Micro reaction in Europe and in Asia: status of R&D and industry, applications and markets

Micro Nano Breakthrough Conference
Portland, July 28th 2004

WTC – Wicht Technologie Consulting
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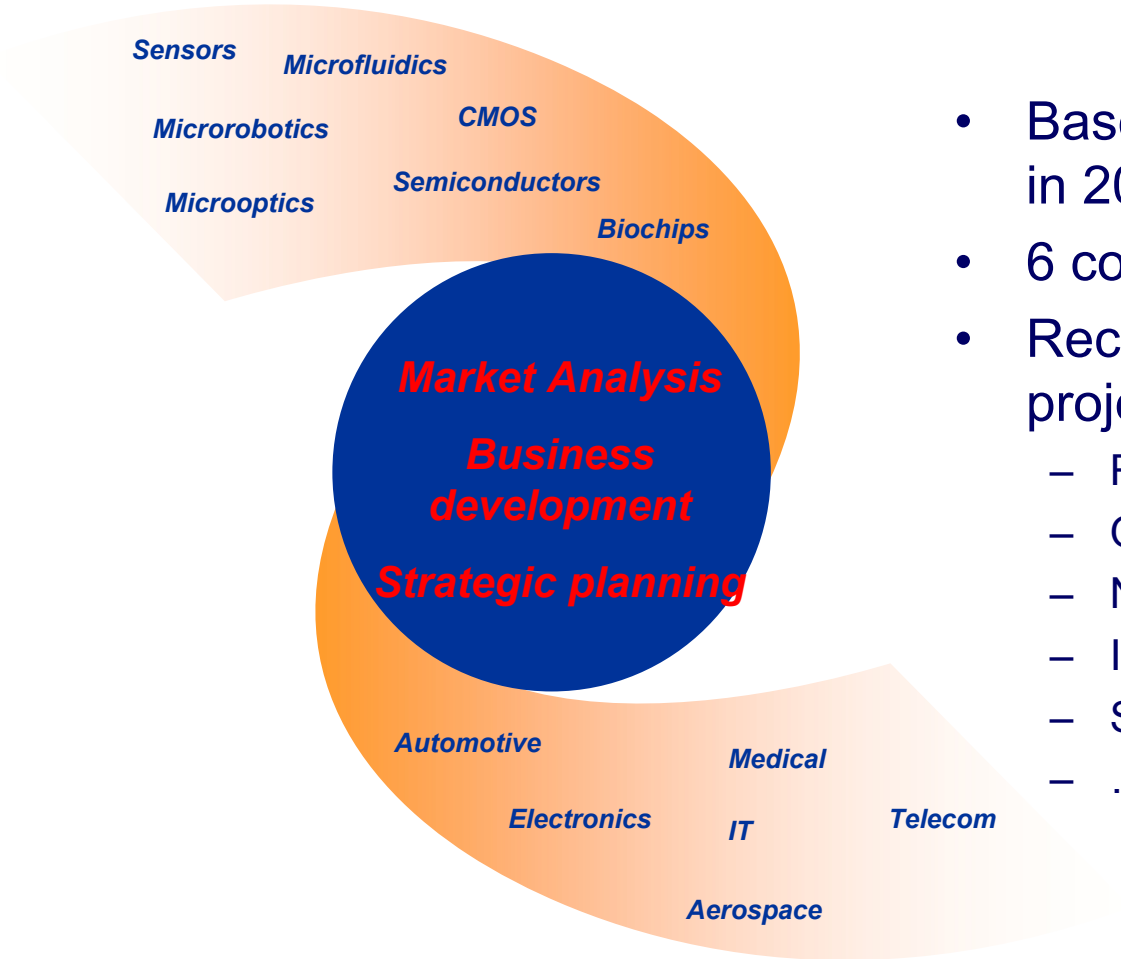
WTC investigates markets for Micro and Nano



- Based in Munich, founded in 2000
- 6 consultants
- Recent and on-going projects on
  - RF MEMS
  - Optical MEMS
  - Nano-bio
  - Inertial MEMS
  - SiC/GaN
  - …

Outline

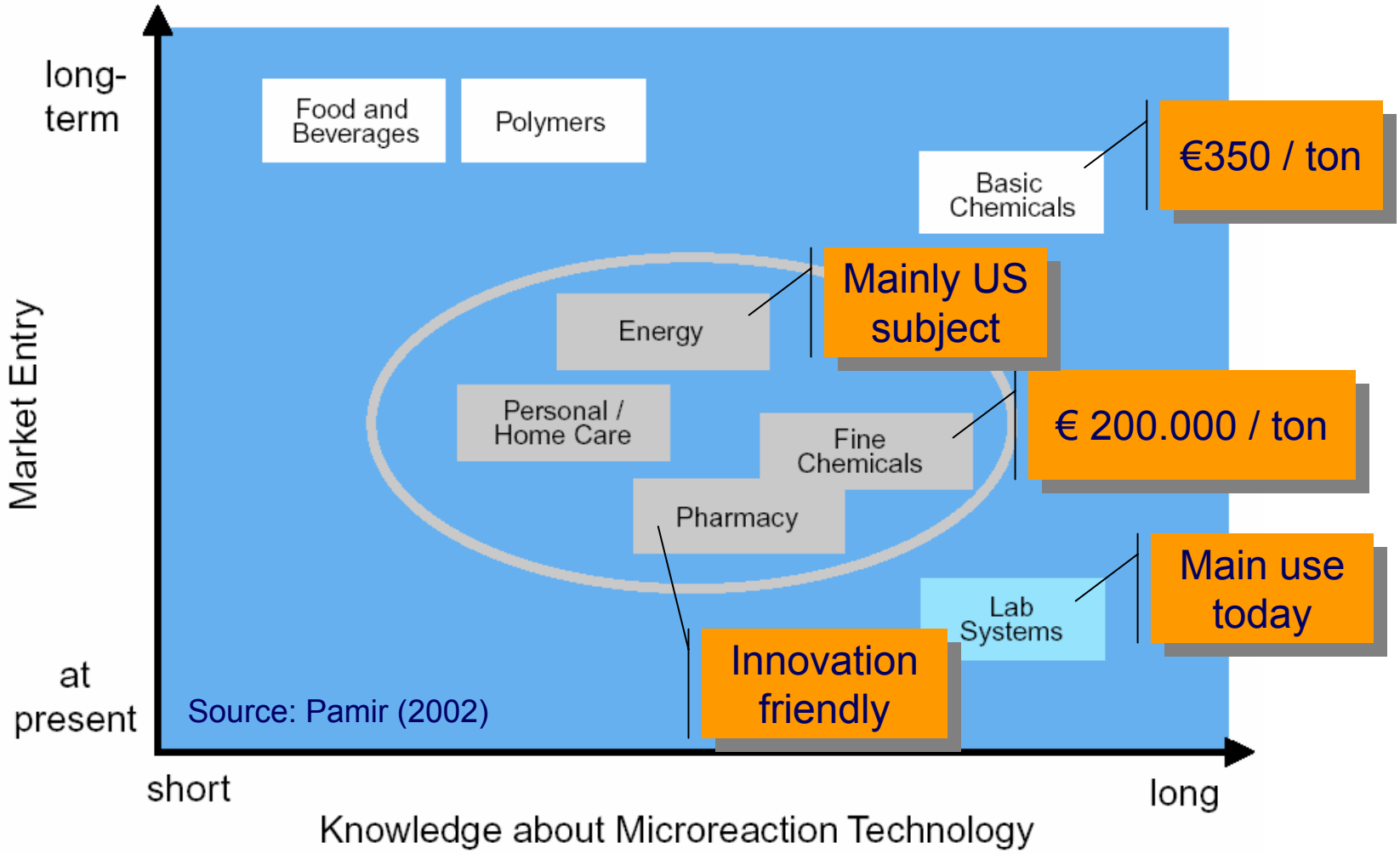
- Status of the micro-reaction industry and R&D
  - Definition
  - Micro-reaction applications
  - Micro-reaction offer
  - When will the market breakthrough come?
- Regional analysis
  - Micro-reaction in Europe, case study Germany
  - Micro-reaction in Japan

Definition (from PAMIR Study, 2002)

- „Microreaction technology (MRT) is the whole of strategies and techniques used to introduce the inherent advantages of microstructures to chemical process equipment and production.

- Benefits of Micro-reaction Technologies:
  - Effective heat management which leads to process intensification
  - Novel process regimes
  - Enhanced safety and environmental issues
  - Highly uniform dispersions (without detergents)
  - Major cost savings
  - Flexible production on-site and on-demand
  - Reduction of time scale
  - Higher yields and selectivities as well as less waste“

Applications of micro-reaction

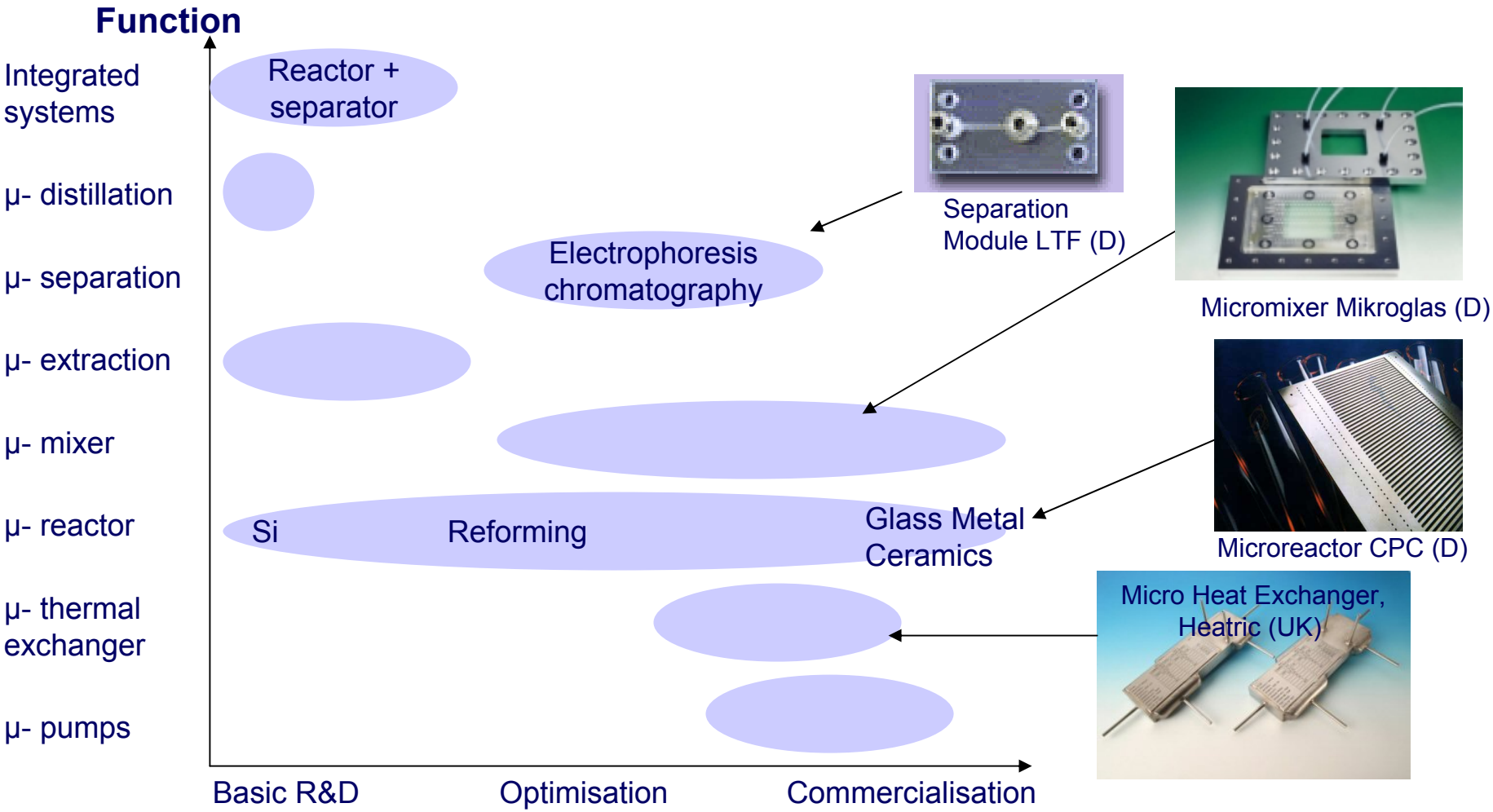


Examples of applications of micro-reaction

	Enabled function	Applications
R&D	• Parallel networks for R&D	• Finding new catalyst • Combinatory synthesis and high throughput screening for new molecules discovery • Development and optimisation of new processes
Production	• In-situ production on demand	• Hazardous and toxic reactions • Fuel cells, reforming
	• Special environments	• Space and oil industry platforms • Specific synthesis
	• Mass production using parallel system concepts	• Formulation • Waste and pollutants reduction
Analytics	• On-line control	• Quality control, pollutant detection

Source: CEA (2004)

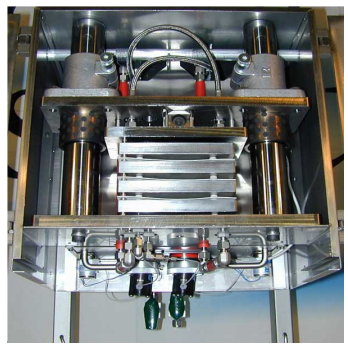
Offer of micro-reaction products: status in 2004



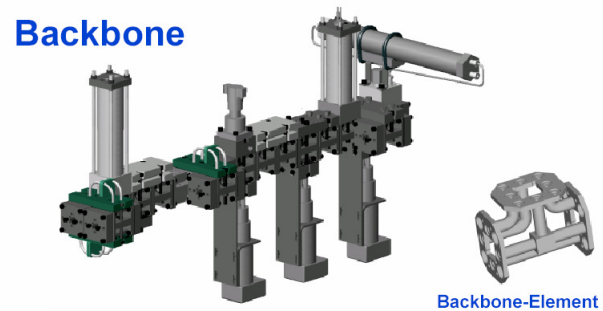
Source: CEA and WTC (2004)

Trends in micro-reaction offer

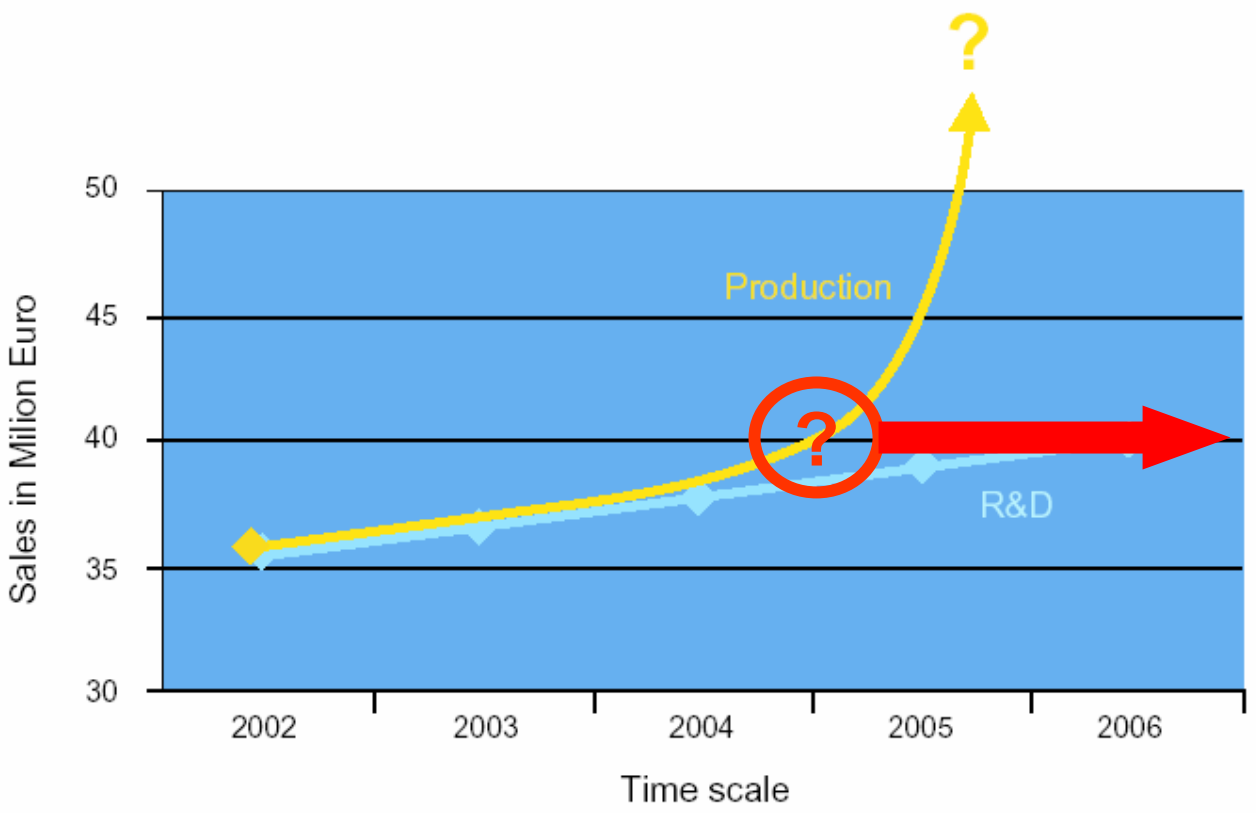
- Supplyers are R&D institutes and start-ups
  - IMM and Research Center Karlsruhe (Germany)
  - Chemical Micro Systems (UK, start up from Uni. Hulls), CPC (D), Mikroglas (D), Ehrfeld start-ups from IMM
- From component supplier to system supplier
  - Assembly of modules (Mikroglas, Ehrfeld...)
  - On-Chip integration (CEA-Leti, (F))
- Standardisation effort initiated
  - Backbone element
  - Mikro Heat Exhanger (LTF, FZK)
  - Micro-reactor (IMM)...



Cytos System
CPC (D)



When will the breakthrough come?



Market for micro-reaction technology
(Source PAMIR study, 2002)

How to make the breakthrough?

Learn from recent investigations

	PAMIR (EU) 2001-2002, asking 90 Institutes & companies	DECHEMA (D) (2003, asking 40 members	WTC (D) 2003, asking 20 institutes, users and suppliers	CEA (F) 2003-2004, asking 40 users in chemicals, pharmaceuticals…
Barriers to use in production	• Small productions volumes • Costs • Bad synergies suppliers/users • Missing success stories	• No clear concept for implementation and interfaces in production sites • Lack of info and comparison on market and economics • Missing success stories	• Technical problems: interfaces, life cycle (harsh environment), missing sensors, control of parallel systems... • Economics: long investments cycles of chemical industry	• Resistance to pressure, temp, solvents. Contamination • Control of parallel systems • Clogging • + Integration, Packa-ging, interfaces
Proposed actions	• Standardisation • Education • Increased communication	• **Technique:** Interfaces, sensor integration... • **Market:** Investigate economical aspects • Education	• **Technique:** Interface micro-macro. Simulation. Intelligent complete systems. • **Market:** Economics and competitive analysis	• **Technique:** solving of 3 mentioned main technical issues • **Market:** deeper investigation of ROI

How to make the breakthrough?

Learn from recent investigations

- Technical aspects: development of missing breaks
  - Sensors, actuators
  - Electronic control
  - Develop micro-macro interfaces
  - Lack of experience on reliability, life cycles…
- Economical and social aspects
  - Understanding of economics: Cost/savings analysis compared with established technologies
  - Education of students and engineers
- More industrial demonstrators of technically and economically successful use of micro-reaction in industry!

Outline

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- Regional analysis
  - Micro-reaction in Europe, case study: Micro-reaction in Germany
  - Micro-reaction in Japan

Micro-reaction in Europe: no coordinated R&D at European level, mainly national initiatives

- Germany leader for R&D (IMM, FZK) components suppliers (CPC, Mikroglas, Bartels, LTF...) and industrial users (BASF, Bayer, Degussa, Clariant, Merck...)

- UK strong too:
  - National funding with EPSRC und Department of Trade and Industry (Peptide synthesis, Reaction modelling, Various reaction, Lab-on-Chip consortium)
  - Key players: R&D University of Hull, University of Sheffield, Cardiff University… and suppliers : Micro Chemical Systems (Spin-off of Hull), Heatric…
  - Strong co-operation with pharma. Industry: GlaxoSmithKline and Novartis

- Also academic work in CH (EPFL), F (CEA-Leti), NL (MESA+), I (Fiat Research Center)

Case Study: Micro-reaction in Germany
The entire supply chain!

German federal funding program: MST (€ 50 M. / year)
€ 15 M for micro-reaction over 3 years projects: MRT for production

DECHEMA (Chemical industry corporation)
µ-reaction working group

Academic research:
- Max Planck
- Uni Erlangen
- Uni Dortmund
- TU Chemnitz
- TU Ilmenau...

Components and Sub-systems:
- CPC
- ~~Ehrfeld~~
- LTF
- Mikroglas
- ~~Accoris~~ ?

Chemical plants building and planning
- Uhde (ThyssenKrupp)
- Siemens Axiva
- ...

Chemical and pharma Industry
- BASF
- Clariant
- Degussa
- Du Pont
- Merck
- Roche

R&D Institutes
- IMM
- FZK
- FhG alliance µ-reaction systems

Services and components suppliers:
Materials (MEH), µ-components and fabrication (ThinXXS, AMT, Bartel, HNP...), Modelling (FEMLAB)...

Example of demonstration project: ADEMIS

Uhde ThyssenKrupp

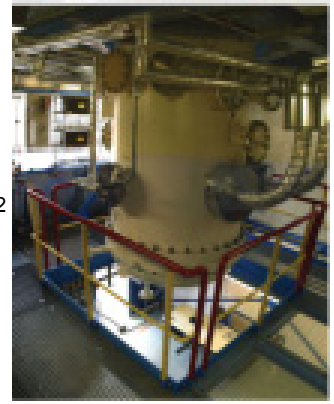
degussa. creating essentials

Industrial concepts for microstructured reactors on the example of heterogeneously catalyzed gas phase reactions

DEMiS®

(Demonstration project for the Evaluation of Microreaction technology in industrial Systems)

Duration: 06/2001 - 05/2004
Budget: 4,5 Mio. €



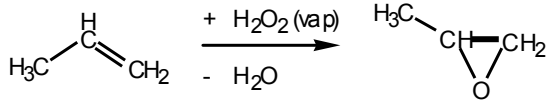
Technische Universität Chemnitz

Technische Universität Darmstadt

Max-Planck-Institut für Kohlenforschung, Mülheim-Ruhr

(Univ. Erlangen-Nürnberg)

Model reaction

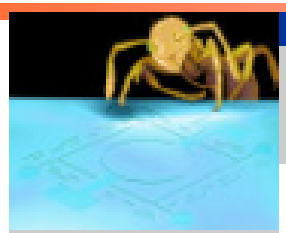


UHDE High Pressure Technologies

industrie.park Wolfgang

Quelle: Schirrmeister / Uhde GmbH , Markowz / Degussa AG

Example of demonstration project: Corapol (1/2)



Siemens A&D SP

Corapol – Continuous radical polymerization

Continuous free-radical polymerization with a micro mixer

- task

  development of a continuous free-radical polymerization process in a plug-flow reactor

  continuous very fast mixing of monomer and initiator required

  acceleration of the mixing process in order to prevent fouling of the static mixer due to the formation of long-chain polymer molecules

  pilot plant scale: about 6 kg/h

- solution

  installation of a micro mixer in front of the static mixer

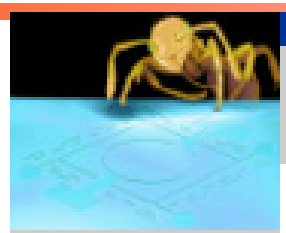
- **results**

without micro mixer:
fouling of the static mixer

with micro mixer:
no fouling

SIEMENS

Example of demonstration project: Corapol (2/2)



Siemens A&D SP

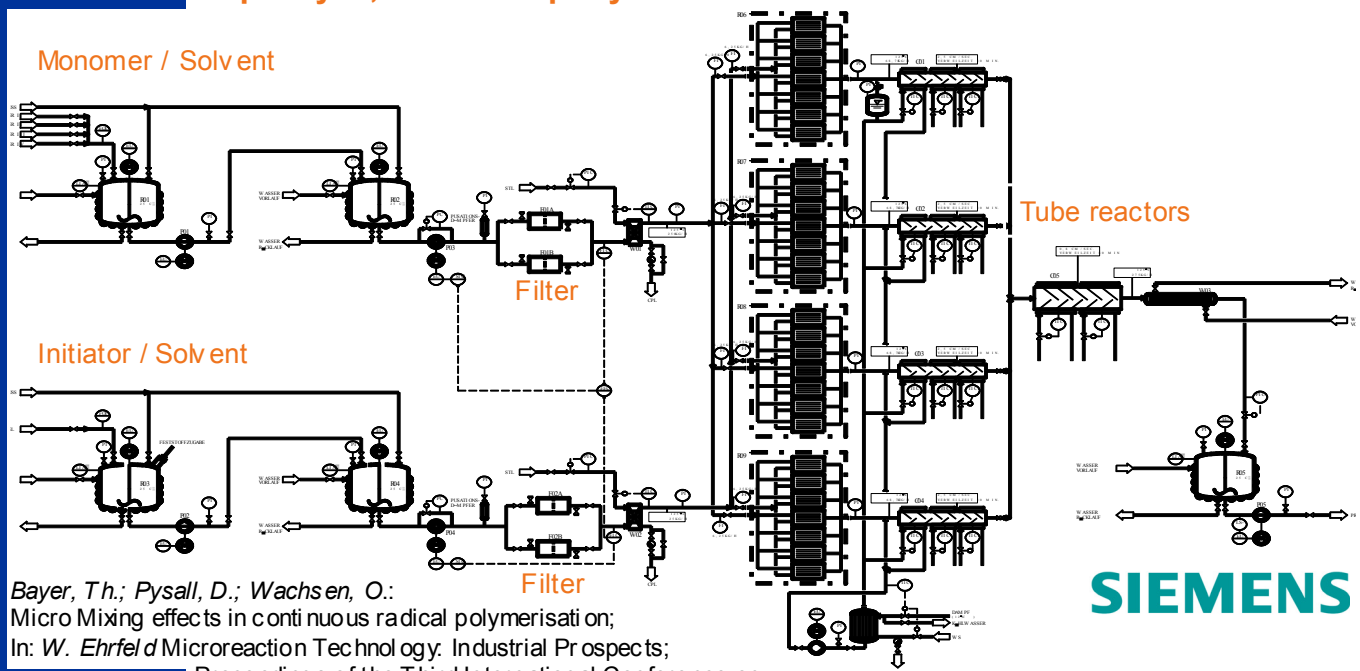
Automation and Drives

Corapol – Continuous radical polymerization

Integration of micro mixers and tube reactors in an existing plant infrastructure

Capacity: 2,000 m tons per year

28 Micro Mixer



Bayer, Th.; Pysall, D.; Wachsen, O.:
Micro Mixing effects in continuous radical polymerisation;
In: *W. Ehrfeld* Microreaction Technology: Industrial Prospects;
Proceedings of the Third International Conference on
Microreaction Technology, Springer Verlag 2000 S. 165-170

Industrielle Anwendungsbeispiele, DECHEMA e.V. 16.-17. Juni 2004

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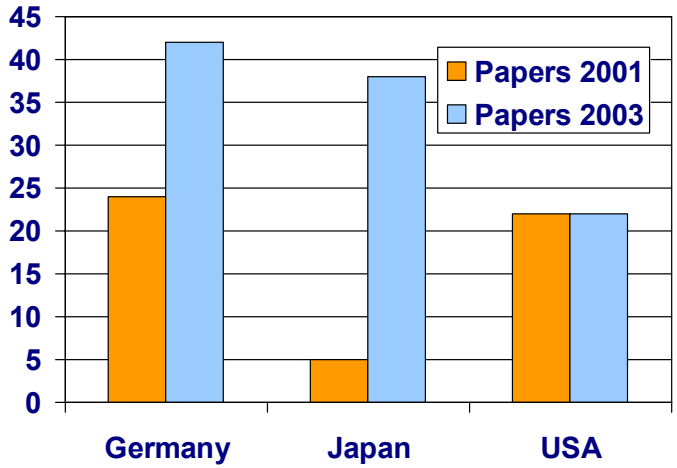
Folie 2

Micro-reaction in Japan: first observe and then massive involvement

- Recent and massive investment!
  - „Nothing to notice“ in PAMIR Study (2002)
  - Now one Priority of METI: $ 80 M. in micro-reaction over a 6 years program (NEDO)
  - See participation to International Conference on Microreaction Technology (IMRET) 5 and 7



Participation to IMRET 5 and 7

- Also strong involvment from Japanese industry
  - 29 industrial participants (February 04) including: Asahi Chemical, Mitsui Zosen, Olympus, Nippon Steel, Hitachi Seisakusho, Kaken, Fuji Film, Mitsubishi (Gas) Chemical, Toray, Jasco, Hitachi Chemical,....
  - $ 40 M invested by industry
- Objective: reduce the implementation time into commercial use
- Focus on chemical industry and biotech application (diagnostic chips)

Japanese project: „Highly Effective Micro Chemical Process Technology„

1. Basic developments for chemical micro plants:
   - Micro reactors, -mixer, -heat exchanger, -separation modules, new –compounds
   - Simulation and optimisation methods for suitable compounds
2. Development of micro chip technology
   - Phenomenological analysis: reactions, multi phase flow, energy and mass transfer, kinetic of the reaction in micro channels
   - Improvement of basic operations like mixing, reaction, condensation, extraction, separation, etc
   - Development of analytical chips, new sensitive detection and coupling with conventional detectors
   - Standardisation quality and reliability control
   - Flow control compounds like micro pump, valves, interfaces, flow sensors, temperature and pressure
3. Development of micro process technology
   - Chemical micro plant technology
   - Development of a scientific data base for analysis of materials and properties of micro structures
   - Modelling and simulation

Conclusion

- Micro-reaction in Europe mainly focuses fine chemicals and pharmaceuticals
- Single micro-reaction components commercially available
- Today, micro-reaction is used mainly for R&D. Pilot projects for production, but no market breakthrough yet
- Barriers for larger use in production identified. Focus of funding programs in Germany and Japan!
- The market breakthrough for production will probably take another 3-4 years
- Germany is leading today. But Japan is catching up
- What about Micro-reaction in the US?

Thank you!

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Micro-reaction in the German federal funding program for Microsystems

- New Microsystem funding program 2004-2009, € 50 M / year (nano funded in other program)
- 5 subjects:
  - Instrumentation and production techniques for Microsystems
  - **Micro-reaction**
  - Smart tags/RFID
  - BioMEMS
  - MEMS for automotive
- Call for micro-reaction technique open in April 2004: € 15 M in first round
  - Objective: focused **implementation of Micro-reaction in production** environment with pilot projects for chemical products synthesis:
    - ↳ Statements on reliability, life cycles, corrosion,
    - ↳ Electronics, sensor integration, actuators
    - ↳ Micro-macro interfaces, equaling up concepts
    - ↳ Cost analysis, ROI study, competitive analysis