# Microfluidics to Perform Hazardous Gas Phase Reactions

10.491 Presentation

Professor Jensen

Miyasato, Rogers, Smith, Spooner

3/5/01

# Rationale for µscale Study

- Problem
  - oxidation reactions are exothermic, explosive
  - complete combustion products have no value
- Objective
  - construct microreactor
    - improved safety through point-of-use
- Scale Up
  - improved process control, rapid implementation

# Rationale for µscale Study, Cont.

- Size does Matter
  - smaller channels = smaller concentrations
  - length dimension is less than quenching distance for $H_2$ flame
  - inhanced process control
    - faster response time b/c surface/volume leads to efficient heat and mass transfer
- Collect data on toxic gas phase reactions

# Fabrication of the Device

- Rxn: $H_2$ (g) + $O_2$ (g) = $H_2O$ (g) ($\Delta H$=-57.9 kcal/mol)
- Catalyst: $Al_2O_3$/Pt Deposition

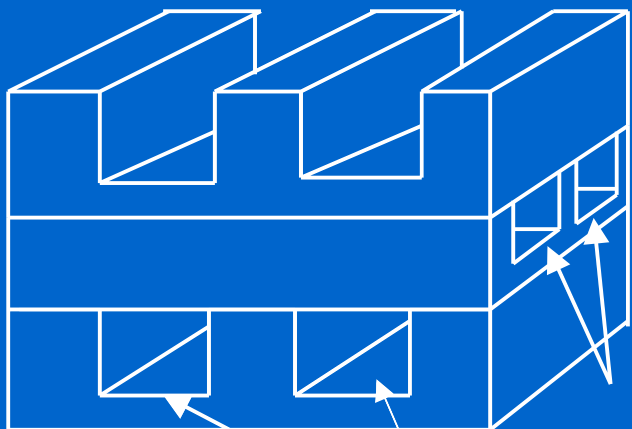
  -$Al_2O_3$ deposited via Atmospheric CVD

  -Pt deposited on $Al_2O_3$ via wet impregnation

  @ high and low loadings
- Reactor System Design

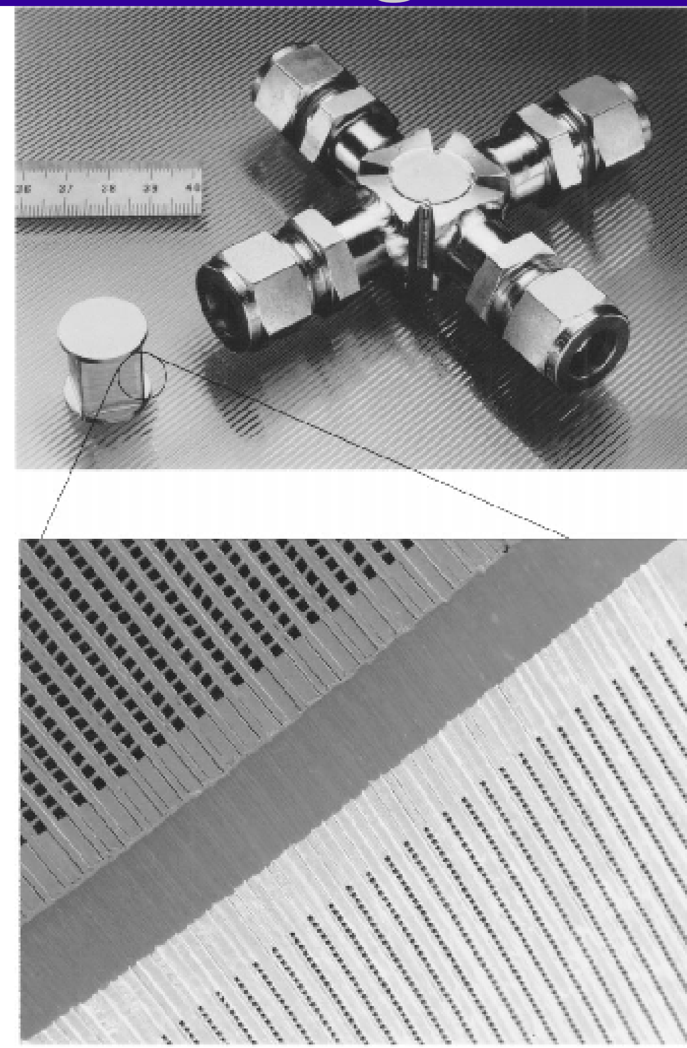
  -Mass flow controllers, One-way valve, shut-off valves, cold trap

# Microreactor/Heat Exchanger



Smaller Channel Sizes ($70\ \mu m \times 100\ \mu m$) with $N_2$ coolant

Larger Channel Sizes ($140\ \mu m \times 200\ \mu m$) with $Pt/Al_2O_3$ catalyst



- -Stainless Steel Plates w/micromachined channels
- -Stacked with 90$^o$ rotations
- -Diffusion bonded

# Design Concepts

- Transport Phenomena
  - Heat Transfer
    - Cross-flow heat exchangers
    - Control of reaction temperature
  - Mass Transfer
    - Concentration of reactants in nitrogen diluent
    - Mixing
- Heterogeneous catalyst options

# Why Miniaturization?

- Advantages
  - Runaway scenario eliminated
  - More efficient heat exchange
  - Improved selectivity
- Disadvantages
  - Difficult to collect data
  - Equipment not readily available
  - Low production rate

# Results of Study

- Concentration determines outlet gas temperature
- Low-loading of catalyst requires heaters to initiate reaction
- Induction period reduced in successive runs
- Safe operation under explosive conditions

# Areas for Improvement

- Micromixers
  - Multilamination
    - $t \alpha d_{sh}^2/D$
      - t is mixing time, $d_{sh}$ is width of laminar sheets, D is diffusion coefficient
    - Sinusoidal channels increase mixing area
  - Use multiple mixers in parallel

# Areas for Improvement

- Heat Exchangers
  - Increase heat transfer area (diameter of coolant tubes)
  - Change coolant (increase heat capacity)
  - Change inlet temperature of coolant
- GC at end of reactor
  - Accurately determine conversion

# Areas for Improvement

- Removable foils
  - Direct analysis of Pt/Alumina support
- Alumina deposition on removable foils
  - Increase response time of foils (lower heat capacity and increase reactive surface area)
  - Mimic conditions in normal reactor

# Contribution of Study

- Establishes capability of safe partial oxidation for research purposes
- Provides background for further fuel cell applications
- Provides design of microfluidic device upon which better devices could be built

# References


- Janicke, “The Controlled Oxidation of Hydrogen from an Explosive Mixture of Gases Using a...” Journal of Catalysis. Vol 191 p.283-293. 2000
- Jensen, “Micromachined Reactors for Catalytic Partial Oxidation Reactions” AIChE Journal. Vol 43, No. 11, p. 3059.
- Schmidt, “High Selectivities to Ethylene by Partial Oxidation of Ethane” Science Mag. Vol 285, p. 712, July 1999.