Helmholtz Research School Energy-Related Catalysis

Opening Workshop 17 November 2010

Karlsruhe Institute of Technology (KIT)

Prof. Olaf Deutschmann (Speaker)
Prof. Eckhard Dinjus
Prof. Roland Dittmeyer (Vice Speaker)
Prof. Manfred Döring
Prof. Jan-Dierk Grunwaldt
Prof. Ellen Ivers-Tiffée
Prof. Bettina Kraushaar-Czarnetzki
Prof. Peter Roesky
Prof. Georg Schaub
Dr. Steffen Tischer (Coordinator)
Prof. Christof Wöll
21st century: Diversification of raw materials for energy, fuel, and chemicals

- oil sands
- natural gas
- coal
- nuclear power
- solar power
- wind power
- hydro power
- bio mass
- alges

Efficient technologies needed

Catalysis

Chemical products
**Principle of heterogeneous catalysis: ammonia synthesis**

Haber/Karlsruhe and Bosch/BASF 1905-1913

![Diagram of ammonia synthesis](image)

- **Hydrogen** + **Nitrogen** → **Iron-based catalyst** → **Ammonia**

  - Reaction is extremely slow
  - Reaction is rapid
Catalysis: key technology for sustainable conversion and efficient use of chemical energy carriers

- bio mass
- solar energy
- alternate fossil fuels

- synthetic fuels
- chemical mass products
- clean combustion
- electricity (fuel cells)

Challenge: rapid transfer from research to sustainable technology
Driving forces: interdisciplinarity and integration of new technologies from different fields

<table>
<thead>
<tr>
<th>Interdisciplinary Science and Technology</th>
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<tbody>
<tr>
<td>chemistry</td>
<td>nano materials</td>
</tr>
<tr>
<td>physics</td>
<td>micro structured reactors</td>
</tr>
<tr>
<td>biology</td>
<td>high-throughput methods</td>
</tr>
<tr>
<td>process engineering</td>
<td>in-situ analytics</td>
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<tr>
<td>energy technology</td>
<td>system technology</td>
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<tr>
<td>materials sciences</td>
<td>rational design</td>
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Need for inter-faculty and technology-driven qualification of graduate students
Helmholtz Research School Energy-Related Catalysis at Karlsruhe Institute of Technology

**Research:**
KIT possesses scientific and technological **expertise**
→ School boosts integration of science and engineering groups in catalysis research (from molecules to pilot plants)

**Teaching:**
KIT offers courses reaching from fundamental research to technical application
→ School supports interdisciplinary aspects in teaching among science and engineering departments (lectures, lab courses, seminars for graduates)

**Innovation:**
→ School boosts development and realization of new catalytic processes in the energy sector
→ KIT benefits from patents, licenses, and spin-offs

**Structure:**
Close collaboration with KIT School of Energy and Karlsruhe House of Young Scientists (KHYS)
### University Departments

- Chemistry and Biosciences at KIT (Deutschmann, Grunwaldt, Roesky, Wöll)
- Chemical and Process Engineering at KIT (Dittmeyer, Kraushaar-Czarnetzki, Schaub)
- Electrical Engineering and Information Technology at KIT (Ivers-Tiffée)
- Chemistry and Earth Sciences at Heidelberg University (Dinjus, Döring)

### National Laboratory

- Institute for Technical Chemistry, Division of Chemical-Physical Processing (Dinjus, Döring, Grunwaldt)
- Institute for Micro Process Engineering (Dittmeyer)
- Institute of Functional Interfaces (Wöll)
- Institute for Nuclear and Energy Technology (Deutschmann)

#### 10 Groups from 4 University Departments and 4 Institutes of the National Laboratory
**Helmholtz Research School Energy-Related Catalysis: Qualification concept**

Excellent graduates: Co-organization of courses, workshops, and schools by graduates

**Graduates teach Graduates**

<table>
<thead>
<tr>
<th>Joint courses</th>
<th>Summer school</th>
<th>Workshop</th>
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<tbody>
<tr>
<td><strong>Lab courses</strong></td>
<td><strong>Lab courses</strong></td>
<td><strong>Specific courses</strong></td>
</tr>
<tr>
<td>In-situ analytics Reactors (ITCP)</td>
<td>Chemical technology (ITC-CPV)</td>
<td><strong>Internships in industry</strong></td>
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<tr>
<td>Surface analytics (IFG)</td>
<td>Micro reactor technology (IMVT)</td>
<td>BASF, Bayer, BMW, Bosch, Daimler, Evonik, Haldor Topsoe, Linde, Umicore, Süd-Chemie, …</td>
</tr>
<tr>
<td>X-ray analytics (ANKA)</td>
<td>Process Engineering (ICVT)</td>
<td><strong>Research visits abroad</strong></td>
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<tr>
<td></td>
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<td>U Alberta, Colorado School of Mines, TU Delft, DTU, U Minnesota, NTNU, Kyoto U, Politecnico de Milano, ETH Zürich, …</td>
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<tr>
<td></td>
<td></td>
<td><strong>Publications, patents</strong></td>
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KIT – Universität des Landes Baden-Württemberg und nationales Forschungszentrum in der Helmholtz-Gemeinschaft
Helmholtz Research School Energy-Related Catalysis:
Recruiting and supervision of members

Recruiting of excellent graduates by internationally open recruiting process
(approx. 30% from abroad, >30% females)

Two independent supervisors for each graduate

Individual qualification program

Integration into international scientific community

Graduates elect a student’s representative and two deputies

Support by Karlsruhe House of Young Scientists (KHYS), House of Competence (HoC),
KIT School of Energy, Studienkolleg, Akademisches Auslandsamt
Helmholtz Research School Energy-Related Catalysis:
Financial budget

Total budget (Mio €)

- Uni 1,51
- HC 1,20
- Partners 2,71
- HG 1,65
- Uni 0,67
- HC 0,98

Assignment of the financial budget funded by the Helmholtz-Gemeinschaft

- Direct personnel costs (coordinator)
- Materials and Supplies
- Scholarships
- Investments
Helmholtz Research School Energy-Related Catalysis: Establishment of an infrastructure for continuous qualification

Helmholtz Research School: 45-50 graduates in two cycles

- 2011: 10 Graduates
- 2013: 5 Graduates
- 2015: 10 Graduates
- 2017: 10 Graduates
- 2019: 5 Graduates

Funding:
- 2011-2015: External (Helmholtz) + internal funding
- 2017-2019: Internal funding
## Helmholtz Research School Energy-Related Catalysis: Objectives

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<thead>
<tr>
<th>Objective</th>
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<tr>
<td><strong>Excellent Doctors</strong> in Science and Engineering for the solution of the 21\textsuperscript{st} century’s problems of raw materials and energy conversion using catalysis</td>
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<td><strong>Interdisciplinary knowledge and experience</strong></td>
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<td><strong>Scientific thoroughness</strong></td>
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<td><strong>Rapid transfer of fundamental research into sustainable technology</strong></td>
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<td><strong>Personnel management</strong></td>
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<td><strong>Ability to work in a team</strong></td>
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<tr>
<td><strong>Capability to be innovative</strong></td>
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Thank you for your attention!

O. Deutschmann
E. Dinjus
R. Dittmeyer
M. Döring
J.-D. Grunwaldt
E. Ivers-Tiffée
B. Kraushaar-Czarnetzki
P. Roesky
G. Schaub
C. Wöll
S. Tischer
Katalysezentren und -verbünde in Deutschland

Leibniz-Institut für Katalyse e. V.
250 Mitarbeiter; 12,5 Mio. € Etat; Forschungsschwerpunkte in Homogener Katalyse, Organischer Synthese

Exzellenzcluster UniCat (Unifying Concepts in Catalysis)
250 Mitarbeiter; Forschungsschwerpunkte zur komplexen Katalyse, zu natürlichen und künstlichen Enzyme und zu komplexer Reaktionstechnik

CAT Catalytic Center Aachen
Joint Venture RWTH + Bayer; 20 Wissenschaftler; Grundlagenforschung zu Homogener & Heterogener Katalyse

Katalyselabor CaRLa Heidelberg
Joint Venture Uni HD + BASF; 12 Wissenschaftler; Grundlagenforschung zu angewandter Homogener Katalyse

Katalyse am KIT
Über 200 Wissenschaftler; Forschung und Prozessentwicklung zu angewandter Heterogener Katalyse

TUM Catalysis Research Center
200 Mitarbeiter; Forschungen in allen Bereichen der Katalyse mit Schwerpunkten in der universitären Grundlagenforschung
## Helmholtz-Kolleg Energierelevante Katalyse: Themen und Methoden der Graduiertenausbildung

### Themen

<table>
<thead>
<tr>
<th>Ringvorlesung</th>
<th>Methoden</th>
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<tr>
<td>Conversion of alternate raw materials into chemical products and energy</td>
<td>Preparation of catalytic active materials</td>
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<tr>
<td>Photo catalysis, photolysis, and water splitting</td>
<td>In-situ characterization of catalysts and processes incl. ANKA</td>
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<tr>
<td>Activation of and syntheses with CO₂</td>
<td>Mechanistic studies</td>
</tr>
<tr>
<td>Electro catalysis (batteries, fuel cells, and O₂ separation)</td>
<td>Model systems &amp; validation</td>
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<tr>
<td>Energy-related materials</td>
<td>Catalytic process engineering and process intensification</td>
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<tr>
<td>Atom efficient reactions</td>
<td>Mathematical modeling &amp; Simulation</td>
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### Methoden

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<th>Sommerschulen</th>
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<tr>
<td>Workshops</td>
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- Industriepraktika
- Auslandsaufenthalte
- Konferenzen
- Publik.
Energy-related catalysis: Implementation into KIT structures – Competence fields

**Matter and Materials (6)**
- Elementary Particle and Astroparticle Physics
- Condensed Matter
- Nanoscience
- Microtechnology
- Optics and Photonics
- Applied and New Materials

**Applied Life Sciences (4)**
- Biotechnology
- Toxicology and Food Science
- Health and Medical Engineering
- Cellular and Structural Biology

**Earth and Environment (4)**
- Atmosphere and Climate
- Geosphere and Risk Management
- Hydrosphere and Environmental Engineering
- Constructed Facilities and Urban Infrastructure

**Technology, Culture and Society (3)**
- Cultural Heritage and Dynamics of Change
- Business Organization and Innovation
- Interaction of Science and Technology with Society

**Information, Communication, and Organisation (6)**
- Algorithm, Software and System Engineering
- Cognition and Information Engineering
- Communication Technology
- High-Performance and Grid Computing
- Mathematical Models
- Organisation and Service Engineering

**Systems and Processes (7)**
- Systems and Embedded Systems
- Power Plant Technology
- Mobile Systems and Mobility Engineering
- Product Life Cycle
- Fluid and Particle Dynamics
- Chemical and Thermal Process Engineering
- Fuel and Combustion
Energy-related catalysis: Implementation into Helmholtz programs (POF)

<table>
<thead>
<tr>
<th>Energy</th>
<th>Renewable Energies</th>
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<tbody>
<tr>
<td></td>
<td>Nuclear Fusion</td>
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<td></td>
<td>Nuclear Safety Research</td>
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<td></td>
<td>Efficient Energy Conversion and Use</td>
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<tr>
<td>Technology, Innovation &amp; Energy Systems Analysis</td>
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| Earth and Environment           | Atmosphere and Climate                                                            |

| Key Technologies                | Biointerfaces                                                                     |
|                                | Nano- and Microsystems Program                                                     |
|                                | Scientific Computing                                                               |
| Technology, Innovation & Energy Systems Analysis |

| Structure of Matter             | Astroparticle Physics                                                             |
|                                | Synchrotron Radiation Source ANKA                                                 |
Crude oil: Raw material for the production of fuels and chemicals in the 20th century
Heterogeneous catalysis: Major technology in production of fuels, chemicals, and emission control

All Processes

- Catalytic Processes: 85%
- Non-Catalytic Processes: 15%

Catalytic Processes (Catalysts: 14.7 Billion USD)

- Heterogeneous Catalysts: 80%
  - Homogeneous Catalysts: 17%
  - Biocatalysts: 3%

- Non-Catalytic Processes: 15%
Energy-related catalysis: Experiences of cooperating partners at KIT

- Three partners (Dittmeyer, Grunwaldt, Wöll) joined KIT in 2009 and 2010

- Recent initiatives: Proposal for Helmholtz-School, Position paper on catalysis research in Karlsruhe

- Scientific awareness: > 400 ISI publications (since 2005), already > 3500 citations, > 150 patents, many editorial boards and honorary positions in the scientific community

- DFG experiences: many SFBs (e.g., Wöll = Coordinator of SFB 558) and research groups (e.g., Kraushaar-Czarnetzki = Coordinator of FOR 583, Graduate Colleges (GRS), Priority Programs (SPP), CFN (Ivers-Tiffée))

- > 100 PhD students since 2005