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(Macro2014)
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Exhibition Centre (Thailand)
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# Polymer Education and Human Development in Graduate Courses in an Industry-University Cooperation

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UYAMA Laboratory


適塾：大阪大学の原点
1838
175th
22世紀に輝く
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大阪大学
OSAKA UNIVERSITY

大阪大学
OSAKA UNIVERSITY

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# Osaka University

## Past, Present, and Future

**1838** - Origin in 'Tekijuku',
academy of Dutch studies

**1931** - Osaka Imperial University's Foundation

**2014** - 11 Schools・16 Graduate Schools
29 Centers and Institutes・2 Hospitals…
Japan's Leading Research University

Evolving towards the future

**2031** – Osaka University's 100th Anniversary

**Aspiring to be**
**one of the world's top 10 research universities**

# Osaka University

4 campuses — Suita, Toyonaka, Minoh, and Nakanoshima
11 schools, 16 graduate schools, 29 research institutes/centers
2 university hospitals, and 4 libraries
**One of Japan's most outstanding comprehensive universities**

| Students | |
|---|---|
| Undergraduates | 15,562 |
| Graduates | 7,999 |
| Others | 1,050 |
| Total | 24,611 |

| Faculty and staff | |
|---|---|
| Faculty | 5,066 |
| Staff | 4,718 |
| Total | 9,784 |

**International Students : 1,985** (as of May 1, 2013)

# Program of Human Resource Development by Industry-University Cooperation (2009-2011)

Supported by Ministry of Economy, Trade and Industry (METI)

## Osaka University

## Program of Core Human Development for Manufacturing on the Basis of Polymer Science and Engineering

**Program Purpose**

Resolution of mismatch between needs from industry and actual education in university in relation to human resource development in the chemical field

**Project Members**

- ✓ Osaka University (3 graduate schools)
- ✓ 6 Companies (core: Mitsubishi Chemical & Kaneka)
- ✓ 4 Societies/Organizations

# Background

## Current Situation (University Side)

### Undergraduate Students and Master-course Students

- Decline in Basic Academic Skills
- Unbalance of Subjects by Research-oriented Education
  (Deficient offer of subjects on polymer science & engineering and chemical engineering, resulting in little response to demands of industry)

### Doctor-course Students

- Drop in advancement rate in doctor course
- Research ability of postdoctorals
  (Low activity to design and develop researches based on wide vision, resulting in insufficient response to requests in industry side for supply of high-level and diverse researchers)

### Academics

- Insufficient recognition for current situation of industry
- Low ability of academics for high-level education in response to demands of the present age

Discussion from Recognition of Current Situation by University and Industry

**Program for Human Resources Development by Industry-University Cooperation**

# School of Engineering
# Graduate School of Engineering

- ✓ School of Engineering consists of 6 divisions including division of applied science
  - 3724 Undergraduate students (2013)
- ✓ Graduate School of Engineering consists of 10 divisions including division of applied chemistry
  - 165 Master course students (2013)
  - 62 Doctor course students (2013)

# Division of Applied Science

## School of Engineering

- ✓ Division of Applied Science consists of four departments (**Applied Chemistry**, Biotechnology, Precision Science and Technology, and Applied Physics)
- ✓ Prescribed student number of division of Applied Science: 217
- ✓ Required credits for graduation: 133
  - Liberal art subjects: 27 credits (mainly as first year grade)
  - Professional basic subjects: 24 credits (mainly as first year grade)
  - Professional subjects: 82 credits (including graduate thesis)
- ✓ Professional basic subjects: Mathematical analysis, Linear algebras, Mechanics, Electromagnetics, General chemistry, General biology, Student experiments of physics & chemistry, etc.
- ✓ Professional subjects (Applied Chemistry): Physical chemistry (6 credits), Inorganic chemistry (4 credits), Organic chemistry (8 credits), Analytical chemistry, Polymer chemistry (4 credits), Chemical engineering (4 credits), Biochemistry (4 credits), Industrial chemistry (6 units), Practices of physical chemistry & organic chemistry (4 credits), Student experiments of analytical chemistry, physical chemistry, & organic chemistry (6 credits), etc.

**Systematic Education Program**

# Division of Applied Chemistry

## Graduate School of Engineering

| Molecular Chemistry |
| --- |
| Molecular Reaction Chemistry |
| Molecular Design Chemistry |
| Molecular Interaction Chemistry |
| Industrial Organic Chemistry |
| Resources Chemistry |
| Catalytic Synthetic Chemistry |
| Organometallic Chemistry |
| Condensed Matter Physical Chemistry |
| Cooperative Areas |
| Molecular Excitation Chemistry |
| Organic Molecular Materials |
| Environmental Chemistry |

| Materials Chemistry |
| --- |
| Applied Electrochemistry |
| Structural Physical Chemistry |
| Physical Organic Chemistry |
| Structural Organic Chemistry |
| Synthetic Organic Chemistry |
| Inorganic Materials Chemistry |
| Polymer Materials chemistry |
| Functional Organic Chemistry |
| The Research Field of Functional Materials |
| Cooperative Areas |
| Quantum Functional Materials |
| Beam Molecular Science and Technology |

Division of Applied Chemistry consists of two courses (Molecular Chemistry and Materials Chemistry).

# Department of Applied Chemistry

- ✓ Prescribed number of master-course students: 77
- ✓ Required credits for graduation: 30 (plus pass of master thesis)
  - Required subject: seminar in each laboratory (2 credits)
  - Intensive course by distinguished professors and researchers outside university: maximum 8 credits
- ✓ All the laboratories (total 22) have charge of one subject (2 credits) for master course students, related to each specialties.

**No systematical education program for master course students**

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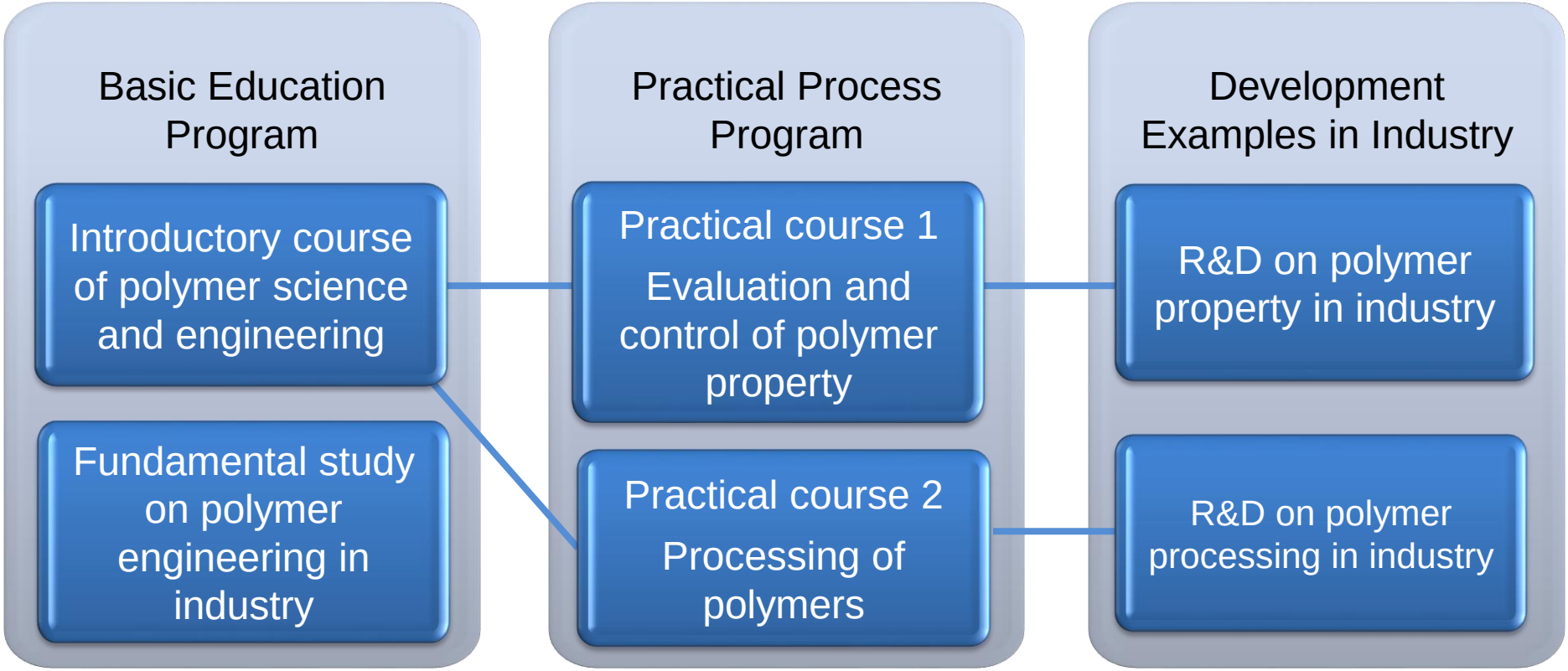
Discussion from Recognition of Current Situation by University and Industry

**Program for Human Resources Development by Industry-University Cooperation**

# Basic and Practice Polymer Education Program

Target: Master-course students



# Basic and Practice Polymer Education Program

Purpose: Acquisition of fundamental knowledge for practical research and development using polymeric materials

Content: Systematically designed subjects covering from fundamental to applied engineering of polymeric materials

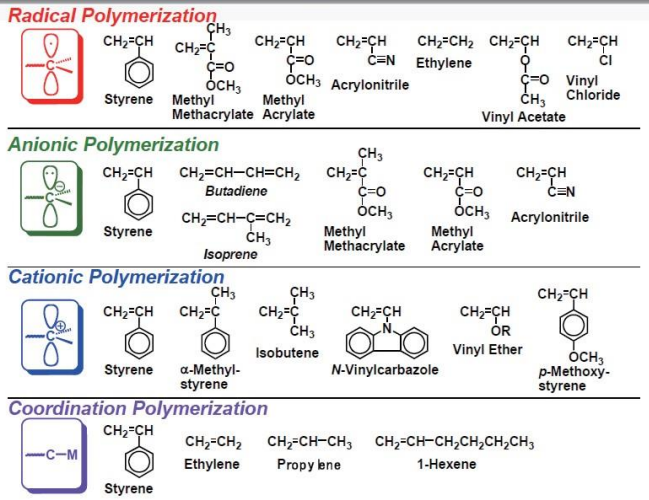
- Emphasis on basic and fundamental fields of polymer science and engineering such as solid state of polymers, relationships between structure and function, analysis of polymers, etc.
- Based on this knowledge, the program is developed to practical subjects of polymeric materials.
- Successful commercialization examples of polymers in industry are demonstrated by company researchers.
- Educational materials (lecture slides) of polymer science and engineering were systematically produced with the aid of professional university and company researchers.

# List of Educational Materials

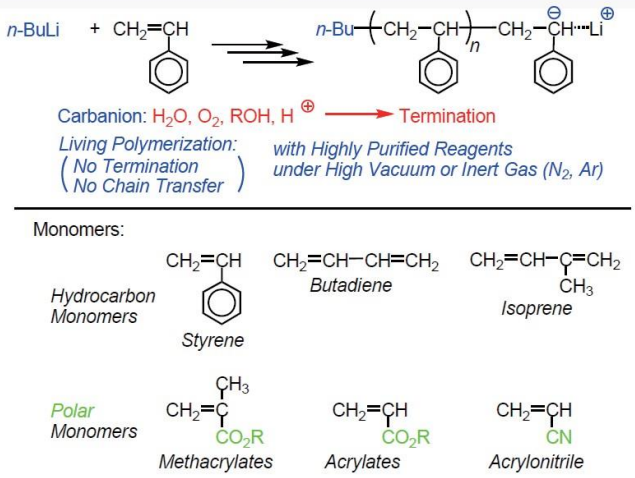
| Course | Subject | |
|---|---|---|
| Introductory course of polymer science and engineering | Introduction of polymers<br>Basic polymerizations<br>Solid state of polymers<br>Structure-property relations | History of plastics industry<br>Polymers in solutions<br>Rheology<br>Industrial production processes |
| Practical course 1 Evaluation and control of polymer property | Thermal properties<br>Optical properties<br>Stability and degradation<br>Engineering plastics<br>Functional polymers | Mechanical properties<br>Surface analysis<br>Water-soluble polymers<br>Thermosetting resins |
| Practical course 2 Processing of polymers | Practical processing<br>Films and coating technology<br>Advanced composites<br>Gels<br>Bioplastics | Nanoprocessing<br>Fibers and membranes<br>Adhesion<br>Polymer alloys |

# Educational Materials (Examples)

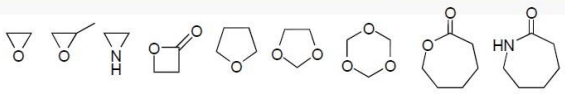
## 付加重合における代表的モノマー




## リビングアニオン重合



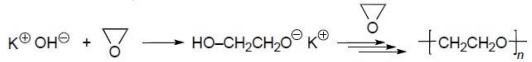

## 開環重合



開環重合性モノマーの例

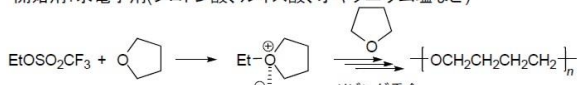
**アニオン開環重合**

開始剤：求核剤(アルカリ金属のアルコキシド、水酸化物、アミド、水素化物など)



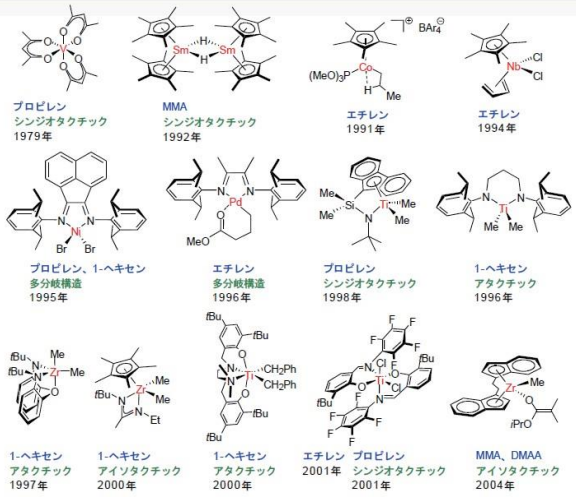

**カチオン開環重合**

開始剤：求電子剤(プロトン酸、ルイス酸、オキソニウム塩など)




安定なオキソニウムカチオン

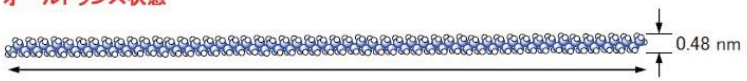
## リビング配位重合触媒



# Educational Materials (Examples)

## ポリエチレン分子の様々な形とサイズ

**オールトランス状態**



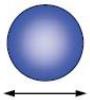

主鎖炭素数：100（重合度：50）

全長：$R = 0.154\ \text{nm} \times \sin\left(109.5^\circ/2\right) \times 99 = 12.5\ \text{nm}$

体積：$\upsilon = \pi\left(0.48\ \text{nm}/2\right)^2 \times 12.5\ \text{nm} = 2.3\ \text{nm}^3$

**ゴーシュ状態を混在させると**

**凝縮（グロビュール）状態**



直径：$r = 2 \times \sqrt[3]{(2.3\ \text{nm}^3)/(4\pi/3)}$
$= 1.6\ \text{nm}$

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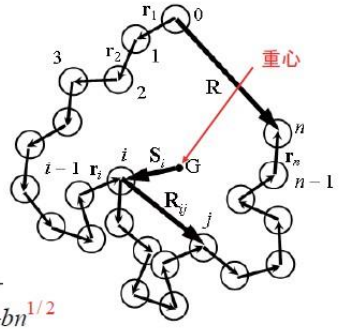
## 回転半径

**回転半径の定義式：**

$$\langle S^2 \rangle^{1/2} = \left[ \frac{1}{(n+1)} \sum_{i=0}^{n} \langle \mathbf{S}_i^2 \rangle \right]^{1/2}$$

$$= \left[ \frac{1}{2(n+1)^2} \sum_{i,j=0}^{n} \langle \mathbf{R}_{ij}^2 \rangle \right]^{1/2}$$




**ガウス鎖の回転半径：**

$$\langle S^2 \rangle^{1/2} = \frac{1}{\sqrt{6}} \langle R^2 \rangle^{1/2} = \sqrt{\frac{C_\infty}{6}} b n^{1/2}$$

**自己回避鎖の回転半径：**

$$\langle S^2 \rangle^{1/2} \propto \langle R^2 \rangle^{1/2} \propto n^{0.6}$$

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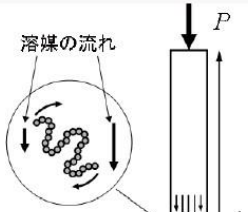
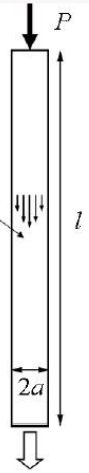
## 粘度法

毛細管内の高分子溶液の流れ
↓
高分子鎖の回転運動
↓
高分子鎖と溶媒との間の摩擦
↓
粘度の増加




$\eta_r$：溶液と溶媒の粘度の比　$c$：高分子質量濃度

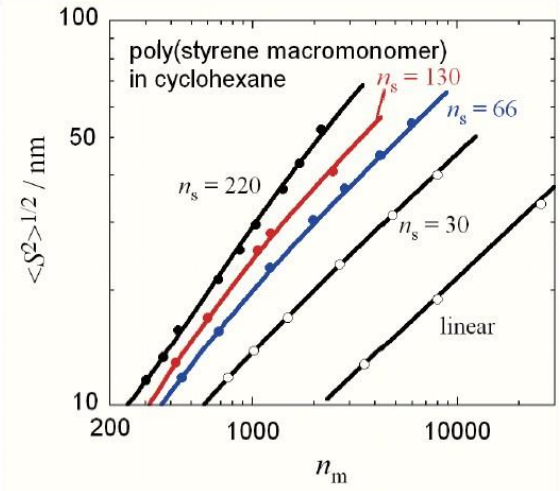
固有粘度：$[\eta] \equiv \lim_{c \to 0} \frac{\eta_r - 1}{c} = \Phi \frac{\left(6\langle S^2 \rangle\right)^{3/2}}{M}$

$\Phi \approx 2.6 \times 10^{23}\ \text{mol}^{-1}$　Floryの粘度定数

高分子の分子量

単位体積流出

## みみず鎖モデルによる解析




| $n_s$ | $q$/nm |
|---|---|
| 30 | 5 |
| 66 | 11 |
| 130 | 18 |
| 220 | 40 |

側鎖が長くなると
持続長が増大

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# To Self-standing Program

Education Course for Company Researchers & Engineers

- ✓ Start in April 2011 by cooperation of alumni society of school of engineering, Osaka University
- ✓ Program in Osaka University (near central station of Osaka city)
  - Introductory course: 10 classes (each 90-100 min, all participated)
    Mainly focus on polymer physics (solid & solution chemistry, rheology)
    About 160 people participated in this program (2011-2013)
  - Practical course: 5-7 classes (each 180 min, selected)
    Engineering plastics, Thermosetting plastics, Composites, Adhesives etc.
    About 100 people participated in this program (2011-2013)
- ✓ Program in company
  - Tailor-made design of course according to request of company
  - 9 Companies used this system for education of young researchers

**Up-to-date reflection system of education program development according to request for academic and practical subjects in the standpoint of industry**

# Intense Interaction Internship and Training

Half-day Internship **in Company**

Program for doctor course students

Through presentation of research topics and intense discussion with company researchers, doctor course students have a close relationships with them.

- ✓ Start in 2010; total 15 companies in 2010-2014.
- ✓ Students can understand their research significance and situation in industrial viewpoints by discussions with company researchers.
- ✓ Students also obtain a good chance to know research and development in company by close contact of company researcher.

# Acknowledgement

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