Innovation at “The Chemical Company” – Challenges and New Perspectives

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Outline of the Talk

- Introduction to BASF
- R&D at BASF
- Innovation Examples
- We Innovate for Growth – Growth Clusters at BASF
- BASF Future Business/BASF Venture Capital
At a glance

BASF – The Chemical Company

- The world’s leading chemical company
- Our portfolio ranges from chemicals, plastics, performance products, agricultural products and fine chemicals to crude oil and natural gas

- Sales 2005: €42,745 million
- Income from operations (EBIT) 2005: €5,830 million
- Employees as of December 31, 2005: 80,945
### BASF sales by industry

**Percentage of sales in 2005**

<table>
<thead>
<tr>
<th>Category</th>
<th>Industries</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 15% each</td>
<td>Chemicals (not an industry with end users)</td>
</tr>
<tr>
<td></td>
<td>Energy</td>
</tr>
<tr>
<td>10–15% each</td>
<td>Automotive</td>
</tr>
<tr>
<td></td>
<td>Agriculture</td>
</tr>
<tr>
<td>5–10% each</td>
<td>Construction</td>
</tr>
<tr>
<td>&lt; 5% each</td>
<td>Electrical/electronics</td>
</tr>
<tr>
<td></td>
<td>Carpets</td>
</tr>
<tr>
<td></td>
<td>Cosmetics</td>
</tr>
<tr>
<td></td>
<td>Detergents/cleaners</td>
</tr>
<tr>
<td></td>
<td>Furniture</td>
</tr>
<tr>
<td></td>
<td>Health</td>
</tr>
<tr>
<td></td>
<td>Leather/shoes</td>
</tr>
<tr>
<td></td>
<td>Packaging</td>
</tr>
<tr>
<td></td>
<td>Paper</td>
</tr>
<tr>
<td></td>
<td>Textiles</td>
</tr>
</tbody>
</table>

**Other industries: approximately 10% in total**
<table>
<thead>
<tr>
<th>Segments</th>
<th>Products (examples)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemicals</strong></td>
<td>Inorganic basic chemicals and specialties, electronic chemicals, glues, resins, petrochemical feedstocks, plasticizers, amines, diols, polyalcohols, carboxylic acids, specialty intermediates</td>
</tr>
<tr>
<td><strong>Plastics</strong></td>
<td>Styrene, styrene-based polymers and copolymers, caprolactam and nylon, engineering plastics, polyurethane basic materials and polyurethane systems, specialty elastomers</td>
</tr>
<tr>
<td><strong>Performance Products</strong></td>
<td>Performance chemicals for coatings, plastics and specialties and for detergents and formulators, textile and leather chemicals, fuel and lubricant additives, automotive OEM and refinish coatings, industrial coatings, acrylic monomers, superabsorbents, adhesive raw materials, construction chemicals, paper chemicals</td>
</tr>
<tr>
<td><strong>Agricultural Products &amp; Nutrition</strong></td>
<td>Herbicides, fungicides, insecticides and seed treatments, vitamins, carotenoids, aroma chemicals, pharmaceutical active ingredients and excipients, pharma contract manufacturing, UV absorbers</td>
</tr>
<tr>
<td><strong>Oil &amp; Gas</strong></td>
<td>Crude oil and natural gas (exploration, production as well as transmission, storage and trading)</td>
</tr>
</tbody>
</table>
BASF Group:
Sales by segment in 2005

Billion € (change compared with previous year in percent)

Other 1.9 (+25.5%)

Oil & Gas
7.7 (+45.5%)

Agricultural Products & Nutrition
5.0 (-2.3%)

Performance Products
8.3 (+3.3%)

Chemicals
8.1 (+15.4%)

Plastics
11.7 (+11.3%)
BASF Group: Sales by region* in 2005

Million € (change compared with previous year in percent)

- **Europe**: 25,093 (+11.3%)
- **Germany**: 17,100 (+12.4%)
- **North America (NAFTA)**: 9,542 (+16.9%)
- **South America, Africa, Middle East**: 2,068 (+7.4%)
- **Asia Pacific**: 6,042 (+23.0%)

* By location of company
World Class R&D Capabilities

- R&D Expenditure 2004: 1.17 billion Euro (incl. Oil & Gas Exploration)
- > 6,800 R&D personnel worldwide
- Operating divisions finance 80% of our R&D
- 20% Corporate funded Research

Businesses and markets drive our R&D
Research organization

Central technology platforms

- Specialty Chemicals Research
- Operating divisions
- Research institutes
- Universities
- Subsidiaries
- High-tech joint ventures
- Industry partners
- Polymer Research
- Chemicals Research & Engineering
Idea is not equivalent to Market Success

Source: Universität St. Gallen, Prof. Gassmann
Patent Race BASF - Zeneca

Cooperation with Uni Kaiserslautern (Prof. Anke) and Munich (Prof. Steglich)

Strobilurin A (Juli 83)  
Oudemansin (Juli 82)

Enol ether stilben

Enol ether patents
30.05.85  19.10.84

Oxime ether patents
16.07.86  18.07.86

Kresoxim-methyl  
Azoxystrobin
The Ionic Liquid Story

John Wilkes
Imidazolium salts

Prof. Ken Seddon
„Ionic Liquids“

Prof. Peter Wasserscheid

1960s

1980

1999

2002

Number of papers

Time

BASIL™
Lucirin® TPO-L

Building blocks

Photoinitiator for UV curing
Lucirin® TPO-L
Diethoxyphenylphosphine (DEPP) Synthesis

\[
\text{DCPP} + 2 \text{EtOH} + 2 \text{R}_3\text{N} \rightarrow 2 \text{R}_3\text{N} \cdot \text{HCl} + \text{DEPP (solid salt)}
\]
Lucirin® TPO-L
Separation: Solid Liquid

Lab scale

Technical process
Lucirin® TPO-L
Separation: Liquid-Liquid

Simple, reliable and cheap!
Can 1-Methylimidazole do the job?

\[
\text{DCPP} + 2 \text{EtOH} + \overset{\text{Me}}{\text{N}}\overset{\text{N}}{\text{N}} + \overset{\text{Me}}{\text{N}}\overset{\text{N}}{\text{N}} + Cl^- \rightarrow \overset{\text{Ph}}{\text{P}}\overset{\text{OEt}}{\text{OEt}} + \overset{\text{Me}}{\text{N}}\overset{\text{N}}{\text{N}} + \overset{\text{Cl}}{-}
\]

Liquid salt (ionic liquid)
Continuous process with jet reactor

Space-time-yield

8 kg m⁻³ h⁻¹

Batch reactor

Space-time-yield

690,000 kg m⁻³ h⁻¹

8 · 10⁴

Reactor design

New Reactor Concepts

Lucirin®

TPOT®

LL
Another Example from BASF
Nucleophilic HCl

HCl + DCB + CBO + THF → DCBE

Nucleophilic HCl as alternative to phosgene

DE 10341308 (BASF)
Ecoflex - new biodegradable polyester

- Statistical polyester synthesized from BASF monomers: 1,4-butane diol, adipic acid and teraphthalic acid.
- Good thermoplastic properties.
- M.p.: 110 °C; Tg = -33 °C.
- Forms semi-transparent films for packaging.
- Low water solubility

![Ecoflex structure](image)

- Composting initial
- Composting after two weeks
- Composting after four weeks
Polymers from CO₂ in Air

Epoxide + CO₂ → cat. → Aliphatic Polycarbonates

- CO₂-circle
- Gas-barrier-properties
- Material properties tunable
- Biodegradability
- Transparency

Epoxide  Carbon dioxide  Aliphatic Polycarbonates
Structural changes in the chemical industry

**External driving forces**

- Globalisation of customer industries
- Increasing cost pressure, especially on commodities
- New technological challenges, particularly in the area of biotechnology, genetic engineering and nanotechnology
- Appearance of small high-tech companies
- Strong pressure to increase shareholder value
- Environmental pressure to increase sustainability of the industry

**Internal processes of adaptation**

- Development of transnational chemical companies
- Focus on core competences
- Continuing consolidation
- Marked increase in the number of joint ventures in sub-segments of the portfolio
We innovate for growth!
Stimulate growth from inside

Cross-platform developments in growth clusters: 2006 – 2008 of approx. €800 million

- Plant biotechnology: 270 million
- Industrial biotechnology: 150 million
- Energy management: 180 million
- Raw material change: 100 million
- Nanotechnology: 90 million

Chart showing distribution of €800 million investments across different growth clusters.
Biocatalysis: Use of Enzymes

ChiPro® - Plant, Ludwigshafen
Products via Biocatalysis: Chiral Amines

**Aryl-Alkyl-Amines**
- NH$_2$
- Cl
- NH$_2$
- O

**Alkyl-Amines**
- NH$_2$
- NH$_2$
- NH$_2$
- NH$_2$

**Aminoalcohols**
- NH$_2$
- NH$_2$
- O
- OH
- NH$_2$
- O
Optically active amines

New facility
Geismar, USA
capacity: 2,500 t/a

S-MOIPA

Outlook®
Vitamin B2

Cooperation with Uni Salamanca (Prof. Revuelta)

glucose

soybean oil

Ashbya gossypii
Wildtype

Mutant M 2/14

Vitamin B2
Energy storage
Metal organic frameworks for gas/hydrogen storage

Target
- Storage density of liquid hydrogen
- Setting and removal within seconds
- Use for mobile and portable fuel cells

Approach
- Modelling of high surface structures
- Synthesis, scale-up and shaping of MOF
- Cooperation with Prof. Yaghi, University of California at LA
MOF-Nanocubes

MOF = Metal Organic Framework
Linkers Possibilities
MOF-Nanocubes
BASOCUBE™

3 000 m²/g

Simple chemicals into novel nano-networks
MOF-Nanocubes
Gas-Storage in MOF

uptake

pressure [bar]

0 5 10 15
7.5 wt % Hydrogen uptake at 77K
(30 % more Hydrogen in a tank filled with MOF)
Gas Storage – Methane (295 K; prototype)

Methane Adsorption

- empty canister
- Ceca AC40, active carbon (1030 g)
- IRMOF-8 (474g)
- MOF-5 (686 g)
MOF-Nanocubes
BASOCUBE™
MOF-Nanocubes
BASOCUBE™
MOF-Nanocubes
Applications

- Gas storage
- Catalysis
- MOF = Metal-Organic Framework
- Odor control
- Gas purification
- Gas separation
Catalysis: Multiplicator and Innovation Engine for Chemicals

About 90% of all chemicals are produced using catalysis!!!!

Global Chemicals Market 2005
c.a. € 1500 billion/a

Global Catalyst Market 2004
c.a. € 12 billion/a
Catalysis -
a Key Technology Platform for Business and Society
Catalysis Research at BASF

History

Ammonia-Laboratory was founded by Bosch and Mittasch

- 1903 Research on ammonia began: \( \text{N}_2 + 3 \text{H}_2 \rightleftharpoons 2 \text{NH}_3 \)
- 1913 First production of ammonia by the Haber-Bosch-Process
- 1931 Nobel Prize: Bosch / Bergius

Carl Bosch  
Historic Reactor  
Plant Antwerp

500 million tons of artificial fertilizer per year employing 1% of the world's energy. It sustains about 40% of our planetary population
Example: Acrylic Acid

Increase in yield through improvement of catalytic system
Propylene Oxide Technologies

Chlorohydrin
1930

SMPO
1975

BASF-HPPO
JDA with DOW
2008

1.5 t salt/t PO

2.2 t SM/t PO

water only

\[
\text{H}_2\text{O} + \text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{O} + \text{H}_2\text{O}
\]

\[
\text{Cl} + \text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{CaCl}_2 + \text{Ca(OH)}_2 + \text{H}_2\text{O}
\]

\[
\text{C}_2\text{H}_4 + \text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{ClCH}_2\text{CH}_2\text{OH} + \text{CaCl}_2
\]

\[
\text{O} + \text{O}_2 \rightarrow \text{H}_2\text{O}
\]

\[
\text{O}_2 \rightarrow \text{O}_2 + \text{H}_2\text{O}
\]

\[
\text{SMPO} \rightarrow \text{C}_2\text{H}_4
\]
Co-product free epoxidation of propylene with crude H₂O₂

Heterogenous liquid phase epoxidation with methanol as solvent

Fixed bed technology using a proprietary TS-1 catalyst
Propylene Oxide – HPPO Process

Chemistry of the Process

Side products: formed by addition of nucleophiles to PO
Parallel reaction: $O_2$ formed by the decomposition of $H_2O_2$
Propylene Oxide – HPPO Process
Catalytic Cycle
Propylene Oxide – HPPO Process

BASF Catalyst – Proprietary Ti-zeolite System
Innovation Process – Roles & Responsibilities
Opportunity fields and projects

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**Energy Management**
New materials and technologies to transform, save, or store energy
Challenge: Enhanced materials, system integration
Projects (among others): Fuel cells, Thermoelectric Materials, Lighting

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**Quality of Life**
New materials and technologies to enhance quality of life
Challenge: Business model to target consumers
Projects (among others): Individualize Nutrition and Body Care

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**Communication, Information, and Entertainment**
Organic semiconductors in displays, chips, or photovoltaics
Challenge: Participation in next level of value chain
Projects (among others): Printed Electronics, Electrophoretic Displays
Mission and Strategy

- Identification and development of new business segments for BASF group
  - Outside of the existing global and regional business units
  - Based on chemistry and/or related technologies
  - Markets with above-average growth rates

- Building a sustainable competitive position in these segments
  - Selecting the appropriate business model
  - Developing proprietary technology and system solutions
  - Establishing partnerships

- Investing in new technology-based companies and funds
  - Return on investment adequate to the high risk
  - Window on technology
BASF Venture Capital GmbH

Current BASF Venture Capital-Portfolio

Venture for the future