# Chemical Microsystems Applications

Fundamentals of Micromachining

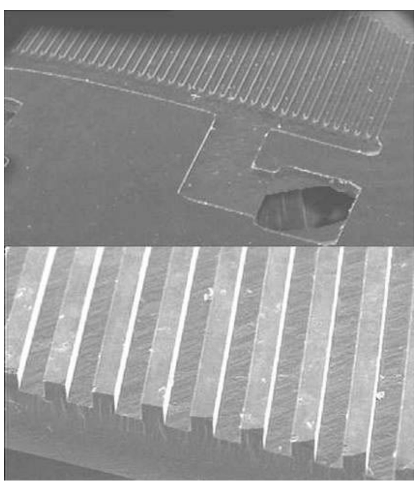
Dr. Bruce Gale

With Special Thanks to Dr. Ron Besser

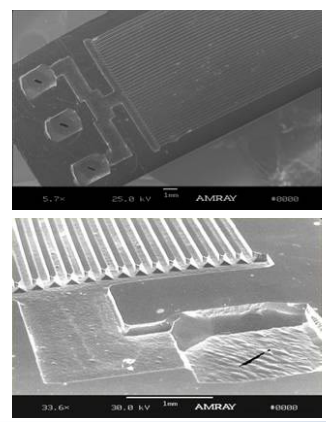
# Outline

- Microfluidic Component Examples
- Chemical Microsystems for Analysis
- Chemical Microsystems for Synthesis

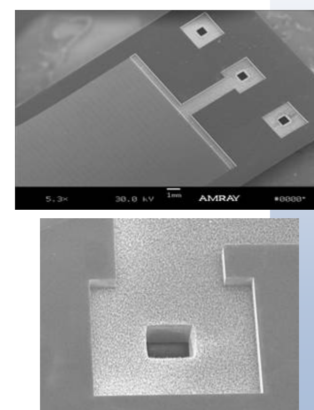
# Microchannels, Fluidic Vias



# KOH Etch vs. DRIE

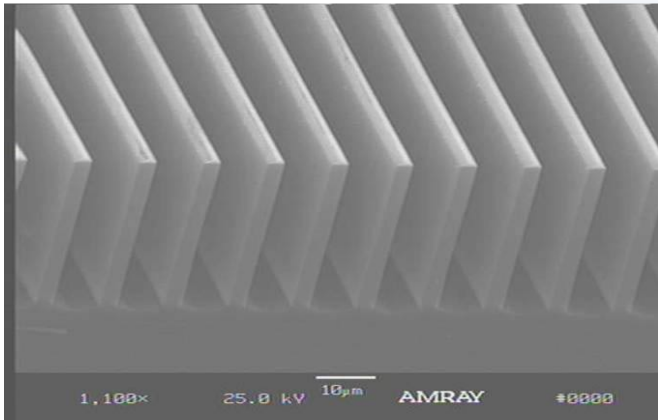


KOH Etched (100 µm channels)



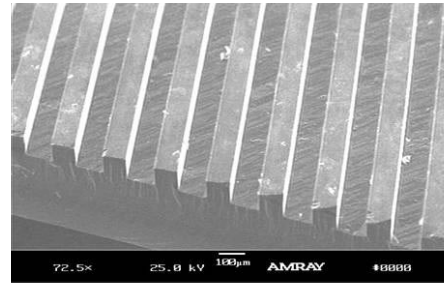
DRIE Etched (5 µm channels)

# Microchannels

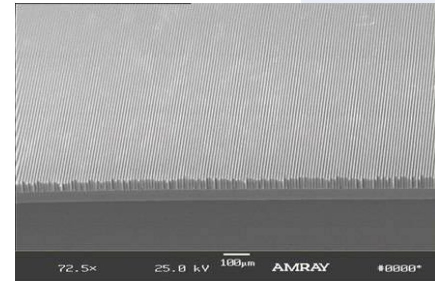





# Microchannel Reaction Zone



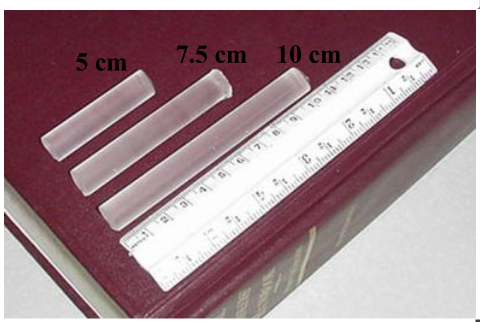

100 μm Channels



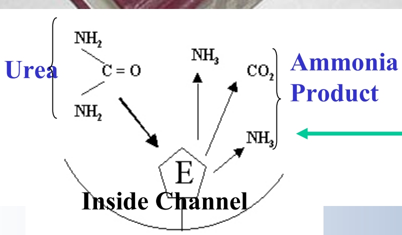

5 μm Channels

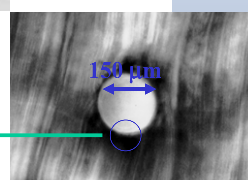


# *"First generation" PDMS Microreactors*



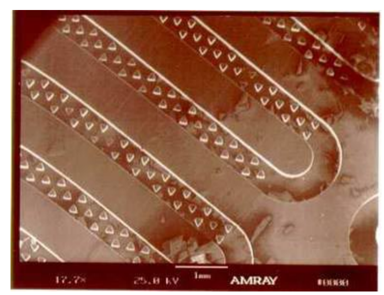

Reactor Cross Section



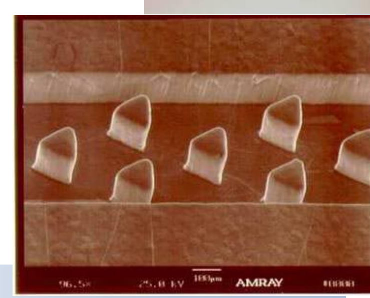






# *PDMS MicroReactor*




Scale = 1 mm



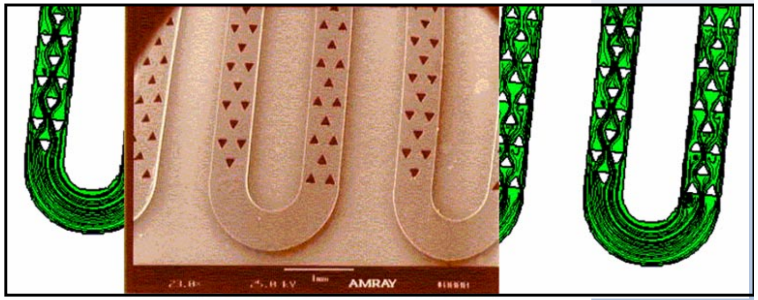

Scale = 100 μm

## *Flow characteristics of transverse mixing features*

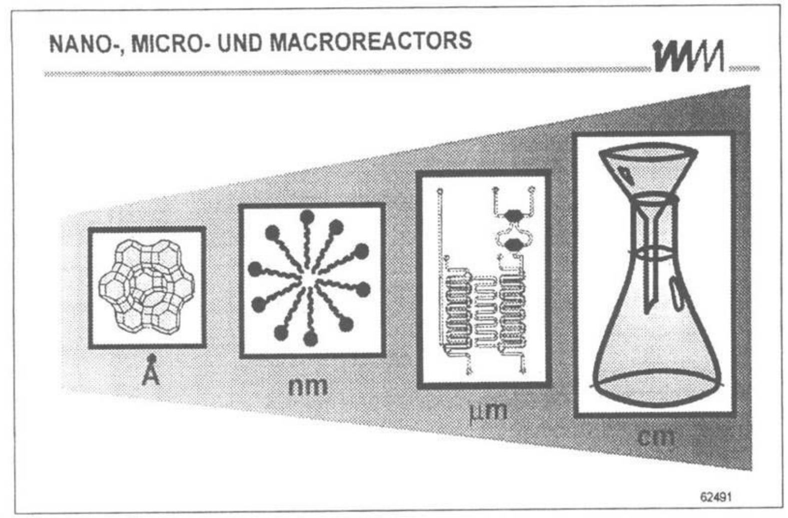
**Features**

- **Flow depicted by contrasting dark lines/light green areas**

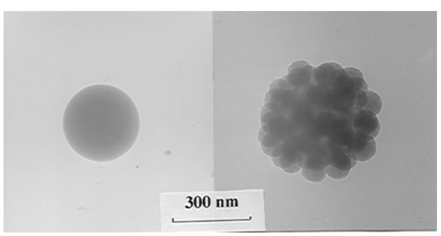
- **Fluid mixing to bring soluble reactant into contact with catalyst surface**



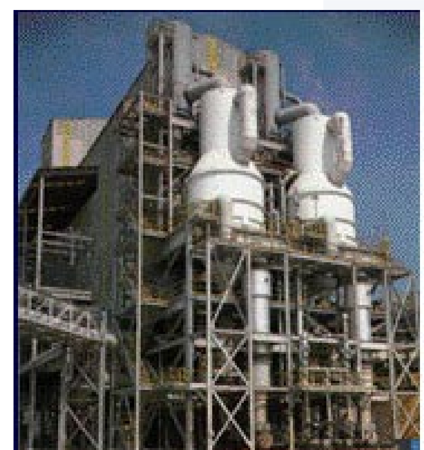

## Scale Comparison




## Nanoreactor or Micelle




## Macroscale, Industrial Scale



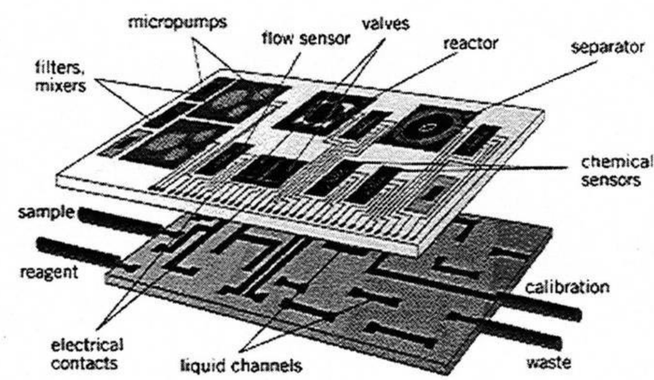
# C.M. for Analysis

- Definition
- Lab-on-chip
- Example: micro gas-analysis device
- Example: Caliper oligonucleotide separation
- Example: Nanogen biochips



# Lab-On-Chip

## The Future Lab on a Chip

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# Micro-Gas-Analyzer

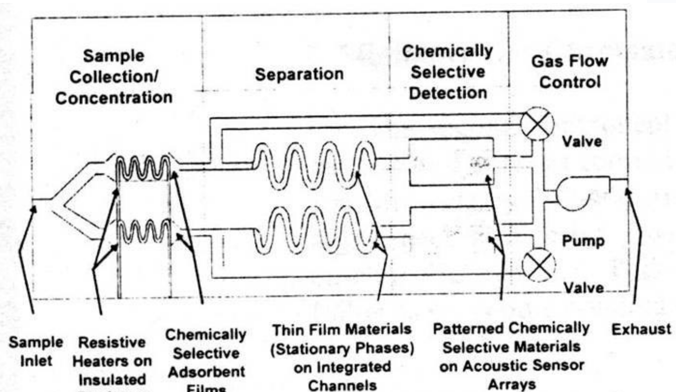


*Figure 1: System design uses multiple analytical channels with three cascaded microfabricated components.*

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# Micro-Gas Analyzer Result

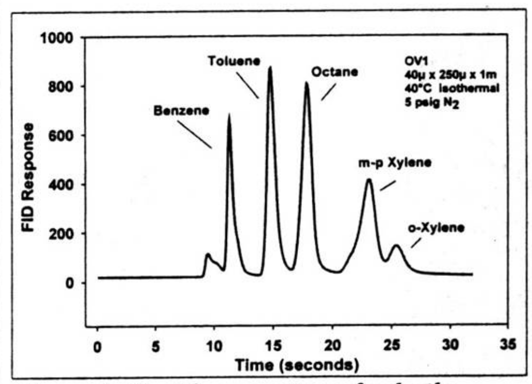


*Figure 3: Rapid separation of volatile organics demonstrated with microfabricated gas chromatographic column.*

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# Applications of Microreactors

1. Distributed Processing
2. Toxic or Hazardous Chemicals
3. Chemical Prototyping
4. High-Value, Low-Volume Chemicals
5. Bulk Production of Commodity Chemicals
6. Special Environments
7. Laboratory Systems
8. Combinatorial Chemistry



# C.M. for Synthesis

- Definition
- Conversion
- Selectivity
- Example: IfM Microreactor

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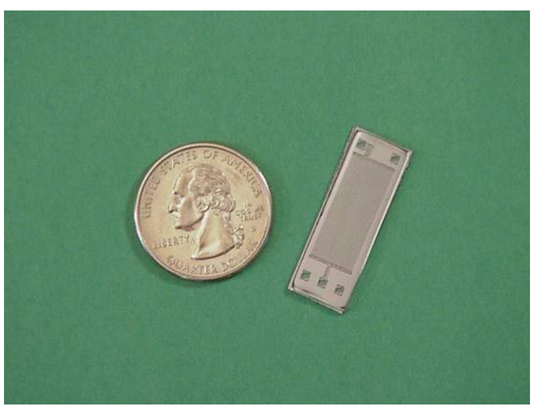
# IfM Microreactor for Synthesis



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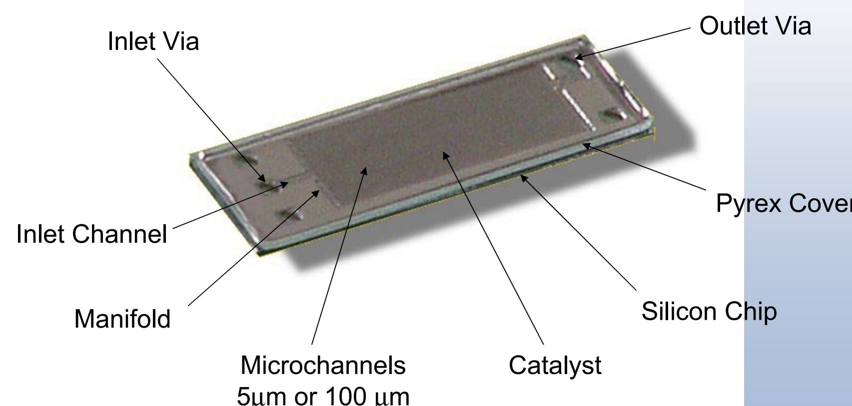
# Device Design

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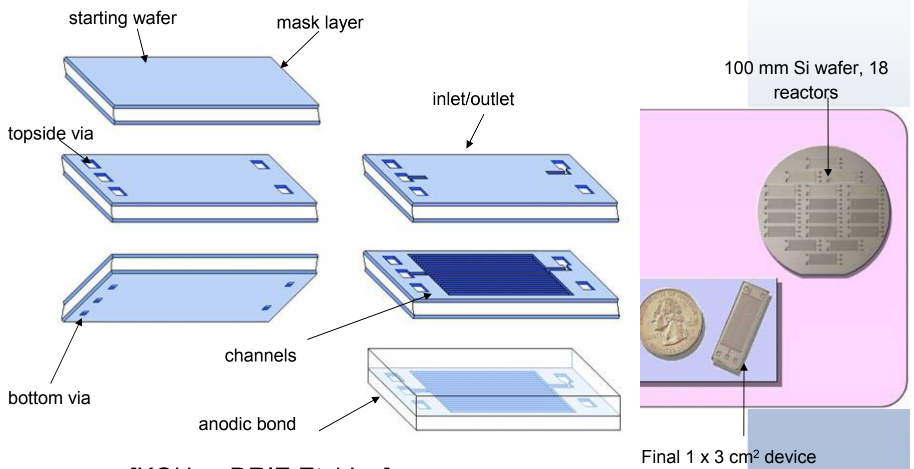
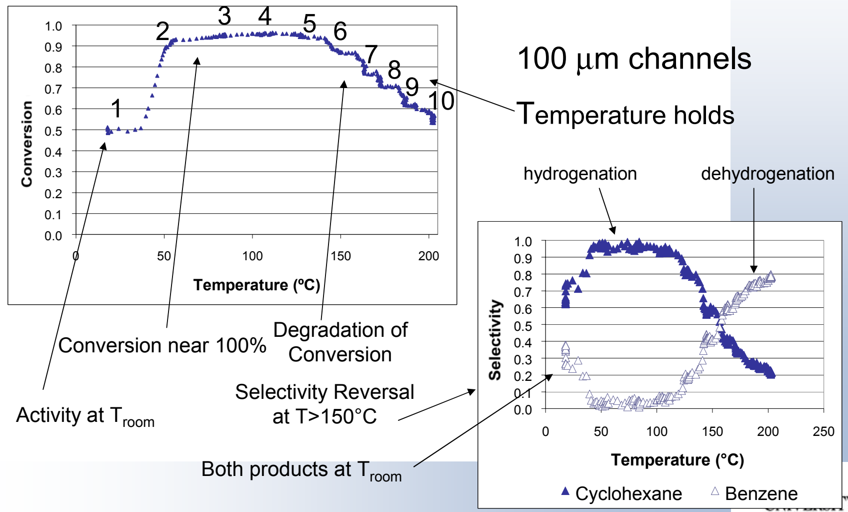
# Device Fabrication




[KOH or DRIE Etching]



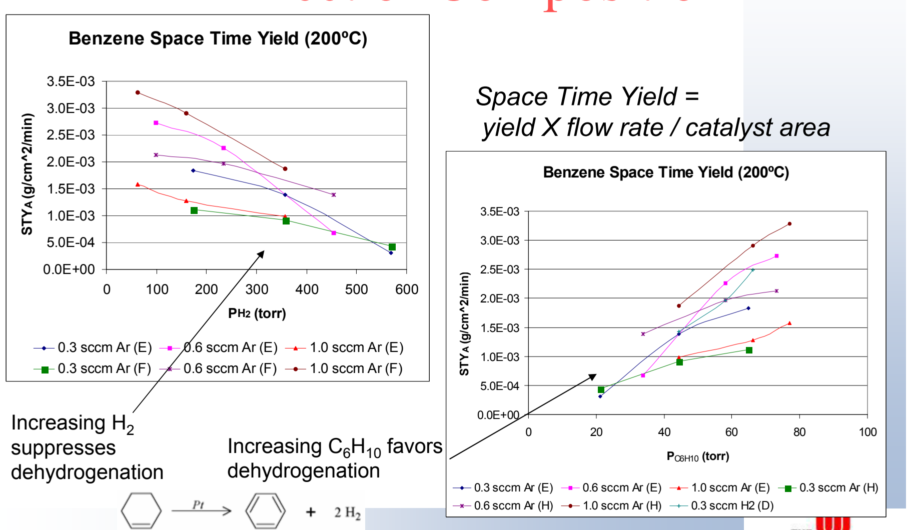
# Temperature Effect






# Benzene Space Time Yield- Effect of Composition

*Space Time Yield = yield X flow rate / catalyst area*

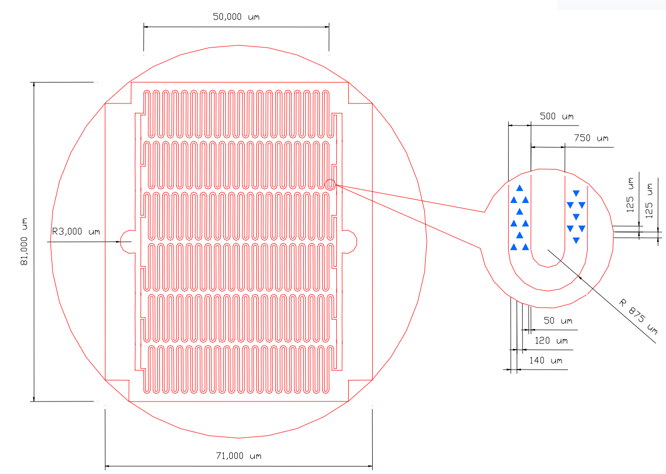





# Microreactor 2 Design

**Features**

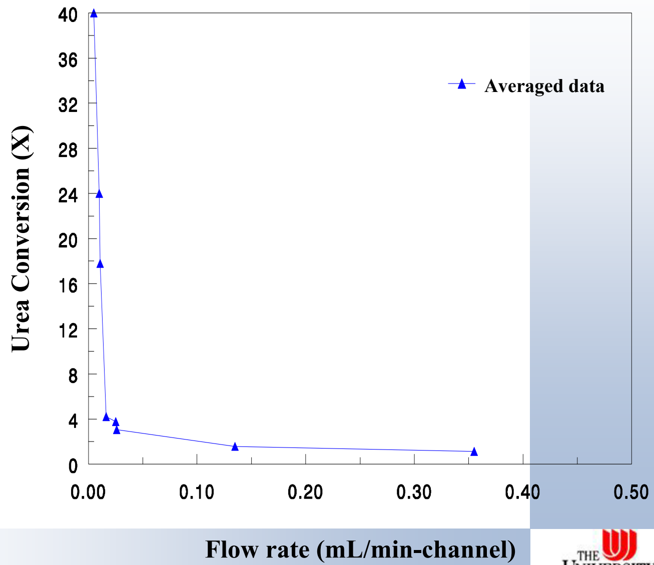
- **6 channels**
- **50 channel length**
- **transverse mixing features in each straight section**



## Continous Microreactor Results

50 cm channel with transverse features

**Observations**
- 4-6 samples averaged for each data point
- critical influence of residence time evident
- microreactor operated 48 hours with no substantial loss in enzyme activity

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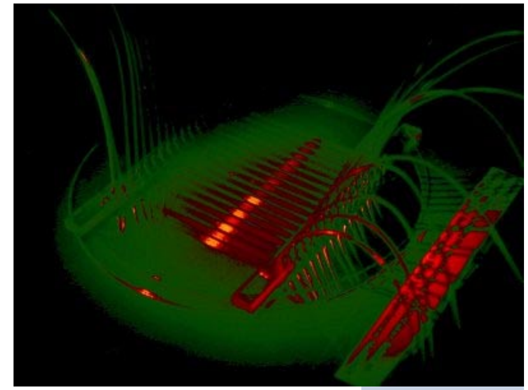
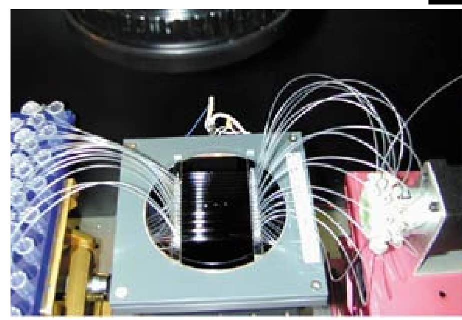
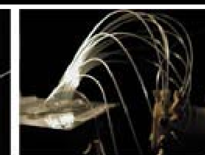
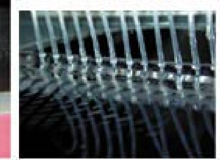
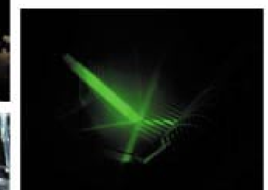
# Packaged Microreactor Systems











# Distributed Processing

- Nature’s Model
- Example: Oil Processing
- An Analogy of Distributed vs. Centralized Processing

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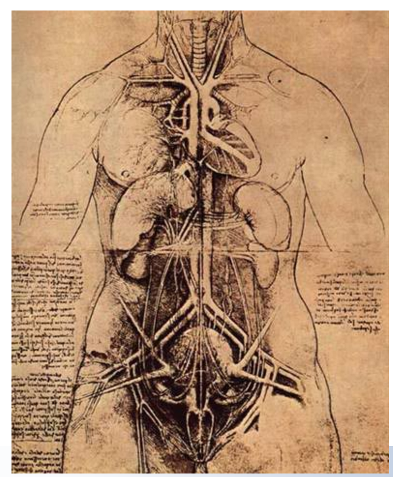
# Distributed Processing: the Cell




Mitochondrion: chemical factory in every cell

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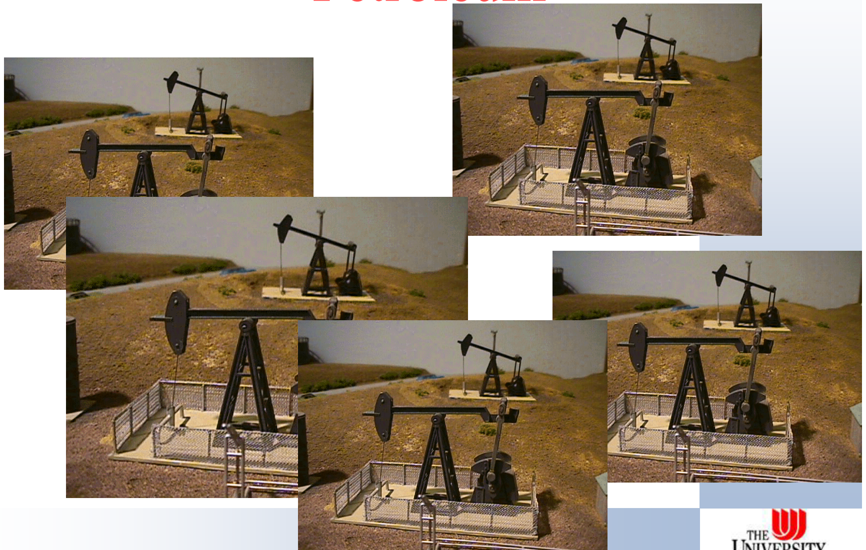
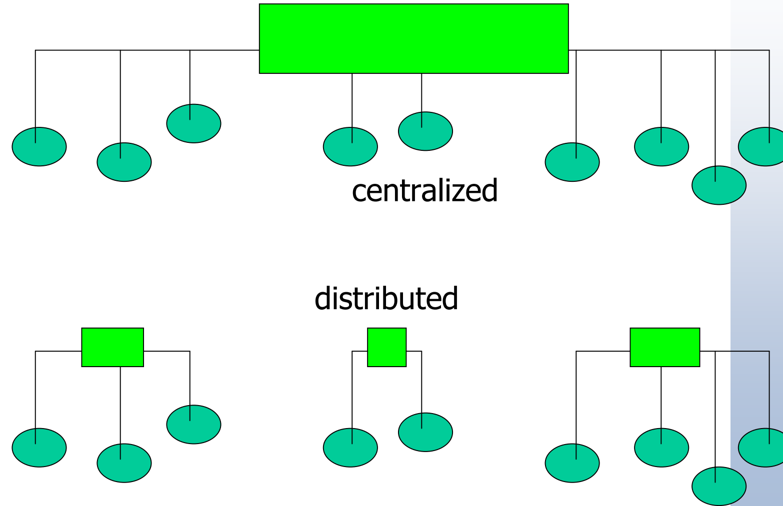
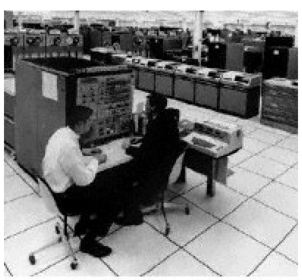
# Distributed Processing: Petroleum



# Petroleum Processing




# Analogy: Centralized vs. Distributed



1965

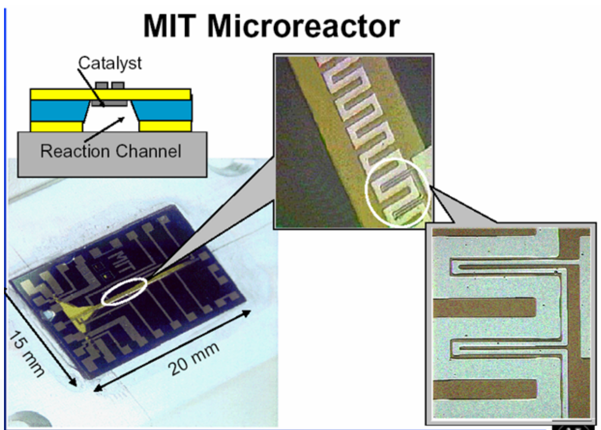
2000

# Toxic or Hazardous Chemicals

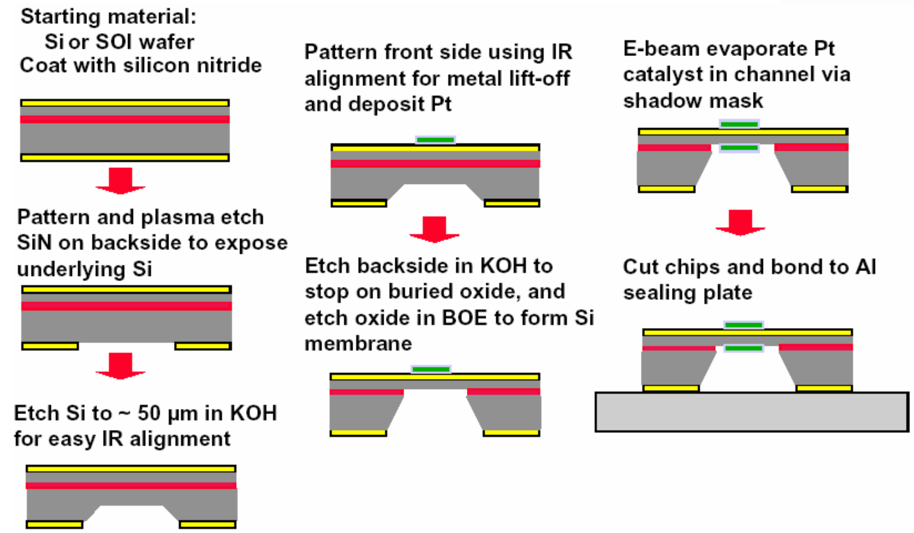
- Toxic =
- Hazardous =
- Motivation: Operation in “explosive regime”
- Motivation: transport, storage, monitoring
- Example: ion-implantation of $As^+$

# Explosive Regime Example

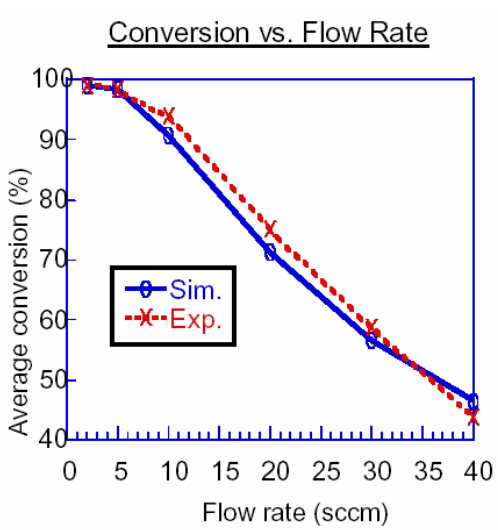
- $H_2 + ½ O_2 \rightarrow H_2O$
- 500°C, water produced without explosion

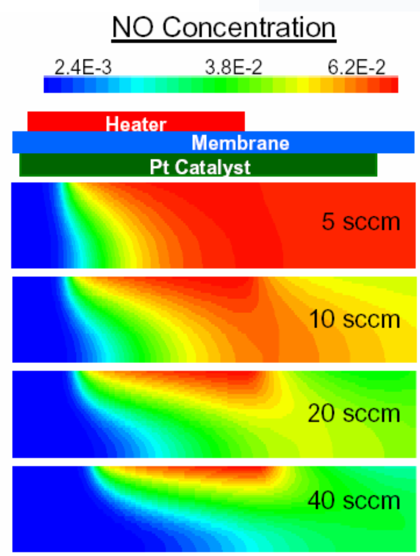



# MIT Microreactor Fabrication

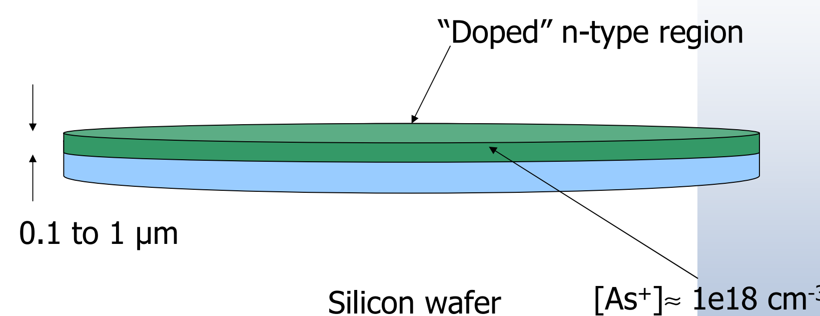



# Mass Transfer Characteristics: MIT

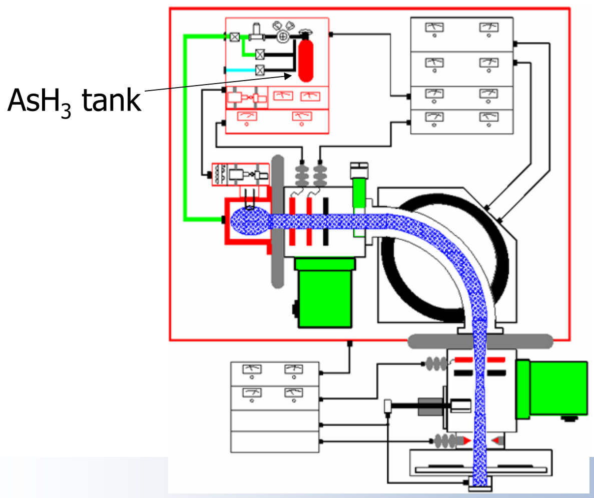


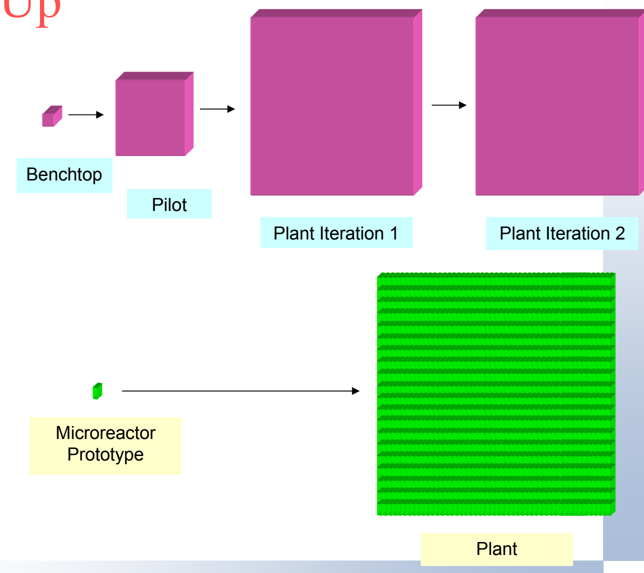

# Example: Ion-Implantation Source



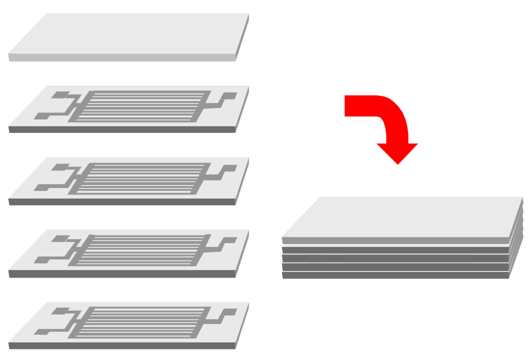
# Ion-Implanter Schematic




# Scale-Up




# Scale-Up Example



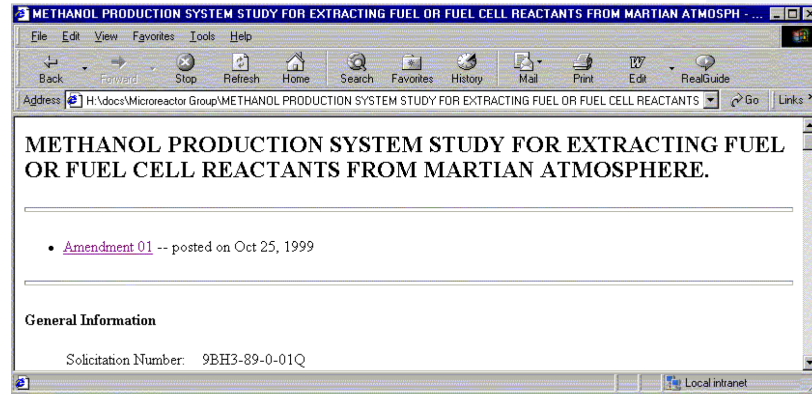
# High-Value, Low-Volume Chemicals

- Examples
  - Pharmaceuticals
  - NO
- Motivation
  - Short shelf lives
  - Toxicity
  - New therapies
  - Implantation

# Bulk Production of Commodity Chemicals

- Definitions: No distinction by "brand"
  - Oil
  - Polymers
- Motivation
  - Higher yields
  - Less pollution
  - Modularity (repairs)
- Likely impact
  - Slow adoption

# Special Environments: Space


METHANOL PRODUCTION SYSTEM STUDY FOR EXTRACTING FUEL OR FUEL CELL REACTANTS FROM MARTIAN ATMOSPH - ...

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**METHANOL PRODUCTION SYSTEM STUDY FOR EXTRACTING FUEL OR FUEL CELL REACTANTS FROM MARTIAN ATMOSPHERE.**

- Amendment 01 -- posted on Oct 25, 1999

**General Information**

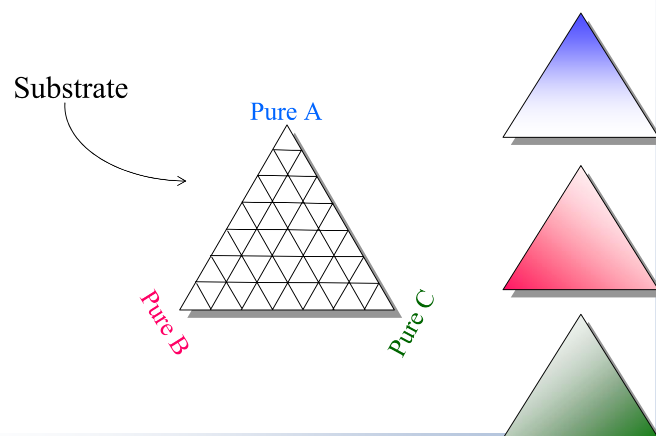
Solicitation Number: 9BH3-89-0-01Q

Local intranet

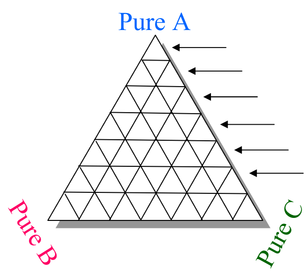
# Combinatorial Screening for Discovery of New Materials

- Applications
  - Pharmaceuticals
  - Luminescent Materials
  - Superconductors
  - Magnetic Materials
  - Heterogeneous Catalysts
- Method
  - Batch Processing
  - Systematic Variation of Composition or Substitutional Groups
  - High Sample Count
  - Rapid Evaluation

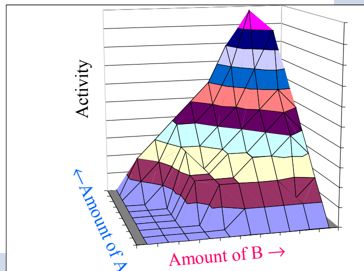
# Systematic Variation of Component Compositions



# Rapid Evaluation




Rapidly Probe Each Unit Sample for Desired Activity

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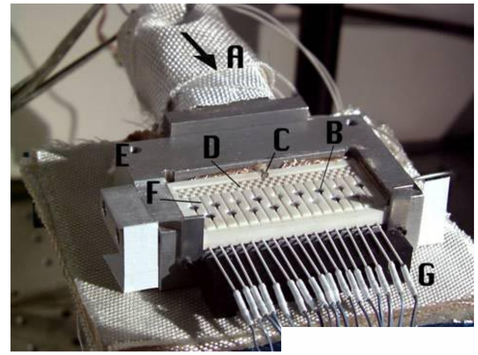
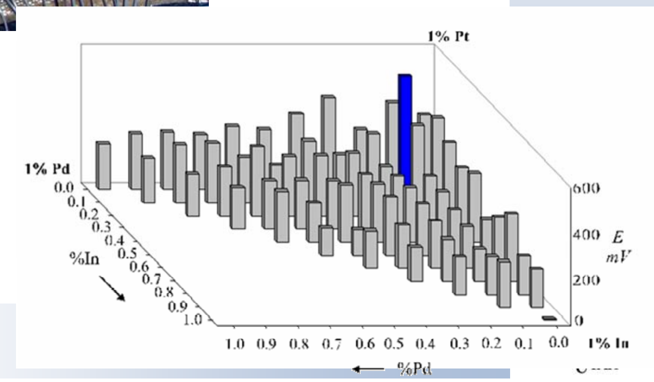
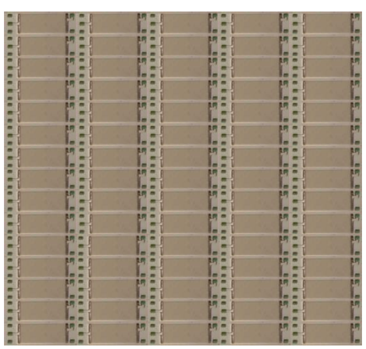
# UCLA System




**Array Microreactor System: A: Feed gas preheater; B: Catalyst pellets; C: Reactant gas inlet; D: Flow distribution baffles; E: Bottom aluminum heating block; F: Reactor channels; G: Signal detection microelectrodes;**




# Combinatorial Array for Screening Catalysts



75 Microreactor Array

Systematic variation of catalyst by sputter deposition

Evaluation of conversion and selectivity by Mass Spectrometry

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