, and many other laboratories in microalgal biofuels field.

Project Background

With the increasing level of anthropogenic CO2 and the rapid reduction of petroleum reserves world-wide, biomass has been gaining a significant attention for the last several years as a potential renewable energy source and biochemical feedstock. The increase of the world population, economic growth of developing countries and resulting increase in demand for energy projected within the next 10 to 20 years force the governments and R&D institutions throughout the world to look for appropriate solutions to solve the energy security. Korea is not an exception to this predicament and began to invest substantially in R&D efforts of biomass-based biofuels. The team led by Professor Ji-Won Yang (KAIST) has successfully competed for a call from the former MEST (the Ministry of Science and Technology) for a Global Frontier Project and began the R&D activities in 2010.

Goal of the Project

The vision of the project is to prepare Korea to become one of the top four countries in the world in the areas of biofuels and biomass-derived valuable products within the next 10 years. The main objective of the project is to develop an extensive array of scientific and engineering breakthroughs that will make microalgae-based biofuels economically viable as a replacement for petroleum-based transportation fuels such as biodiesels, gasoline, and jet fuels. In addition, the project is interested in developing biomass-based feedstock for fine chemicals, polymers and materials that can replace the petroleum derived chemical that are currently used worldwide.

Major Topics of the Project

Major research topics range from the isolation of high-performance microalgae, genetic transformation tool box development, comprehensive cultivation using both open-raceway ponds and photobioreactors, microalgal harvest technology, oil extraction, conversion and sustainability. ABC aims to identify and develop solutions for key technical challenges and ultimately engender an integrated process for economically viable microalgal biofuels production system that can be commercialized.

Expected Effects

The successful execution of the project will result in strengthening of Korea’s future position in the global market as one of the key leaders in green-technology based biofuels and biochemical industry.
**Research Group**

The Department of Chemical and Biomolecular Engineering at KAIST aims to tackle important life-science and chemical engineering challenges by applying traditional and evolving chemical engineering principles. Chemical engineers are responsible for the design of chemical processes for the manufacture of various types of product. Broadening the area of interest to a wide spectrum of fields, we seek to nurture chemical and biomolecular engineers who can address current societal issues, ranging from energy crisis to environment preservation to improvement of daily living.

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<th>Leader</th>
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<td>Kim, Do Hyun</td>
<td>Process Analysis Laboratory</td>
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Microfluidic system has several advantages in small scale chemical and biological processes. We have been working on the development of novel fluid handling methods including electrohydrodynamic control of droplets or multiphase streams. Those handling methods can be applicable to chemical reaction, separation such as extraction, and synthesis of organic/inorganic particles.

Bio-mimetic surface modification
Polydopamine, which is formed by spontaneous oxidative polymerization of a mussel-inspired monomer, has attracted considerable attention because of its wide range of applications such as surface metallization, grafting of polymer brushes, and control of surface wettability. By using a strong metal-binding ability of polydopamine layer, deposition of noble metal nanoparticles was achieved for the fabrication of core-satellite or core-shell nanocomposites. These materials can be applied to plasmonic-based sensors, catalysis, and biomedicine.

Superhydrophobic surface and wetting phenomena
Our research in this area includes development of a fabrication process of a superhydrophobic surface for mass production and theoretical analysis of the surface. We are rectifying existing equations on a contact angle, such as Cassie-Baxter equation and Wenzel equation, etc. and developing new equations for predicting the contact angle on a real surface.

Feedstock Recycling of polymer and fatty acid
Several different approaches using either environmentally benign solvents or novel catalysts to depolymerize polymer products into monomer or dimerize fatty acid have been investigated in our group. The objective is to develop an eco-friendly process for sustainable growth. To get further insight, the reaction mechanism and kinetics, and the modeling and simulation of the process is under investigation.

Mathematical modeling and numerical analysis
Our research in this area includes numerical analysis of transport processes in microfluidic systems, semiconductor processes, and immune response to virus infection or vaccination. We analyze those processes using numerical modeling techniques to obtain valuable information from accumulated experimental data.

Key Achievements
1. In Vitro Biosynthesis of Metal Nanoparticles in Microdroplets, ACS NANO, 6 (8), 6998-7008 (2012)
Polymer Nano Electronics Laboratory

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Education
• Ph.D. in Chem. Eng., Univ. of Cal., Santa Babara, 2006
• B.S. in Chem. Eng., Seoul National University, 2000

Awards & Honors
• Wiley-Polymer Society of Korea Young Scientist Award [2011]
• Ewon Assistant Professorship at KAIST [2010-2013]
• Best Student Award, Gordon Conference (Polymer West), 2005

Research

Polymer Electronics
Polymer Solar cells
Polymer solar cells have attracted significant attention as a promising candidate for renewable energy sources due to their flexibility, solution processability, and potential for low-cost fabrication. In our lab, many researches are in progress for achieving higher efficiency and better stability. Our studies are largely divided into four parts as followed: 1) improving thermal stability of organic solar cells, 2) polymer/inorganic hybrid solar cells, 3) synthesis of new electron acceptor materials, and 4) synthesis of new conjugated polymer.

Organic Light Emitting Diodes (OLEDs)
As a start to the commercialization of practical visible-spectrum (red) LED, LED has remarkable improvement with a wide range of application areas. Among these LEDs, white organic light-emitting diodes (WOLEDs) have attracted great attention for their potential use in full color displays and solid-state lighting applications for its several advantages, such as low cost and flexibility. Currently, in our research group, we are researching on white OLED technology as next-generation lighting.

Polymer Hybrid Nanomaterials
Polymer Thin Films, Sensors, Particles, and etc.
Functional nanoparticles and organic polymer hybrid techniques have advantages such as light, strong and versatile functions of new materials. Nanoparticles dispersed well in the polymer domain can enforce the mechanical property of the polymer. Also, by using phase separation of polymer, we can locate conducting nanoparticles at specific region. By modifying the surface of inorganic nanoparticle with polymers, we can create synergies on polymer hybrid materials.

Key Achievements
6. Effects of End Group Modification in o-Xylenyl C60 Bis-adducts Derivatives on Normal and Inverted Type BHJ Polymer Solar Cells”, Chemistry of Materials, 24, 2373 (2012).
Research

Microencapsulation and controlled release

Encapsulation technologies have been intensively developed due to their increasing importance in various applications, ranging from drug delivery, cosmetics, and foods to emerging areas of display devices and medicine. Double-emulsion droplet is one of the most attractive templates for microcapsule fabrication due to their core-shell geometry. Recent advances in microfluidics have enabled to make such double-emulsion droplets in precisely controlled manner. In particular, multiple emulsions with controlled numbers of phases and cores have been prepared, which are useful to make microcapsules for controlled storage and release of core materials.

Functional microparticles

Anisotropic or functional microparticles have great potential as a new class of colloidal materials with advanced applications. For example, Janus particles can be used as active pigments in new types of display devices, while chemically-patterned microparticles can be used as building blocks to construct photonic structures through directional interactions. Therefore, there remains intense demand for new classes of microparticles. However, surface energy drives microparticles spherical and isotropic, which makes it difficult to design new types of microparticles. We address this problem using various drop-based approaches in microfluidics.

Colloidal photonic crystals

Photonic crystals which have periodic modulation of dielectric constant in half-wavelength scale show unique optical properties of photonic bandgap. Colloidal self-organization has enabled the construction of such 3D photonic crystals in facile and economic fashion by comparison with direct-writing or e-beam lithographic methods. Unfortunately, however, practical uses of colloidal crystals were rarely reported due to their complex production conditions and low chemical resistance or physical rigidity, in spite of their high potential in various photonic applications. We have developed practical platform of colloidal photonic crystals to apply them into real application including display, miniaturized spectrometer, and photonic crystal fibers.

Key Achievements

Biomedical Micro-Nano Delivery Laboratory

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Education
- B.S. in Chem. Eng., Yonsei University, 1999

Awards & Honors
- Doh Won Suk Memorial Award of Korea Institute of Chemical Engineers-US Chapter (2005)

Research

Biomedical device
A biomedical device is a tool used for medical purposes such as diagnosis and therapy. There are numerous biomedical devices to improve human health and welfare by altering pharmacological, metabolic, or immunological functions. To achieve fast, economic, non-invasive, and sensitive biomedical applications like diagnostics, treatment, and drug delivery, development of smaller scale medical device is demanding. We are interested in development and application of micro- or nano-scale biomedical devices such as micro-or nano-needles and various types of micro- or nano-implants.

Drug delivery
Drug delivery is the modulation of pharmaceutical or biopharmaceutical administration for efficient therapeutic effect. In order to improve the efficacy, safety, and patient compliance of drugs, drug delivery researches have focused on how to reduce toxicity, increase absorption and distribution, and improve release profile. Various routes of delivery including oral, pulmonary, intranasal, intravaginal, and transdermal have been investigated, and we delve into advanced transdermal drug delivery.

Gene therapy
Gene therapy is a technique for inserting, altering, or removing genes within cells and tissues. Generally, a normal gene is inserted into the genome to replace a disease-causing gene. The viral vector is considered the most common method for effective gene therapy, but it has safety issues. We are working on non-viral gene therapy including various physical methods such as electroporation, micro-or nano-particle carriers, nano-needle and biological methods like cell-penetrating peptide gene delivery.

Biomass
Due to upcoming energy crisis which results from a disruption of energy supplies and limitation of fossil fuels, biomass has been considered as a promising alternative for energy source. Biomass can be converted into other energy products such as biofuel and microalgae have been studied intensively as a critical candidate for biomass resources. Using our delivery technique, we can transform and screen best-performing strain of microalgae. In addition, we are interested in recycling of algal residue after lipid extraction to produce extra bioenergy such as biogass or VFA (volatile fatty acid).

Key Achievements
1. Enhanced memory responses to H1N1 influenza vaccination in the skin using vaccine coated-microneedles, J Infect Dis 201, 190-198 (2010).
4. DNA vaccination in the skin using microneedles improves protection against influenza, Mole Ther, 20, 1472-1480 (2012).
**Research**

**Nanogels and valve membranes for DDS**
Stimuli-responsive nanogels actuated by temperature, pressure, pH or direct contact are fabricated for gates, membrane or triggering devices. The phase volume transition of microparticles in temperature and by electrical field were investigated.

**Magnetic patterning for printed electronics**
High-resolution patterning and mass-producible printing technology is discovered for producing electronic devices and biochips, by controlling the spatial distribution of magnetic field. The shape of the printed patterns of nanoparticles was adjusted by changing the superparamagnetic nano-ink, the direction of the external magnetic field and the arrangement of the patterned nickel structures in the magnetic mask.

**Carbon-based energy storage**
Supercapacitors of electrochemical double layer capacitors (EDLCs), which are operated by ion adsorption/desorption on surface of electroactive materials, and pseudocapacitors, by redox reaction of metal oxide material. Replace expensive RuO2 with graphene-based transition-metal oxides by a simple hydrothermal process, using ethylene glycol as a reducing agent.

**Nanoparticles upgrade crude and shale oil**
Rapid Thermal Process (RTP) for upgrading heavy oil in a circulating fluidized bed reactor system in rapidly heated, uses metal nanoparticles as catalysts. Various metal oxide and pure nanoparticle synthesized in water-in-oil emulsion system for size, and structure.

**TAGs recovery from microalge**
A novel extraction process of acylglycerides from dried or wet microalgae is in progress. Chlorella and Chlamydomonas show high extraction efficiency by biodiesel/methanol as a solvent.

**Key Achievements**

3. Effect of a hybrid compatibilizer on the mechanical properties and interfacial tension of a ternary blend with polypropylene, poly(lactic acid), and a toughening modifier, Polymer Composites, 33, 1154 (2012).
Research

Carbon Capture and Sequestration

Carbon capture and sequestration (CCS) is a process in which carbon dioxide is captured before their emission into the atmosphere and buried underground. In our research group, we search for optimal materials that can selectively capture carbon dioxide from point contact sources such as power plant flue gas.

Methane and Hydrogen Storage

The need for alternative fuel source is greater than ever with decreasing amount of oil. To this end, we focus on novel porous materials that have large internal surface area that allows significantly large adsorption of methane/hydrogen gas molecules. Because some of these porous materials are highly tunable, we are interested in develop strategies to design optimal materials in silico (i.e. inside a computer).

Modeling Nanoporous Materials

In practice, it is difficult to correctly model the interactions between guest molecules and framework materials. To accurately model the system, one can in principle conduct thousands of density functional theory (DFT) calculations to obtain the adsorption properties but at a large computational cost. We look for novel solutions in which we can minimize the number of expensive DFT calculations while still retaining a reasonable level of accuracy to screen/characterize new systems.

High-performance Computing Methods for Large-scale Screening/Characterization

Our in-house developed graphics processing units (GPU) code can characterize both adsorption and diffusion properties of porous materials in a very efficient manner that allows large-scale screening of many structures. We look to continue our effort to add various functionalities to the code to enhance its capability. On top of that, we search to combine other advancements in computing to our research to solve problems that were previously deemed too difficult.

Key Achievements

3. Predicting Large CO2 Adsorption in Aluminosilicate Zeolites for Post-combustion Carbon Dioxide Capture, JACS Communication, 134, 18940 (2012)
5. Large-Scale Screening of Zeolite Structures for CO2 Membrane Separations, JACS, 135, 7545 (2013)
Polymer electrolyte membrane fuel cell (PEMFC) is now opening up new energy industries as exemplified by fuel cell electric vehicle and micro combined heat and power generation. EED lab studies micro- and nano-structural design of membrane electrode assembly with an aim to reduce the usage of expensive catalyst while not losing or even enhancing durability and power performance of fuel cell. The control of interactions among ionomer, catalyst, and support expands proton-accessible active catalyst surface, and the evolution of nanoscale separation of hydrophobic and hydrophilic domains maintains air-accessible active catalyst surface even at ultra-high current densities. We pursue deeper understanding on ionic and mass transport under ultra-low catalyst loading and low humidity operation, and support material researchers in introducing their innovative material solutions to fuel cell devices.

Also, we attempt to elucidate the degradation mechanism at various operation modes and improve durability by physic-chemical control of membrane/catalyst layer, catalyst layer/diffusion layer, and catalyst/ionomer interface.

Next Generation Battery

We explore new battery solutions which extend cruise range of electric vehicle and provide better economics for energy storage systems. Our researches include sulfur and air electrode designs with practical applicability, doughty attempt to realize lithium metal secondary battery, and fusion of battery, capacitor, and fuel cell principals such as hybrid capacitor and redox flow battery. We are interested in specific issues of how to accelerate the sulfur and air redox reaction and how to prevent the self-discharge of these active materials.

The acceleration of redox reaction by electrochemical mediator is one of the approaches we take to enhance rate capability of sulfur and air. The battery safety is one of relatively unexplored fields in spite of its enormous practical importance. EED lab develops inorganic-organic hybrid separator, solid electrolyte, and protection layer-forming additives with an eye to enhancing battery safety under various abuse conditions.

Key Achievements

Research

Hydrogen generation under solar light radiation
Photocatalytic water splitting under solar radiation is one of the schemes to solve the global energy problem. In our laboratory, various types of photocatalysts have been designed and prepared to produce hydrogen by water splitting under visible light. The ultimate goal of our research is to design a reactor system which would be the most efficient and economically feasible in the world.

Enhancement of Li-ion battery performance
Li-ion secondary battery has been considered as a primary power source for hybrid electric vehicle (HEV) and electric vehicle (EV). One of the key factors for success of electric vehicle is to improve driving range and charging time. In our laboratory, a modified aerosol was proposed as a process to produce electrode materials to improve charging capacity. A layered-cathode material has been investigated using aerosol process to overcome problems of conventional synthesis methods.

Design of functional materials and processes
Solid state reaction, liquid process (sol-gel, precipitation) and gas reaction process are methods to prepare multi-functional particles. Among these methods, aerosol process is a promising process for preparing “designer particles” of precisely controlled morphology with decorations on surfaces or inside particles. The particles prepared by aerosol process have uniformity in size and composition, and aggregation-free characteristics because of the micro-scale reaction within a droplet of micrometer size and the lack of milling process. We are working on preparing multi-functional particles such as hollow/porous particles, ultrafine/nanoparticles, non-oxide/metal particles, composite/coated particles and thin film via aerosol process.

Development of supercapacitor
Graphene nanosheet plays a role in supplying the conductive support material and carbon nanotube serves as a conductive nanochannel by connecting graphene and metal oxides. In our laboratory, we work on developing metal oxide-based supercapacitor by compositing the graphene and carbon nanotube.

Key Achievements
Research

Optoelectronic Devices

We study on the improvement in power conversion efficiency of polymer solar cells by modifying the structure of active layer and cathode interface using an alternative method that extends the interface area between active layer and introducing nano-patterned morphology.

We study on the improvement in extraction efficiency through the introduction of additional structures suppressing the waveguided light arising at the interface between air and the substrate or the substrate and the ITO layer and coupling the trapped light out from the device.

Colloidal Crystals/Soft Litography

We study on the fabrication of high quality 2D/3D colloidal crystals with minimal defect, preparation of various nano-patterns based on soft lithography method, and patterning other functional material such as CNT or metal nanoparticles using colloidal crystals.

Metal Nanocrystals

We study on the synthesis of size- and shape-controlled metal nanocrystals, the characterization of properties related their morphology, and enhancing the catalytic activity of nanoparticles with tailored composition, size and shape.

Polymer Nanocomposites

The preparation of polymeric nanocomposites filled with carbon-based conductive fillers generally requires the nanofillers being homogeneously dispersed and compatible with the polymer matrix. We study on the surface modification of nanofillers for better dispersion in polymer matrix and various properties of polymer/nanocarbon materials.

Key Achievements

2. Enhanced Light Harvesting in Bulk Heterojunction Photovoltaic Devices with Shape-Controlled Silver Nanomaterials: Ag Nanoparticles versus Ag Plates, RSC Adv., 2, 7268-7272 [2012]
Research

Lithium secondary battery

Polymer electrolyte has higher safety than liquid electrolyte. However, relatively low ionic conductivity is a barrier to the commercialization of polymer electrolyte. To overcome this problem, modification of polymer electrolyte, which satisfies high ionic conductivity and mechanical strength, is going on. In case of separator, we focus on the modification of separator for the thermal stability and compatibility with liquid electrolyte. On the other hand, SEI (solid-electrolyte interface) formed on both electrodes determines cell performance, so controlling electrode/electrolyte interface is necessary. Our research covers the introduction of functional electrolytes to control of SEI layer, which is on the newly developed electrodes. In addition, we deal with the new electrode materials with high capacity (i.e., Si, SiO). Besides, we handle with next generation lithium battery systems like Li-O2 and Li-S battery.

Polymer electrolyte fuel cell

There are several types of fuel cells. Among them, PEMFCs are characterized by using proton-conducting polymer membranes as an electrolyte. The heart of PEMFCs is the MEA that is composed of the membrane, catalyst and electrode binder. Our research is very active in designing and preparing new polymer electrolyte membranes and also polymer binders for electrodes in fuel cells. The studies of interfaces between the membrane and the electrode are also under active progress for long-term operation.

Nano patterning

Directional photofluidization lithography (DPL) is capable of fabricating a generic and sophisticated micro/nanoarchitecture that would be difficult or impossible to attain with other methods. In particular, DPL differs from many of the existing micro/nanofabrication methods in that the post-treatment (i.e., photofluidization), after the preliminary fabrication process of the original micro/nanostructures, plays a pivotal role in the various micro/nanostructural evolutions including the deterministic reshaping of architectures, the reduction of structural roughness, and the dramatic enhancement of pattern resolution.

Key Achievements

Research

The research of our group is focused on devising convenient, sensitive, and reliable strategies for the detection of biomolecules and, in particular, on developing DNA-based methods, including aptamer- or/and DNAzyme-utilized biosensor and DNA microarray for genetic diagnosis. With the goal of becoming an international leader in the field of nucleic acid bioengineering, we have developed unique capabilities to rationally design DNA sequences, utilize DNA analogues or/and mimic molecules, and freely manipulate many kinds of DNA-related enzymes. By innovatively integrating all of these DNA-based technological components, we have been able to create novel engineering tools in form of PCR, biosensor, microarray, and electrochemical devices.

Nucleic acid bioengineering

We proved for the first time that DNA polymerase activity could be intentionally triggered by the presence of Hg2+ and Ag+ through their interaction with the respective mismatched base pairs T-T and C-C, consequently resulting in an unusual and unnatural amplification reaction. This work was featured by Nature. We also have developed novel isothermal DNA amplification methods and diagnostic DNA chips.

Electrochemical technology

One of our main researches is focused on the development of electrochemical detection methods for genetic diagnosis. We developed novel electrochemical strategies to detect nucleic acids and to identify DNA mutation and SNP genotype. We have been also very actively developing electrochemical real-time PCR systems toward the goal to develop procedures to decentralize the utility of PCR. Very recently, we developed for the first time a unique and innovative biomolecular detection platform that utilizes a capacitive touchscreen. By systematically utilizing capacitive touchscreen, we have successfully verified the potential of this technology in the biosensing area.

Nanobiotechnology

We have developed a new array-based route to quantify amino acids including homocysteine that is an important marker for cardiovascular disease and also related to Alzheimer’s and Parkinson’s disease. Various biosensors to detect DNA or biomolecules related with human diseases have been also developed by utilizing enzyme-mimicking nanoparticles, colorimetric properties of PDA, and novel interactions of nucleic acids with metal ions.

Cover articles

Key Achievements

3. Label-free colorimetric detection of nucleic acids based on target-induced shielding action against the peroxidase mimicking activity of magnetic nanoparticles, Small, 7, 1521–1525 (2011)
Research

Total Integrated Genetic analysis Nano/Microsystem

We are developing highly integrated and miniaturized biosystem that consists of a micro-heater, a micro-valve, a nanoliter-scale reaction chamber, and microfluidic channels, etc. Through the sophisticated and serial combination of these functional units, we construct high-performance genetic analyzer for on-site forensic human identification, Korean cow verification, virus/bacteria pathogen detection and cancer screening. Development of a novel nanodevice for single DNA molecule genetic analysis such as SNP detection, DNA sequencing and STR genotyping is one of our research focuses. Through the fusion of nanofabrication, DNA chemistry, and an advanced optics, we strive to manipulate and analyze a single DNA molecule in a nanofluidic system with an ultra-low cost, high speed, and high accuracy.

High-throughput Biomimetic Cell-based Assay

Engineering the cellular microenvironments in the microfluidic device has many advantages over the conventional cell culture systems in terms of automation, integration, and precise cell biology detection by providing biomimetic cell conditions, which can generate more reliable data for biomedical applications. We are working on the fabrication of the large-area single cell array, biomimetic cell culture microfluidic system, and cell separation microdevice for cytotoxicity assays, drug screening and biomedical diagnostics.

Integrated Nanobiosensor

Graphene has recently attracted huge attention due to its extraordinary mechanical and electrical properties, and widely applied in the fields of nanosensors and nanoelectronics. We focus on the development of graphene based optical and electrochemical biosensors for sensitive pathogen and heavy metal detection, and graphene based memory thin film transistors for flexible display device.

Key Achievements

2. Fei Liu, Hyun Dong Ha, Dong Ju Han, and Tae Seok Seo. Photoluminescent Graphene Oxide Microarray for Multiplex Heavy Metal Ion Analysis. Small, Accepted (2013)
Superlattice Nanomaterials Laboratory
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• B.S. in Chem. Eng., Seoul National University, 1976

Awards & Honors
• Top 100 Achievements in the National Research Projects, 2009
• Top 60 Achievements in the MEST Research Projects, 2009
• Kyung-Am Prize for Science and Arts, 2009
• The Man of the Year 2008 in KAIST Award, 2009
• The 6th DuPont Science & Technology Award, 2007

Research

Colloidal self-assembly
Nanospheres of all equal in size can organize spontaneously into ordered crystalline structures in two or three dimensions, called colloidal crystals. We have been working on the development of colloidal crystals for various practical applications including miniaturized spectrometers, laser-emitting platforms, color-barcode immunoassays.

Microfluidic system for droplet manipulation
Droplet microfluidics enables the synthesis and manipulation of droplets that provide numerous benefits for conducting biological and chemical assays. We have demonstrated that control of cleverly designed microfluidic systems can generate droplets with uniform sizes and compositions up to submicrometer scale. For precise manipulation of droplets, pneumatic valve systems can be applied to investigate the droplet motion in microchannels or the chemical reaction in droplets with confined geometry.

Patterned plasmonic nanostructures
Novel periodic metallic nanostructure arrays with tunable optical properties have been developed by using various lithography techniques, including colloidal lithography, soft lithography, block copolymer lithography, and prism holographic lithography. Such plasmonic structures are expected to be useful for chemical or biomolecular sensing applications in microfluidic devices.

Optofluidic fabrication of functional materials
Optofluidic platform enables fabrication of versatile materials which have novel optical or biological properties in facile manner. By using UV curable polymer solution containing colloidal nanoparticles or bioactive ingredients, we can generate spherical colloidal photonic crystals or complex shape bioscaffolds in a microfluidic system.

Key Achievements
Research

Development of robust microalgae through genetic engineering

Genetic engineering techniques are applied to improve the phenotype of desired microalgae for biofuel production such as high lipid contents, rapid growth rate, and resistance to contamination.

Biological waste water treatment using Microalgae

We are working on different approach to use domestic, dairy, and industrial wastewater as a nutrient source for microalgae growth

High density cultivation of microalgae using PBR

This theme covers PBR design and optimization of culture condition (photo-, mixo-, hetero-trophic).

- Development of flat plate photobioreactors
  - Reduction of investment costs below 10%
  - Development of new turbidity measurements for online recording of cell growth and dynamic light intensity regulation

- Continuous fermentation
  - Steady-state fermentation progress under turbidostatic control
  - Real time measurement and automation with LabVIEW
  - Transition from batch culture to continuous culture enables efficient control of the metabolic state
  - Reliable cultivation under standard conditions increases reproducibility and simplifies interpretation of results

Microalgal harvest/lipid extraction/transesterification integrated process system development

Downstream process of energy-efficient harvest and lipid extraction with ionic liquid are investigated in our lab.

Key Achievements

1. Efficient microalgae harvesting by organo-building blocks of nanoclays, Green Chemistry (2013)
3. Direct lipid extraction from wet Chlamydomonas reinhardtii biomass using osmotic shock, Bioresource Technology, 123, 712-722 (2012)
5. Serial optimization of biomass production using microalga Nannochloris oculata and corresponding lipid biosynthesis, Bioprocess and Biosystems Engineering, 35, 3-9 (2012)
Fuel cell

In fuel cells, especially in PEMFC, the electrochemical reaction between hydrogen and oxygen produces water, converting the chemical energy into electrical energy. Due to the high rate of energy conversion efficiency, high power density, small amount of emission, and low operating temperature, fuel cell is noted as one of the potential alternative energy sources for the future.

Artificial photosynthesis

Artificial photosynthesis is a system that mimics the natural photosynthesis, a process where sugar is produced from a reaction between CO2 and H2O with the utilization of sunlight. The catalytic conversion process called artificial photosynthesis is a critical goal that would positively impact the global carbon balance by recycling CO2 into usable fuels such as methanol, formic acid, methane and carbon monoxide.

Transparent conducting oxide material

TCO is an optically transparent and an electrically conductive materials used in optoelectronic devices such as flat panel displays and photovoltaics. It acts as a window for light to pass through to the active material beneath (where carrier generation occurs) and as an ohmic contact for carrier transport out of the photovoltaic.

CZTSSe thin film solar cell

Solar cell is an electrical device that converts the light energy directly to electricity by the photovoltaic effect. Thin film solar cell uses cheap glass as a substrate instead of Si wafer. CZTSSe is a remarkable material to replace CIGS (which uses insufficient and toxic In and Ga).

Key Achievements

1. Improvement of oxygen vacancy migration through Nb-doping on Ba0.75Sr0.3TiO3 thin films for resistance switching random access memory application, Appl. Phys. Let., 100, 262107 (2012)
2. Combinatorial approach for ferroelectric material libraries prepared by liquid source misted chemical deposition method, PNAS, 104, 1134-1139 (2007)
Conversion of water and carbon dioxide into value added hydrocarbon products and fuels requires considerable amount of energy, as the reaction is usually uphill from the energy point of view. Successful integration of photocatalytic system can help address the thermodynamic issue and ultimately improve the carbon footprint of our society. Development of photocatalysts requires thorough understanding of light-matter interactions, and the END laboratory explores the photocatalytic activities of designed nanomaterials.

Self-assembly of inorganic nanomaterials

Locating inorganic nanomaterials with precision is a holy grail of scientists and engineers alike. Through rigorous analysis of interactions between nanomaterials, we aim to predict and program the self-assembly of inorganic nanomaterials into designed hierarchy.

Design and synthesis of nanomaterials

Ultimate test for nanoscience and nanotechnology stands at the demonstration of useful materials and devices. Of course, prerequisite for this is the capability to design and synthesize nanomaterials of desired functionality. Our focus is to understand synthetic chemistry and to unveil a new route to scale up the process.

Key Achievements

Systems Metabolic Engineering for the Production of Chemicals and Materials

Systems metabolic engineering that integrates systems and synthetic biology with metabolic engineering has been pioneered by our lab. Strains and processes efficiently producing various bulk chemicals and materials including alcohols, amino acids, diacids, diamines, polymers are being developed.

In Silico Analysis of Biological Networks

Biological networks of various organisms that are of industrial and medical importance are modeled and simulated to derive novel biological insights. Metabolism has been the important target of such modeling approach, but transcriptional regulations and signaling pathways are also considered. This model-driven approach is conducted in combination with wet experiments that actually demonstrate prediction results from the computational studies.

Natural and Synthetic Biopolymers

Biopolymers have been highlighted as a great source to replace petroleum-based plastics. We have been working on the production of various biopolymers. Bio-based production of polylactic acid for the first time in the world demonstrates successful metabolic engineering. Strains and processes for the production of other polymers including aromatic copolymers, and ultra-high-strength spider silk are being developed.

Production of Next-Generation Biofuel from Renewable Biomass

Microorganisms and bioprocesses for the production of next-generation biofuels including butanol and hydrocarbons are being studied.

Nanobiotechnology

Bio-based nanomaterials and various biosensors are being developed.

Key Achievements

2. Enhanced Butanol Production Obtained by Reinforcing the Direct Butanol-Forming Route in Clostridium acetobutylicum, mBio, 3, 1-9 (2012)
Research

H2 Storage and CO2 conversion

Ammonia borane (NH3BH3, AB) is one of promising new hydrogen (H2) storage materials for H2-powered transportation because it contains the highest H2 content of the hydrides (19.6 wt % H2). However, the main obstacle to adopting AB as an on-board H2 carrier is the slow release at the working temperatures of polymer electrolyte membrane fuel cells (80 – 90 oC). We have recently proposed a new way to accelerate H2 release without sacrificing storage density or adding any promoter: CO2 treatment of AB. The CO2-pretreated AB at 4 bars and 85 oC provides rapid H2 release at a level of 8.33 wt% H2 within one hour, while pretreatment with 30 bars CO2 and 100 oC leads to the formation of graphene oxide-boron nanocomposites in a subsequent thermal decomposition up to 700 oC at ambient pressure. Motivated by these promising results, the central theme of this project is to understand the reaction mechanisms of enhanced hydrogen release of CO2-treated AB and CO2 reduction to the graphene oxide composite using AB. Through this understanding, we aim at achieving usable H2 storage capacity higher than 10 wt% and maximizing the yield of GO-boron nanocomposites.

Dynamic Adhesion Behaviors in Clathrate Hydrate Systems

The main goal of this proposal is to understand the dynamic adhesion interactions between clathrate hydrates and various oil-water interfaces. Elucidating the adhesion behaviors of hydrate particles in multi-phase systems consisting of gas, oil, water, and solid surfaces may provide fundamental insights into the avoidance of hydrate plugs in gas/oil delivery lines and processing units. To understand the adhesion behavior subject to the phase transition and fluid motion, the mechanism for capillary bridge formation and aggregation between hydrate particles, partially converted water droplets, and water droplets should be identified in a micro-scale domain. Then, this micro-scale adhesion mechanism can be interpreted to understand the macro-scale adhesion behaviors. We will quantify the changes in dynamic adhesion when accompanying surface-active agent (surfactants and nano-particles) injection, substrate (e.g. metal surfaces in the pipelines) aging and various surface properties of roughness, hydrophobicity, and hydrophilicity.

Design of integrated reaction and separation

The intensification of reaction and separation can lead to the simplification of a complex process, dramatic economic savings, and environmentally benign operation. The main task in realizing this technology is to achieve a solid understanding of the interaction between multiple reactions and separation in one physical shell or in a fewest number of operation units. We will use the visualization tools with mathematical models.

Key Achievements

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- U.S. National Science Foundation Young Investigator Award (1993).
- Georgia Tech Ziegler Award for Outstanding Faculty Member (2002).
- SAIC Georgia Tech Student Paper Competition, Winner (2009).
- International Federation of Automatic Control (IFAC), Fellow (2011).
- AChE Computing in Chemical Engineering Award (2013)

Research

Biorefinery
The concept of biorefinery, in which various platform chemicals and fuels are produced from renewable biomass feedstock (in addition to petroleum-based feedstock), holds much promise as the chemical industries look for ways to become more sustainable. Systematic design of a complex processing network requires the development of superstructures and mathematical models to formulate the identification of optimal processing pathways as mixed integer programs. Solutions to these optimization problems yield promising biorefinery configurations by determining the optimal processing pathways. Detailed design should follow.

Microalgae Cultivation
Recent investigations have highlighted microalgae as a promising alternative to depleting fossil fuel reserves as a renewable source of biodiesel. We integrate systems biology with system dynamics to design and control a biodiesel production system, considering the nutrient and light elements. We develop a flux balance analysis (FBA) model of the metabolic system and combine it with the macroscopic dynamic model of the reactor. Eventually, the model will be extended to other conditions for optimizing microalgae production system.

Efficiency Improvement
The current energy and environment crisis can be ameliorated considerably, simply by improving the efficiency of current generation/processing technologies. The conventional control studies of ASU (Air separation unit) in IGCC only focus on its process controllability, but its operating cost should be considered because of its large energy consumption. Our work uses self-optimizing control (SOC), which is a manageable way to achieve near-optimal operation despite disturbances through appropriate selection of control structures.

Systems and Policies
CO2 management to counteract the global warming problem involves carbon capturing, utilization, and storage (CCUS) steps. Recently, various CCSU technologies have been developed actively, but each technology is at a different level of maturity, and comes at varying capacity, and cost. This research involves development of a superstructure model for CCUS and its optimization to identify the best options and pathways.

Multi-scale Simulation and Design
In many engineering applications, the understanding and control of events at the molecular scales are critical to producing products of uniform quality, even though the primary manipulation of these events during processing occurs at macroscopic length scales. In such problems, high-fidelity simulation and analysis that are true to the entire spectrum of relevant length scales can be highly valuable. This motivates the creation of simulation/analysis tools for multi-scale systems, e.g., density functional theory study, Chemical Master Equation, kinetic Monte Carlo simulation, etc.

Production Planning, Scheduling, and Control
A fab-wide scheduling in a semiconductor fab is challenging due to its complex product flows, including a large number of reentrant loops, and hundreds of equipment/processing steps involved. A two-layer hierarchical approach is developed for planning and scheduling of an entire fab. In the bottom layer, a model predictive controller (MPC) algorithm based on an aggregated flow model is used to determine processing schedules per operator shift for each station. At the top layer, a scenario planning for addressing supply- or demand-side uncertainties determines target work-in-process (WIP) levels that allow the fab to meet the expected demand without productivity loss.

Key Achievements
3. Elucidation of cellulose accessibility, hydrolysability and reactivity as the major limitations in the enzymatic hydrolysis of cellulose, Bioresource Technology, 2012.
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• The Best Paper Award, KICHE (2010)
• Appointed as KEPCO Chair Professor (2009)
• The 3rd Kyung-Ahm Prize Award, Kyung-Ahm Foundation (2007)
• Academic Achievement Award, KICHE (2007)
• Grand Academic Award, KAIST (2007)
• Award of Sukmyoung Excellent Chemical Engineers, KICHE (2006)
• Selected as “Korea Best 30 Basic Researches”, MOST (2005)
• The Scientist of the Month Award, MOST (2005)

Research

Energy storage using ice-like and sponge-like materials
The green and novel ice or ice-like materials are proposed as the hydrogen storing media because these crystalline hydrates or clathrates create tremendous empty cages in which hydrogen molecules are entrapped. This ice-based hydrogen storage method only requires the mild temperature and pressure condition, but for practical application more researches to overcome the technical barriers should be done using macroscopic and microscopic approaches.

Frontier energy devices using host-guest networks
The inclusion phenomena are introduced in developing functional energy devices with specific-target functions. In particular, pure and mixed ionic clathrates or liquids are synthesized to manufacture fuel cell electrolytes, magnetic materials and other energy-related specialty materials. The first goal is to establish the basic principles of ice engineering for the better understanding of new genre in physical chemistry. Versatile host and guest molecules are specially designed and synthesized to build the host-based frameworks in which nano-cages or nano-channels for guest molecules to pass through are formed. Moreover, structural transitions accompanying with coexistence of multi clathrate structures are carefully investigated to enhance the key physicochemical properties needed for the target-purpose energy devices. This unique approach can greatly contribute to inclusion chemistry and future energy fields.

Swapping exhaust for fuel
When carbon dioxide itself is put under certain pressure, a solid carbon dioxide hydrate can be formed according to the stability regime. On the other hand, large amounts of methane in the form of solid hydrates are deposited on continental margins and in permafrost regions and more importantly receive world-wide attention as a hidden future energy resource. Hopefully, the direct swapping between carbon dioxide and methane might overcome this environmental concern and moreover provide actual production process merits over the conventional ones. Further, we explore the more efficient and real swapping phenomenon occurring in methane hydrate deposits and its potential application to carbon dioxide sequestration, considering the direct use of flue gas mainly consisting of carbon dioxide and nitrogen.

Key Achievements
Research

**Initiated Chemical Vapor Deposition (iCVD)**

iCVD process utilizes very simple machinery with low power consumption. Since the processes are performed at ambient temperature, the iCVD polymers are easily applicable to substrate materials vulnerable to liquid phase process and/or heat, such as paper, fabrics, and membranes, without damaging the substrates.

**Electronic Device**

Organic thin film transistors (OTFTs) have some drawbacks such as a high operating voltage, high level of leakage current density, high hysteresis and interfacial problems. To overcome these problems, iCVD is introduced as it is a powerful method for depositing pinhole-free, conformal and ultrathin polymeric film. Organic electronic devices have critical weakness against moisture and oxygen. iCVD polymer film is applied to fabricate hybrid thin film for the encapsulation.

**Superhydrophobic Surface**

A robust superhydrophobic fabric is obtained by introducing iCVD deposited polymer film. The hierarchical structure of the fabric surface is simply achieved by controlling the operation parameter of iCVD process.

**Microfluidic Device Using Nano-scaled Adhesive**

By employing the iCVD process, it is possible to obtain a robust adhesive layer with resistance to both chemical and thermal stresses. Furthermore, the adhesive developed using iCVD remains flexible without any loss in the adhesion strength.

**Biomedical Devices Using Nano-scaled Patterning**

A platform for guided stem cell differentiation is prepared by biocompatible, conformal iCVD coatings on various nano-patterns. The technology enables the independent systematic control of each parameter of surface chemistry and nano-structure.

**Key Achievements**

1. A stacked polymer film for robust superhydrophobic fabrics, Polymer Chem., 2013, 4, 1664-1671
2. A doubly cross-linked nano-adhesive for the reliable sealing of flexible microfluidic devices, Lab Chip, 2013, DOI: 10.1039/c2lc41266g
Research

Microalgae-based biorefinery

- Simultaneous microalgal biomass saccharification and lipid extraction
- Development of membrane bioreactor system for continuous saccharification of microalgal biomass
- Ethanol production by using Streptomyces strains and crude microalgal biomass hydrolysate
- Microbial production of butanediol by using crude microalgal biomass hydrolysate

Galactan-based biorefinery

- Hydrolysis of agarose, a red algal galactan, into galactose and anhydrogalactose by using β-agarase and neoagarobiose hydrolase
- Ethanol production by using yeast and crude agarose hydrolysate
- Separation and purification of galactose and anhydrogalactose from agarose hydrolysate by membrane filtration and chromatography
- Production of neoagarooligomers from agarose by using β-agarase
- Hydrolysis of agarose by using acids and/or solid acid catalysts
- Detoxification of agarose acid-hydrolysate of agarose
- Separation of galactose, 5-HMF and levulinic acid by chromatography

Others

- Hydrogen production from carbon monoxide by microbial water-gas shift reaction
- Lactic acid recovery from fermented food waste by nanofiltration and electrodialysis

Key Achievements

Engineering of therapeutic proteins

Engineering of proteins for therapeutic purposes still remains a major challenge. In this regard, we have successfully engineered several valuable therapeutic proteins such as human immunoglobulin, enzymes and non-immunoglobulin protein scaffolds. The specificity and affinity of these products could be enhanced by high-throughput screening, and we have established a promising baseline for these purposes.

Engineering of bacterial hosts for efficient production of proteins

Over two decades, Escherichia coli has been used successfully for the production of various recombinant proteins (e.g. therapeutic antibodies, industrial enzymes, etc.). However, several technical limitations in expressing recombinant proteins in E. coli host suppress the high production yield. To address these challenges, we are developing efficient bacterial hosts for high-level production yield through proteomics, and genetic engineering of various genes. Also, we are evaluating the performance of these hosts in high-cell density cultivations for the high-level production of valuable proteins.

Engineering of bacterial host/microalgae for the production of value-added biochemicals

Bacterial and microalgal hosts have gained substantial support as a potential bio-factory to produce value-added biochemicals such as amino acids, biodiesel and bioethanol. Several bacterial and microalgal hosts have been genetically modified to produce these profitable biochemicals at intracellular or extracellular level. Our researches has focused on the development of efficient expression systems for bacterial and microalgal hosts, and establish an efficient platforms for high-throughput screening of those host systems and thereof.

Key Achievements

Research

Nano-fabrications & Opto-electronics Devices

Developing reliable fabrication method for nanostructure has been interested for wide range of applications such as electronic, optics and bio devices. We are developing new nano-fabrication techniques such as Secondary Sputtering Lithography (SSL) technique, creating high aspect nano-patterns below 20nm with high precision over a large area. SSL takes advantage of phenomena which is metal re-sputtering onto the surface of the polymer pre-pattern when the high energy Argon ion hits thin metal film. By using novel fabrication techniques, we investigate optical and electrical properties and apply to actual devices. Using new nano-structures, we are focusing on improving the performance of various opto-electronic devices such as energy, display, biological and environmental devices.

Liquid Crystal Self-assembly

Self-assembly building blocks which have unique shape and functionality have been widely studied. Especially, our research group has specialty in control of self-assembly of liquid crystal forming nanostructure by itself. Also, we synthesize new type of LC molecules and observe its optical property. Nanostructure made by SSL method enhance alignment of LC molecule so that we can fabricate LC device with no defect and ultra-fast on/off response time.

Carbon Nanostructures: CNT and Graphene

Graphene is a two-dimensional monolayer of carbon atoms with a honeycomb structure that has a high surface area, superior electronic conductivity and mechanical strength, making it a highly promising material for various application. Our group invented a novel method to visualize the graphene domain and boundaries by optical birefringency. Moreover, we have been researched on graphene-based materials for the various applications such as transparent electrode, Li-ion battery, and supercapacitor.

Key Achievements

1. Bifunctional ITO layer with a high resolution, surface nano-pattern for alignment and switching of LCs in device applications, NPG Asia Materials, 4, e7 (2012)
2. Chiral Nematic Fluids as Masks for Lithography, Advanced Materials, 24, 3 (2012)
Research

Nanotechnology for Energy & Environment
Development of renewable energy sources and environmentally benign chemical processes are essential for sustainable development of human society. With this respect, our primary research goal is to develop new advanced catalyst materials and catalytic processes that can contribute to the aforementioned issues, especially by using cutting edge knowledge on nanotechnology.

Catalyst Design by Nanotechnology
Advanced catalysts with high reaction activity, selectivity and durability can be synthesized by the design of materials in nanoscale and/or molecular scale. In our research, we will develop and use a new nanotechnology to design advanced adsorbents and catalysts with optimized structural, diffusion and catalytic properties.

Lignocellulose-Based Energy and Chemical Source
Biomass is the only sustainable source of organic carbon. Among various biomass-derived feedstocks, lignocellulose is the cheapest, most difficult feedstock to process. The only limiting factor for using lignocellulose feedstock is that low-cost processing technologies into liquid fuels and chemicals do not yet exist. In this respect, our ultimate goal is to develop a chemical process which can efficiently convert lignocellulose feedstock into liquid fuel source and fine chemicals.

Green Chemical Technology
Chemical technology should be developed in a ‘green’ direction that encourages the design of products and processes that minimize the use and generation of hazardous substances and maximize the energy and resource efficiencies. In this respect, our research interests includes economic production of hydrogen peroxide for clean oxidation, water remediation, development of advanced hydroprocess catalyst for fuel upgrading, and new three way catalysts for the removal of automobile exhaust gas.

Advanced Hydroprocess Catalysts
Advanced hydroprocess catalysts with high activity and poison tolerance at the minimized use of hydrogen are highly important for clean and economic fuel production from low-quality crude oils containing high concentration of sulfur and nitrogen compounds to meet rigorous environmental legislation nowadays. In our research, we will develop and use an advanced hydroprocess catalyst with high activity, selectivity, poison tolerance and coke resistance.

Key Achievements
3. Stable single-unit-cell nanosheets of zeolite MFI as active and long-lived catalysts, Nature 461, 246 (2009)
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