Microchemical Systems

Presented to

Palm Power Workshop

by

Dr Richard J Paur

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U.S. Army Research Office
U.S. Army Research Laboratory
U.S. Army Materiel Command

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MURI project in Microchemical Systems

- **Multidisciplinary University Research Initiative**
- **Funded by DDR&E through OXR's and DARPA**
- **Proposals due 15 Nov 2000**
  - 23 white papers; 4 invited to submit proposals
- **Anticipate having one award of about $1M/year (3 yrs with 2 yr option) in place in spring 2001**

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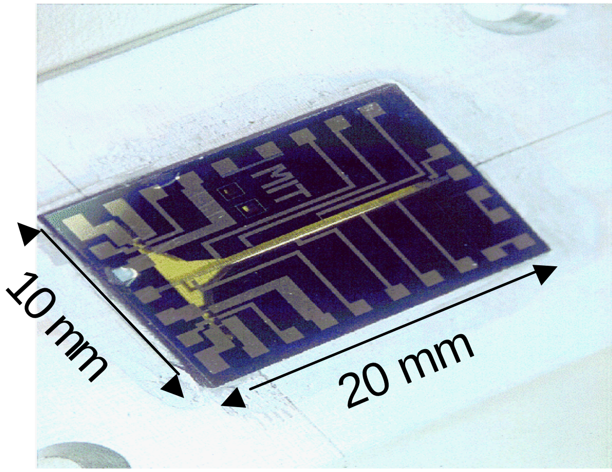
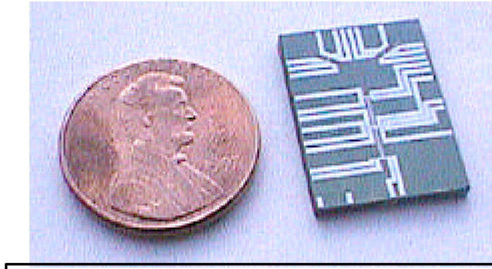
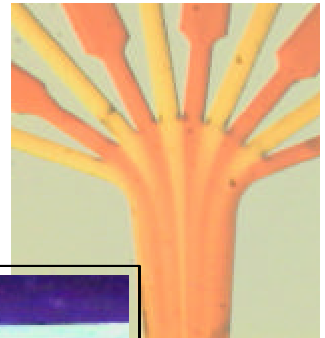
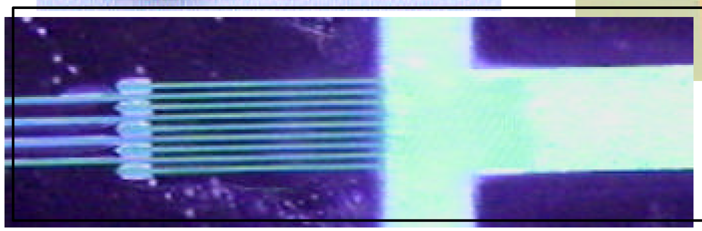
MICROCHEMICAL SYSTEMS
The Future of Fuel Reforming??









Membrane based gas phase reactors with integrated sensors and heaters (T-reactor and Y-reactor), liquid-liquid fast mixing reactor (acid base example), gas-liquid-solid reactor (liquid contains a fluorescent compound).

Potential advantages:

- Safer operation in small dimensions
- Improved chemical performance
- Distributed manufacturing - on demand production of toxic intermediates
- Fast scale-up to production by replication
- High throughput reaction/catalyst screening
- Combinatorial chemistry

ARO/DARPA sponsored workshop in June 1999
DDR&E MURI topic successfully competed May 2000
4 whitepapers invited for full proposal submission
Award expected May 2001 - 3 year base + 2 year opt

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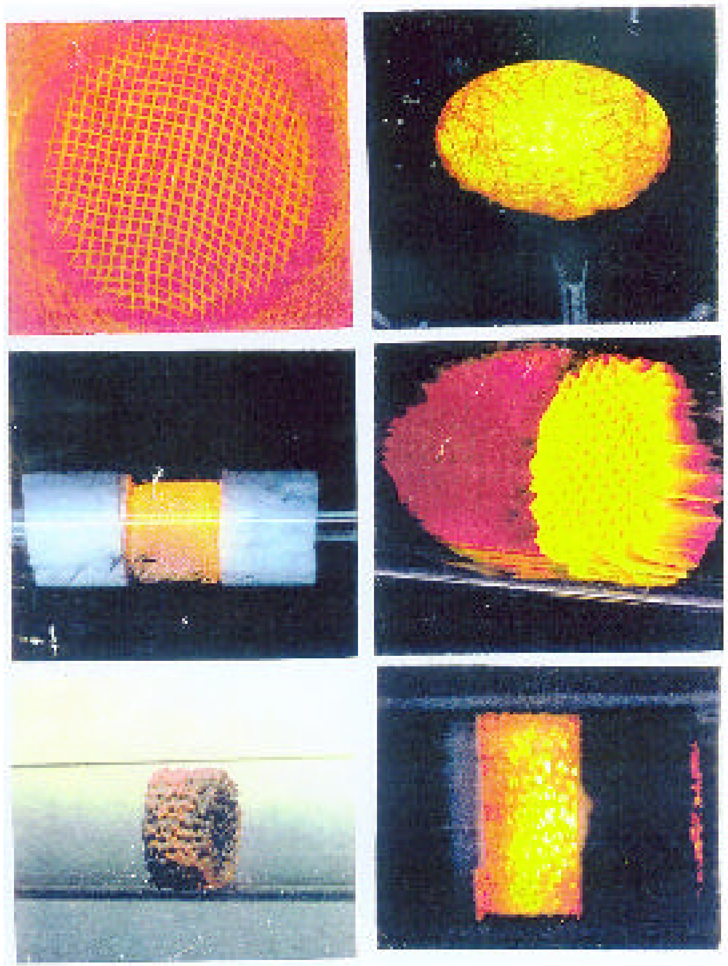
Small Monolith Reactors

Partial Oxidation in Millisecond Reactors

Lanny Schmidt
University of Minnesota



Monolith Reactors:

- -10,000 microreactors in parallel
- -10 tons/day from a 1 liter reactor

1. Methane to Syngas
2. Ethane to ethylene
3. Alkanes to Oxygenates
4. Catalytic Wall Heat Exchange Reactor

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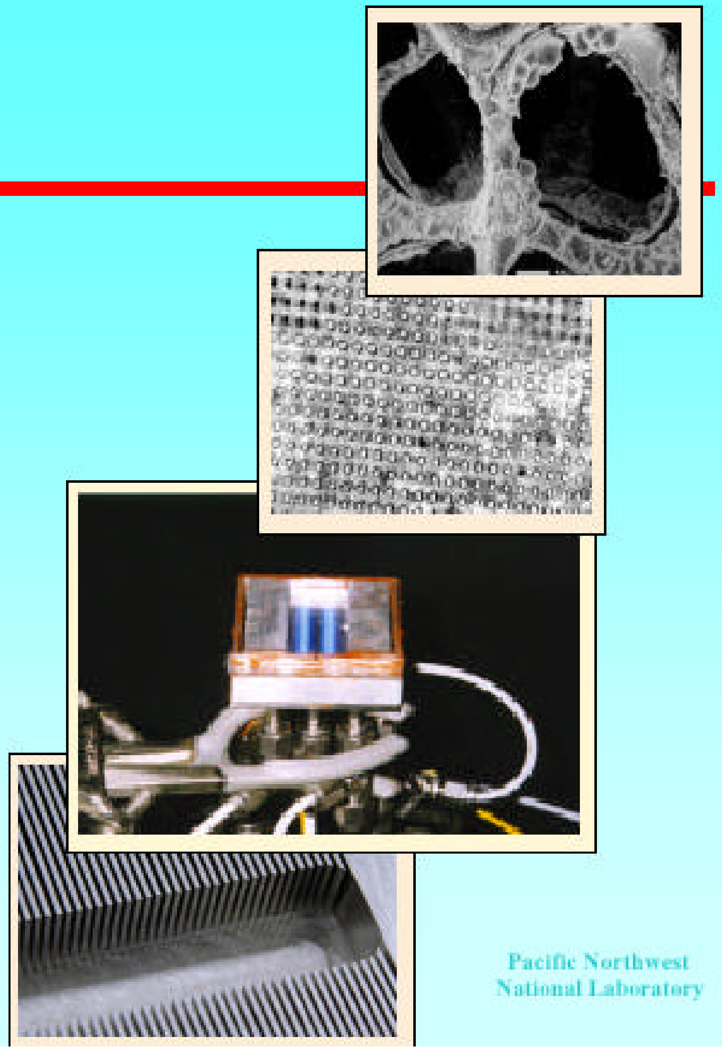
PNNL Microchannel Reactors

Microsystems

- **Components**
  - Reactors
  - Separators
  - Heat exchangers
  - Combustors
- **Systems**
  - Fuel processor
  - Heat pump



Battelle

Pacific Northwest National Laboratory

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Microchemical Systems 1

Microchemical Systems and Their Applications

Sponsored by:
Army Research Office (ARO)
Defense Advanced Research Projects Agency (DARPA)

Organizing Committee:

Peter Fedkiw ARO/North Carolina State University
Klavs Jensen MIT
Robert Nowak DARPA
Richard Paur ARO

June 16-18, 1999

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Microchemical Systems 2

Workshop Objectives

- Review the state-of-art in microchemical systems, with emphasis on microreactor systems for chemical and energy generation applications, including:
  - Fuel processing for hydrogen generation and fuel cells
  - Thermal power sources (microengines, heat pumps, thermoelectric and thermophotovoltaic devices)
  - Synthesis of chemical compounds
- Identify and evaluate:
  - Applications for which microreactors have potential
  - Fabrication techniques that incorporate metals, polymers, and ceramics, beyond standard silicon-based MEMS processes
  - Integration of microreactors with other unit operations, sensors, and actuators
  - Challenges for realization of microreaction technology

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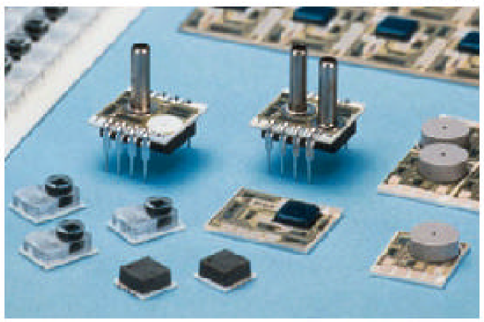
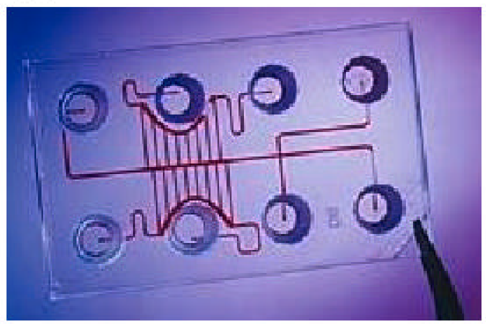
Microchemical Systems 3

MEMS TECHNOLOGY

- MEMS = MicroElectroMechanical Systems
  - Use of microfabrication techniques from semiconductor processing to make small electromechanical devices, including
    - pressure sensors, valves, pumps, accelerometers, ...
  - Increasing use of materials beyond silicon
    - polymers, glass, ceramics
  - Rapid growth in biological applications
    - DNA sequencing - Genome project
    - PCR, capillary electrophoresis, cell sorting
  - Emerging interests in microchemical/energy applications

ARO/DARPA *Workshop Microchemical Systems and Their Applications*

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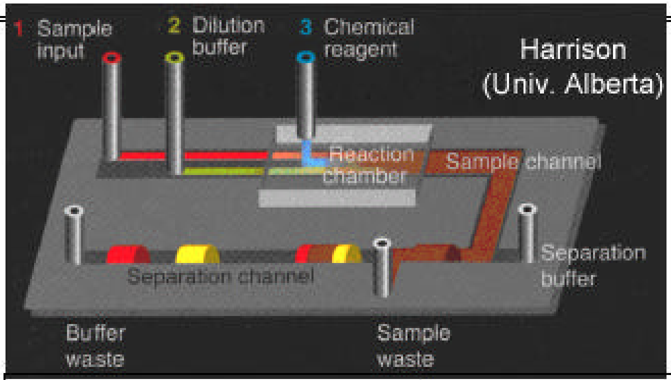
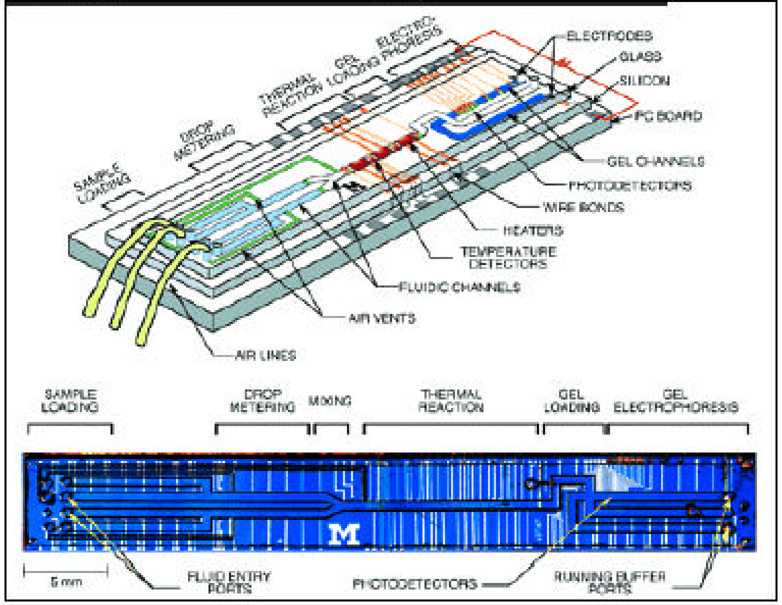
Microchemical Systems 4

μTOTAL ANALYSIS SYSTEMS - "LABORATORY ON A CHIP"

- Drug discovery
- Clinical diagnostics
- Advantages:
  - Small volumes
  - Parallel operation
  - Fast screening
- Examples:
  - Enzyme inhibition
  - DNA/RNA separation and sequencing
  - Receptor ligand binding
  - Immunoassay





Burns *et al. Science*, **282**, 484 (1998)

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