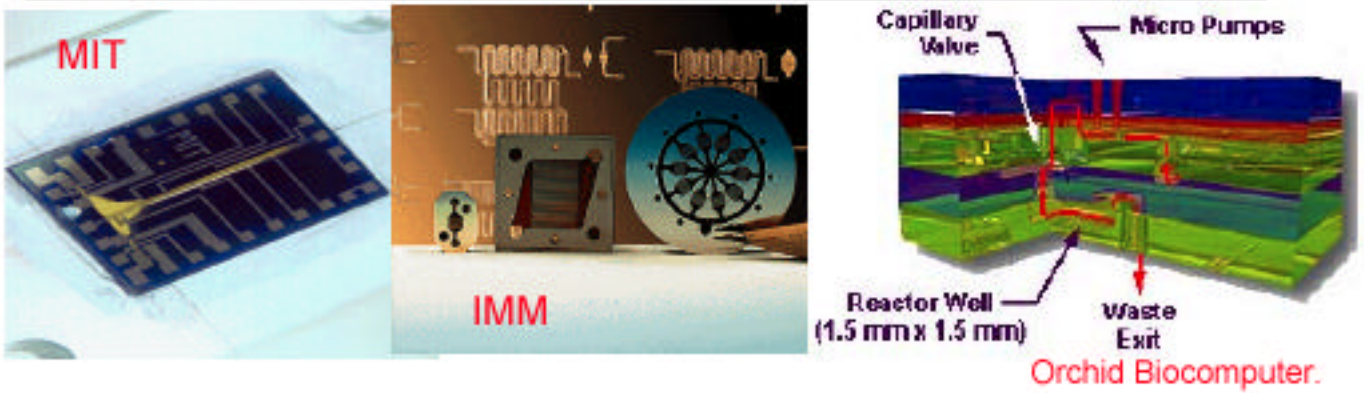
Microchemical Systems 5

Microchemical Systems - Motivation



- Potential advantages:
  - High throughput reaction/catalyst screening - combinatorial chemistry
  - Integration of sensors and actuators
  - Improved chemical performance - operation in small dimensions
  - Improve heat and mass transfer - fast thermal cycles
  - Distributed manufacturing - on demand production of toxic intermediates
  - Fast scale-up to production by replication

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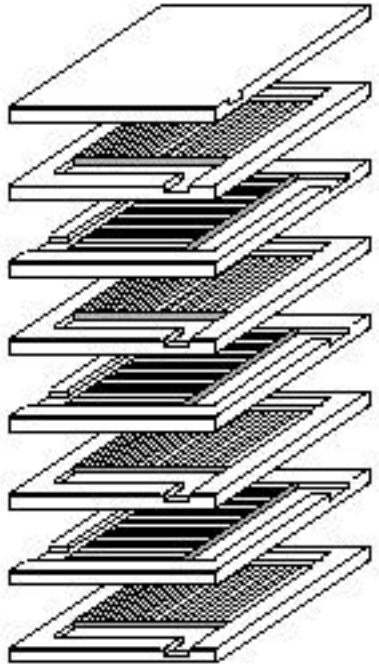
Microchemical Systems 6

Microchemical Energy Systems - Motivation

- Energy devices:
  - Liquid fuel processing for hydrogen fuel cells
  - Cooling/heating
  - Heat pumps
  - Portable - man portable energy source
  - Space applications
  - Air purification
  - Integration with other electrical and mechanical devices



PNNL fuel processing unit

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Microchemical Systems 7

Working Group I: Opportunities for Microenergy Devices

- Moderator: Robert Wegeng, PNNL

  - Fuel processing (partial oxidation, hydroforming, catalysts)
  - Intake and exhaust conditioning
  - Converter technology (TPV,TE, Fuel Cells, Microturbines)
  - Microfluidics (pumps, valves, integration)
  - Energy integration
  - Systems integration and packaging

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Microchemical Systems 8

Working Group II: Challenges and Needs in Microfabrication and Materials

- Moderator: Martin Schmidt, MIT

  - Materials for high temperature, corrosive environments
  - Microfabrication approaches for ceramics, metals, polymers
  - Fabrication and materials challenges in packaging
  - Integration of sensors, actuators, and chemical components
  - Cost, rapid prototyping, robustness, lifetime testing
  - Compatibility with IC processing

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Microchemical Systems 9

Working Group III: Chemical Applications of Microchemical Systems

- Moderator: Klavs Jensen, MIT

  - Opportunities for chemical synthesis, novel applications
  - Advantages of microscale synthesis
  - Speed up of process development - laboratory, combinatorial chemistry
  - Integration with separation and other unit operations
  - Analytical application, integration with micro total analysis systems
  - Barriers to implementation, commercialization

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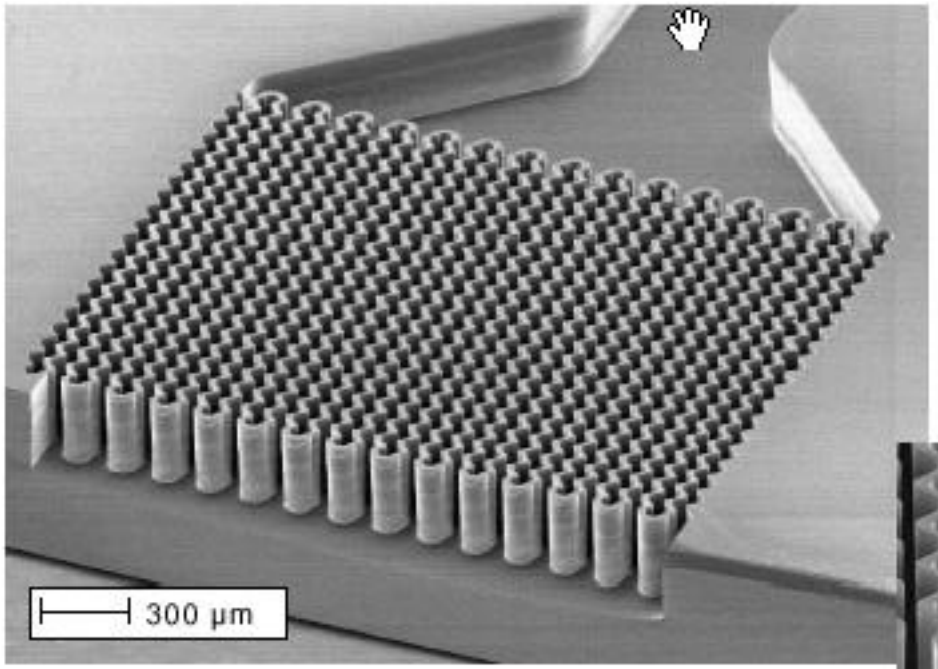
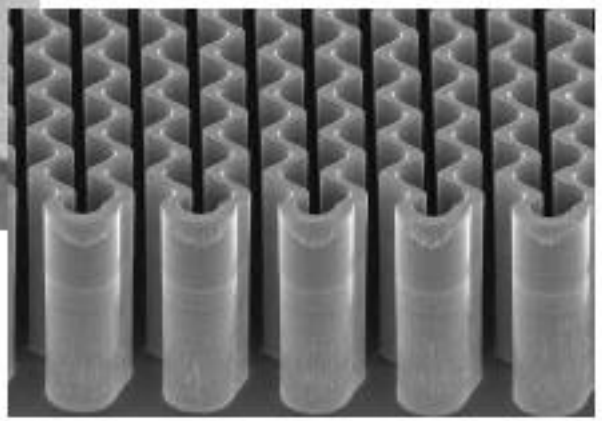
Commercially Available Mixer

Inst fur Microteknik Mainz

MICROMIXER WITH INTERDIGITAL STRUCTURE
REALIZED BY ADVANCED SILICON ETCHING



- Advanced Silicon Etching
- Silicon, thermally oxidized
- Channel width: 40 µm



Product development

VHiLA a90008b

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Some Features of Microchemical Systems

- High surface-to-volume ratio
- Excellent heat transfer; high power density, good control of temperatures
- Large dT/dt; modest flows through small channels yield M/sec velocities; dT of 1000 deg/mm; 10^6 deg/sec
- Rapid diffusion to walls allows activation or quenching in times comparable to reaction sequence
- Number-up rather than scale-up
- Manufacturing technology advancing rapidly
- Battlefield manufacturing?

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Workshop conclusion

Industrial acceptance of microreaction technology will ultimately depend on (I) demonstrated applications examples, (ii) exposure of the technology to decision makers, (iii) the availability of packaged devices easily integrated into chemical laboratories, (iv) development of fabrication infrastructure (foundries and engineering), and (v) development of standards for integration and fabrication. Research and development of microreaction technology will be enhanced by education initiatives; specifically interdisciplinary courses, training of process personnel, and development of reviews and texts on all aspects of microchemical reaction technology.

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Areas of Interest

- Understand the role of surfaces on homogeneous chemistry and reaction intermediates and how these surfaces might be utilized to affect specificity for desired reaction outcome
- Develop techniques to prepare tailored heterogeneous catalytic surfaces for microchemical systems -- this might involve, for example, nanostructured features on the surfaces of micron-scale flow channels
- Develop a transport-theory framework (i.e., an encompassing microfluidics theory) to describe the intra- and interphase movement of momentum, mass, charge, and energy flow channels in which channel-wall surface forces may play a significant role-- the continuum transport theory approach, for example, may not be applicable under certain conditions in microchemical systems

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Areas of Interest - cont

- Apply dynamic modeling of integrated microchemical systems to explore use of novel control strategies that take advantage of short residence and system response times
- Explore techniques to integrate fluidic elements, reactor units, electronics, actuators, and sensors to validate theory
- Develop microfabrication methods for materials and structures unique to microchemical systems
- Develop a mathematical-model toolbox to determine when microchemical systems are better than a macroscale approach

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