Outline

- Objective
- Types of Pumps
- Displacement Pumps
- Piezoelectric Effect
- Types of Valves
- Fabrication
- Analysis
- Conclusion
- Questions
Objective

Design a Micropump to:

- Pump Water from One Atmospheric Container to Another
- Be no larger than 10mm x 10mm
- Have a flow rate of at least 150µL/min
Types of Pumps

- Displacement Pumps
- Centrifugal Pumps
- Electric Field Mediated Pumping
- Magnetic Pumping
- Ultrasonic Pumping
- Interfacial Pumping

Known in Macro Scale

Developed for Micro Scale
Displacement Pumps

Types of Actuations
- Piezoelectric
- Electrostatic
- Electromagnetic
- Pneumatic
- Thermopneumatic
- Thermomechanic
Piezoelectric Effect

- When a voltage is applied polarity causes the material to expand
- Also when contracted the material will create a voltage
- Two common piezoelectric materials:
  - Lead Zirconate Titanate (PZT) \([\text{PbZr}_x\text{Ti}_{1-x}\text{O}_3]\)
  - Zinc Oxide (ZnO)

[Diagram of piezoceramic material with electrical connections]

http://www.morganelectroceramics.com/graphics/unimorph.swf
Types of Valves

- Pressure
- Cantilever Check Valves
- Beam Check Valves
Valve Fabrication Process

1. Pattern silicon nitride for thru hole.
2. KOH anisotropic etch
3. Pattern silicon nitride for valve region.
4. Time-controlled KOH etch.
5. Backside pattern silicon nitride.
6. Short time KOH etch.
7. Deposit parylene
8. Pattern parylene & silicon nitride in RIE.
Pump Layers

- Pump Chamber
- Upper Valve Assembly
- Lower Valve Assembly
- Inlet and Outlet
Final Pump Assembly

Piezoelectric Membrane
Analysis

- Relative Dead Volume
- Chamber Compression Ratio
- Relationship Required to Prevent Trapping Fluid in the Chamber

\[ c_0 \geq \frac{V_0}{\Delta V} \]

\[ \Psi_{gas} = \frac{p_2 + \Delta p_{out}}{p_1 - \Delta p_{in}} \]

\[ c_3^{-1} > \Psi_{gas}^{-1} - 1 \]
Analysis

Volumetric Flow Rate (150µL/min)

\[ \dot{V} = f\Delta V \]

\( f \) is the frequency of the membrane

Finite Element Modeling

- Resonance Frequency
- Membrane Displacement
- Pressure Drop Across Valves

http://www.algor.com/products/analysis_replays/micropump/_asf/micropump250.wmv
Conclusion

Used Displacement Pump
- Piezoelectric Membrane Actuator
- Cantilever Beam Styled Check Valves

Designed to pump 150\(\mu\text{L}/\text{min}\) and fit in a 10mm x 10 mm area
Future Work

- Find frequency and displacement of the piezoelectric membrane
- Finalize dimension of pump
- Fabricate and test pump to see if design specs are meet
References

- http://www.memsnet.org/material/leadzirconatetitanatepzt/
- http://ej.iop.org.proxy.lib.fsu.edu/links/q63/KLDIYjhNh8z6bexYc4P57A/e70106.pdf
Questions