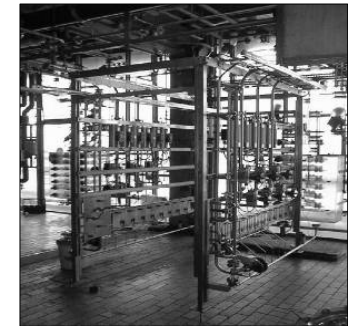
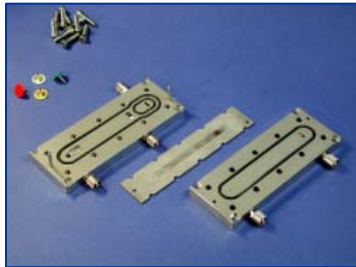


MicroReaction Technologies “Microtechnologies for chemical process intensification”

February 2007



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Scope of the report

- **The applications of microstructured channels described in this report are focused on fine & specialty chemicals and pharmaceuticals.**
- **Microfluidics for energy applications, such as micro fuel cells are not included in the scope of this report.**
- **Biological applications of microchannels, referred to as lab-on-chip, are not included in this report either. Yole Développement dedicates a full report to the biological applications of microfluidics, EMMA Emerging Markets for Microfluidic Applications.**

What has happened in 2006 ?

- **May 06: Siemens unveiled its SiProcess system, an open modular microprocess system, designed for syntheses in the chemical and pharmaceutical industries.**
- **May 06: Corning unveiled its mini-lab, a microreactor with a mutli-injection systems, that allows for a more homogenous mixing and a better control of temperatures.**
- **July 06: the five-year project “Development of Microspace and Nanospace Reaction, Environment Technology for Functional Materials” was started in Japan, involving MCPT, AIST, 7 universities and 9 companies, for an annual R&D budget between 500 to 600 million JPY.**
- **Dec 06: Plan Optik bought Little Things Factory. Thanks to this acquisition, Plan Optik will have access to LTF customers, such as Degussa, BASF, Merck, Schering, Siemens... Moreover LTF had developed a proprietary sand blasting technology for glass & quartz structuration. From the Ilmenau location of LTF, Plan Optik will also benefit from the innovative impulsion of the technology region Ehrfurt – Jena – Ilmenau.**

Introduction to MicroReaction Technologies

MRT definition

- Definition of Micro Reaction Technologies:

MRT refers to the design, fabrication and use of miniaturized fluidic components produced by using microtechnology techniques and precision engineering and leading to channels of diameters smaller than 1 mm.

Basic functions:

- **Micromixers**

from few ml/h up to 30 l/h with the latest products



IMM Interdigital micromixer

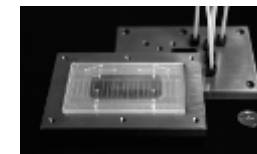
- **Micro Heat exchangers**

maximum value of 700 W/m²K at an air flow rate of 75 l/min

Heatric Cross Flow Heat Exchanger



- **Microreactors: combinaison of μ HE, μ mixers and residence time unit**



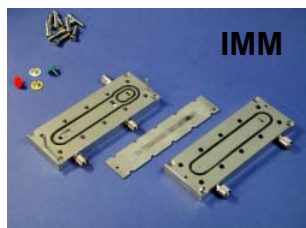
Mikroglas Microreactor

New functions are being explored, especially for work up procedures (purification, filtration, evaporation...)

Introduction to MicroReaction Technologies

MRT devices presentation

LAB



Microcomponents & Systems



0

18 - 24

Months

24 - 36

Source: FzK

Pilot Plants



Production: MRT plant



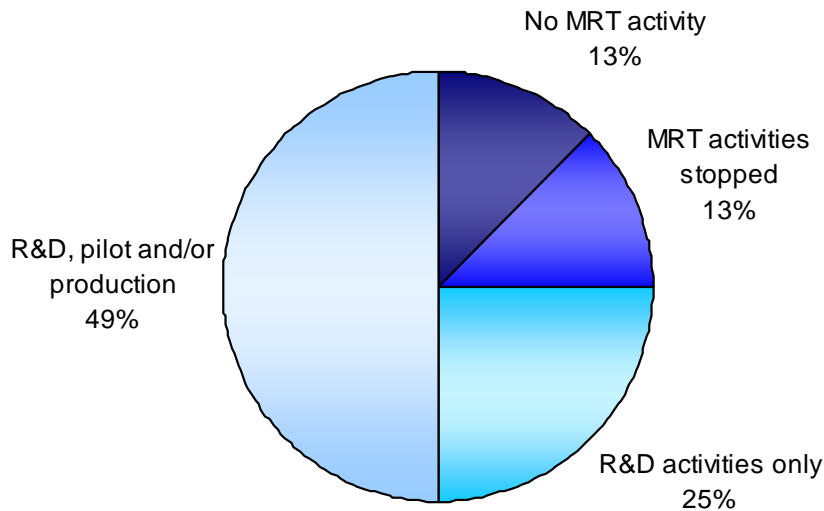
First developed for R&D purpose, MRT devices are entering the production field in the fine chemicals and pharmaceuticals fields.
Following this trend MRT devices are evolving from modules, to systems and finally to plants.

MRT Market Opportunities

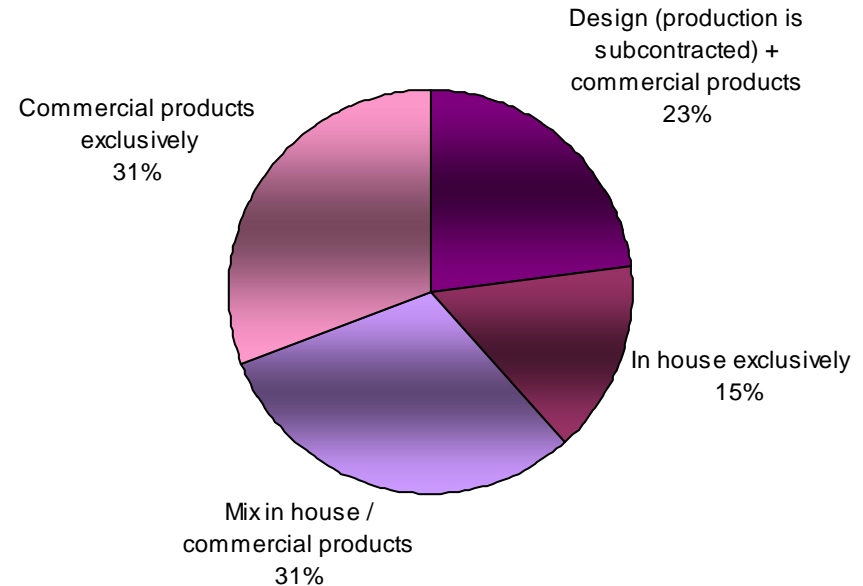
In-house versus commercial MRT products

The data are extracted from the 16 interviews of industrial chemical users realised in the course of the study.

This graph shows the MRT activities of the companies interviewed:



This graph shows the policy of companies active in MRT in MRT equipment procurement:



NB: Pharmaceutical companies tend to use commercially available MRT equipment.

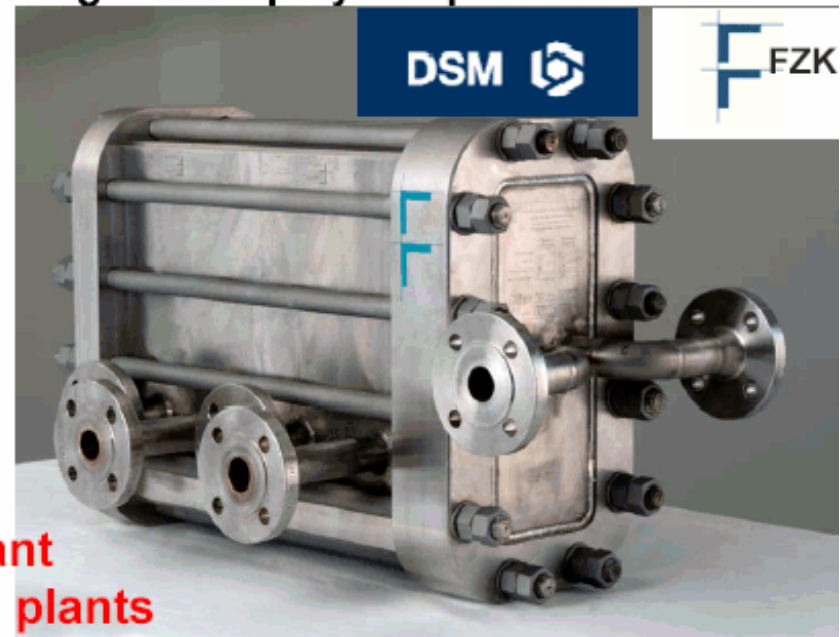
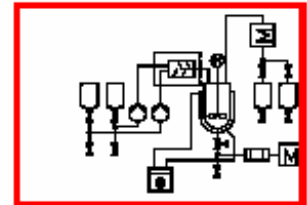
Production plant in DSM (AT)

(scaling out strategy)

FZK Press Release 13/2005 (July 06, 2005)

http://www.fzk.de/fzk/idcplg?ldcService=FZK&node=2374&document=ID_050927

- Chemical production with FZK microstructured reactor at DSM Fine Chemicals GmbH in Linz, Austria.
- Within 10 weeks more than 300 tons of a high-value polymer product.
- Product yield increased compared to conventional processing
- Less raw material use and less waste generation, more process safety
- Micro-reactor dimensions: 65 cm long; 290 kg heavy; 1700 kg/h liquid throughput; several 100 kW power

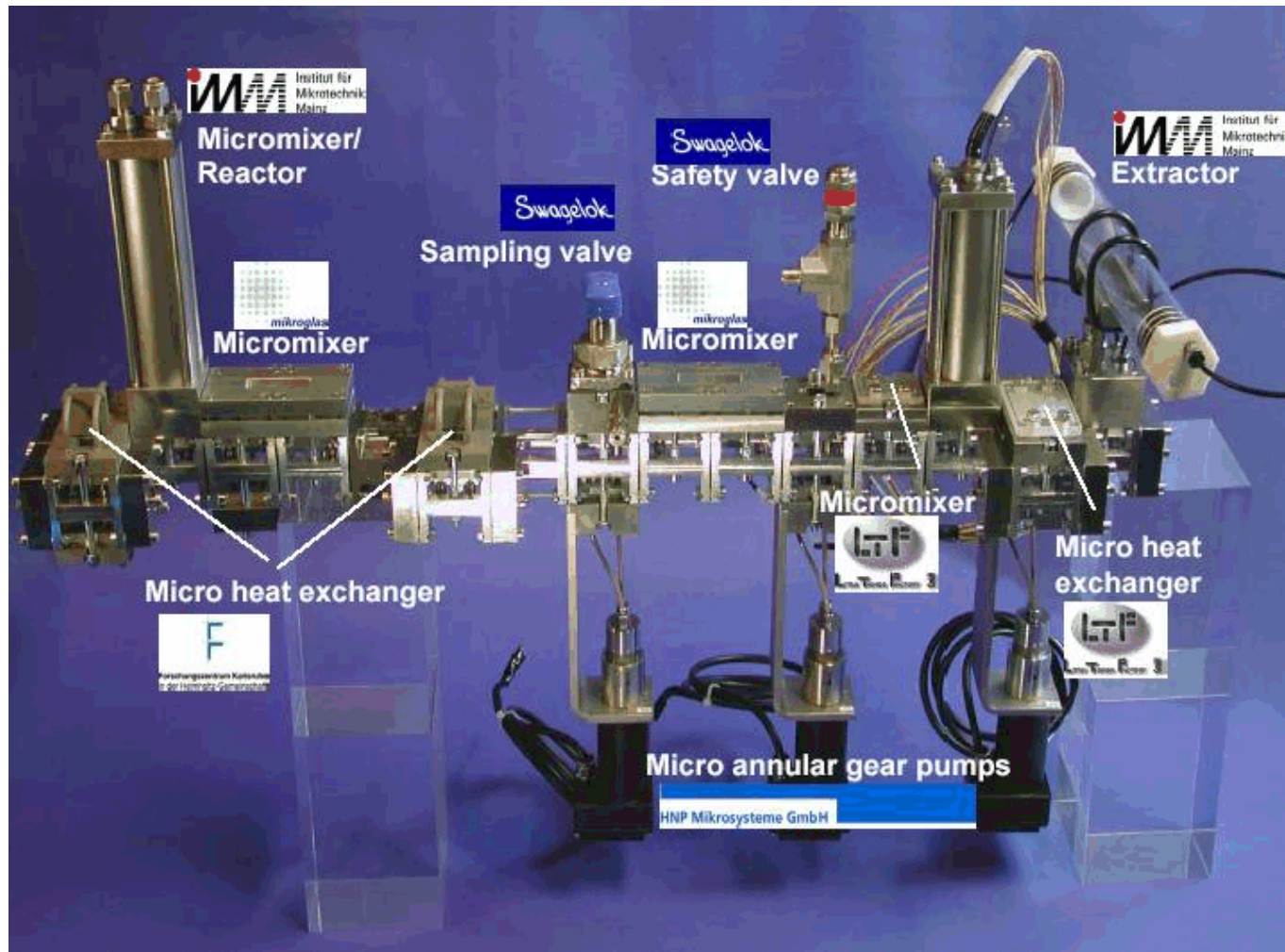


Clariant (2005): 1000 t/a pigment plant
Degussa (2006): several production plants

Industrial status of development

Connection: a standardized platform

Possible to assemble a plant with MRT modules from different suppliers:

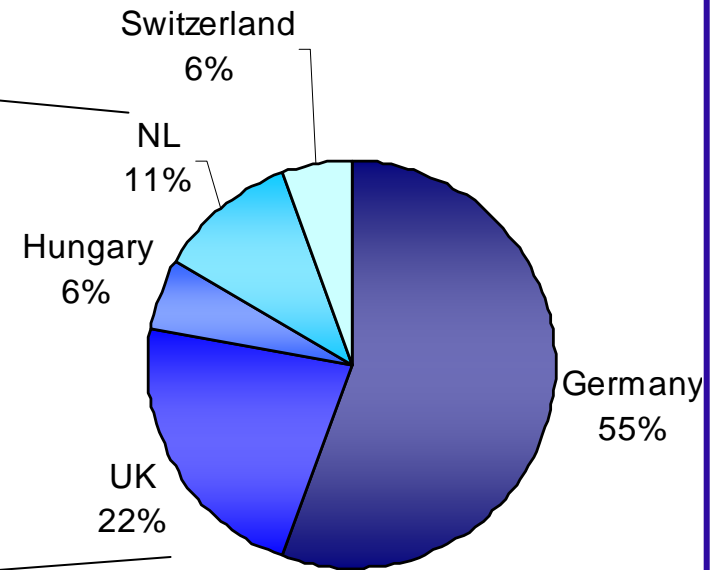
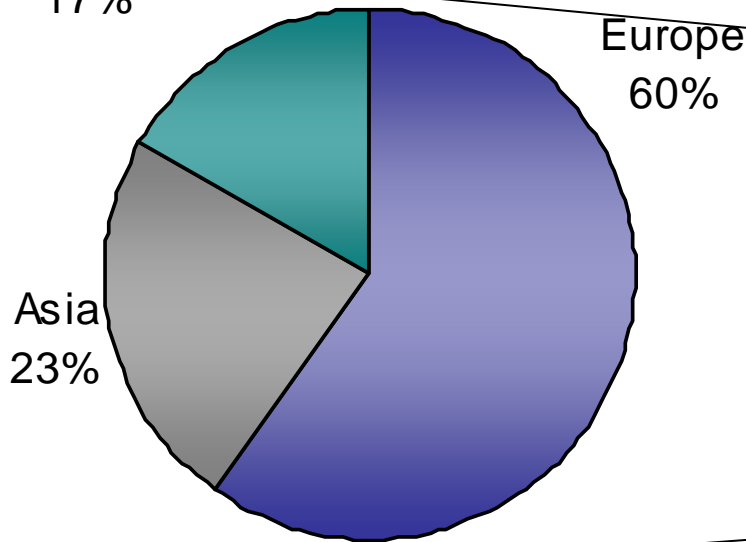


Source:
Mikrogilas

MRT suppliers geographical breakdown

These graphics represent the geographical repartition of MRT suppliers, both MRT modules manufacturers and systems providers (30 companies considered).

North America
17%



Europe is leading the way in terms of numbers of companies selling MRT equipments, but its leadership has decreased over the past years. Activity is increasing especially in Asia.