MEMS Fabrication of a Peristaltic Pump

R·I·T KATE GLEASON College of ENGINEERING

By: Nicholas Amendola

Rochester Institute of Technology, Department of Electrical and Microelectronic Engineering, Rochester NY 14623

I. Project Objectives

Goal: Creation of an actuating pump using a surface micromachining process on silicon substrates.

- Demonstrate actuation of membranes.
  - Actuation viewable under optical profilometer.
- Create a peristaltic effect using three micropumps in series.
- Bond two wafers using anodic bonding.
  - Uses a high (400 V) DC voltage source.

II. Motivation

Current systems use a high voltage to actuate the pump in either a mechanical or non-mechanical device.

- Using peristalsis and a Lead Zirconate Titanate (PZT) material to minimize the energy to operate the micropump.
- PZT is a piezoelectric material, which allows a current to enter the material, causing a deformation in the membrane.

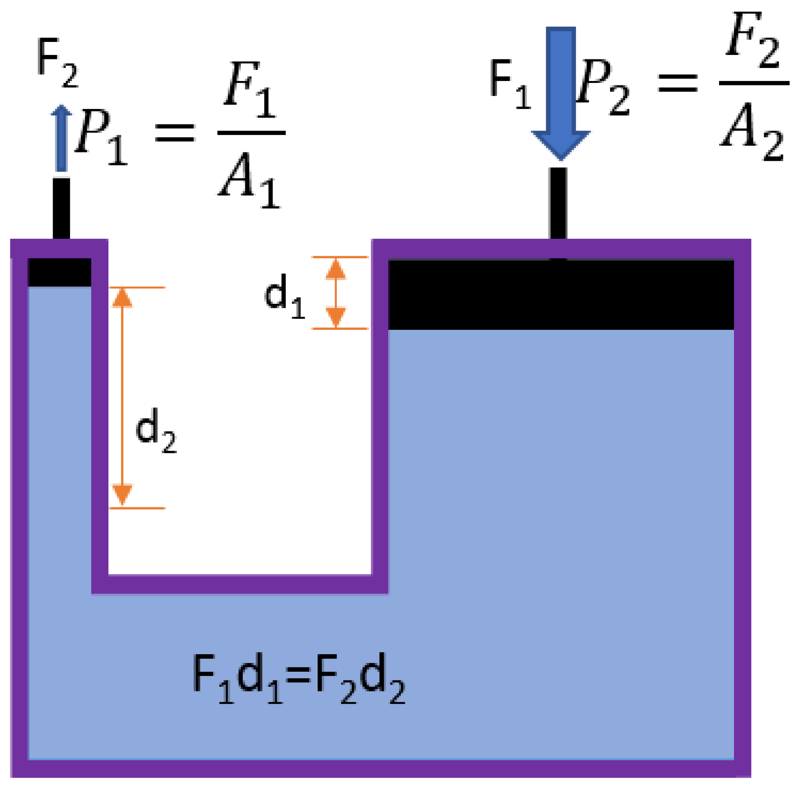
A device of this type can be used for medical purposes which dispense nL amounts of fluid.

III. Displacement Theory

- F = Force
- A = Area of the opening
- P = Pressure
- d = Displacement of fluid.

Using the force to push the large membrane down, causes the fluid to displace the small membrane.

If a small pressure is placed on the large membrane, it causes an amplification on the small membrane.



$d_1 = \frac{F_2}{F_1} d_2 \qquad d_1 = \frac{A_2}{A_1} d_2$

Fig 1. Micropump Displacement Diagram.

- $A = \pi r^2$
- R_1 = .500 mm^2
- R_2 = 1.50 mm^2

Example: d_2= 3.00 µm

- A_1= .785 µm
- A_2= 7.07 µm

d_1= 27.0 µm

IV. Fabrication Details

- This project uses 3 layers of lithography with an option of a 4th layer.
- An additional layer comes from a secondary design which uses a Xactix Etcher.
  - his non-plasma etcher, etches isotropic to remove small amounts of silicon.
  - Usage is for the creation of holding down Parylene C material. Once the membrane is actuated the top material will try to pop off. This etch will prevent the Parylene C from popping off.

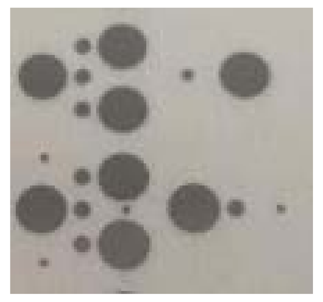


Fig 2. Layer 1.

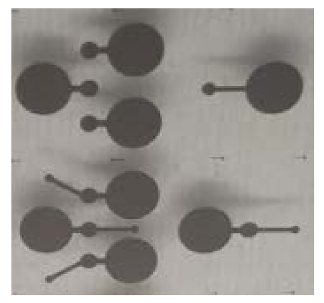


Fig 3. Layer 2.

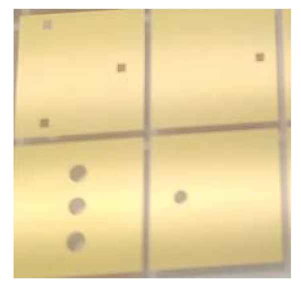


Fig 4. Layer 3.

- Layer 3 is performed on the backside of the bonded wafers.

V. Conclusions

The STS plasma etcher proved to cause issues throughout the process. No conclusive results were found in this project, though process improvements have been added.

Future Work

- Bonding of the wafers using anodic bonding or using the ATP at a high temperature.
- Vacuum filling Fomblin oil into micropump.
- Adding a Lead Zirconate Titanate (PZT) material to the membrane in order to control the electronic pulses.
- Increase peristaltic motion of the closing of the microfluidic tube. Measurement of the microfluid output after the peristaltic pump.

Acknowledgements

- SMFL Staff
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R·I·T Semiconductor & Microsystems Fabrication Laboratory

VI. Fabrication Errors

- Inverted masks
  - Negative field vs. Clear field.
    - A negative field writes everything around the image being imaged. While a clear field just writes the image.
  - Using a negative resist, corrected this issue.
  - nLOF 2020 is an i-line resist.
    - Ensure a PEB occurs at 110 ˚C for cross-linking.
- Off-set Alignment Marks
  - After Layer 1, one set of alignment marks were higher on the y-axis.
  - Solution was to direct write using Heidelberg DWL 66.
- Etching of 1 micron oxide layer
  - Using a 10:1 Buffered Oxide Etch (BOE), etching takes 20 minutes.
  - Layer 2 photoresist is spun on top of etched oxide.
  - Resist was spun unevenly because of the 1 micron etched images.

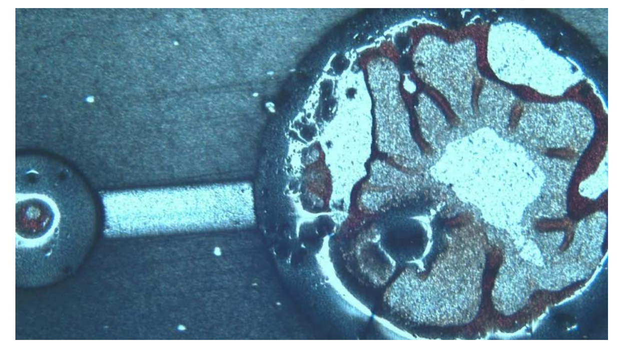

Fig 5. Etching hitting backside oxide layer.

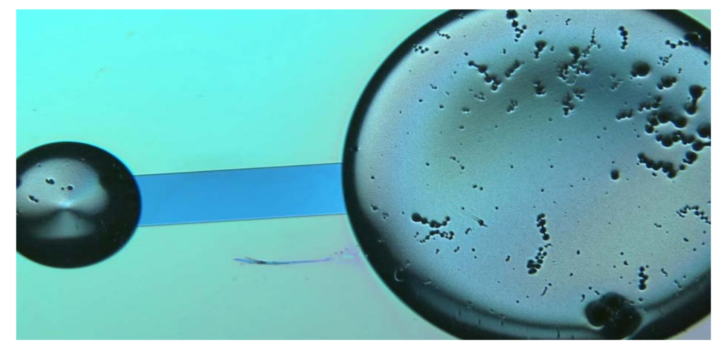

Fig 6. Etching of the channel has just began.

- One micron oxide hard mask
  - STS plasma etcher, etched through both the resist and oxide layer.
  - The STS plasma etcher is not uniform, rotated wafer every 200 cycles. Uses C_4F_8, Argon, Oxygen, and SF_6.
  - Solution: Using a PECVD system to deposit 2 additional microns of oxide to protect the wafer.
    - Quick deposition
    - Application can be done on one side of the wafer.

Fig 7. Defects in membrane area.

Fig 8. Hard mask removal using STS plasma etcher.

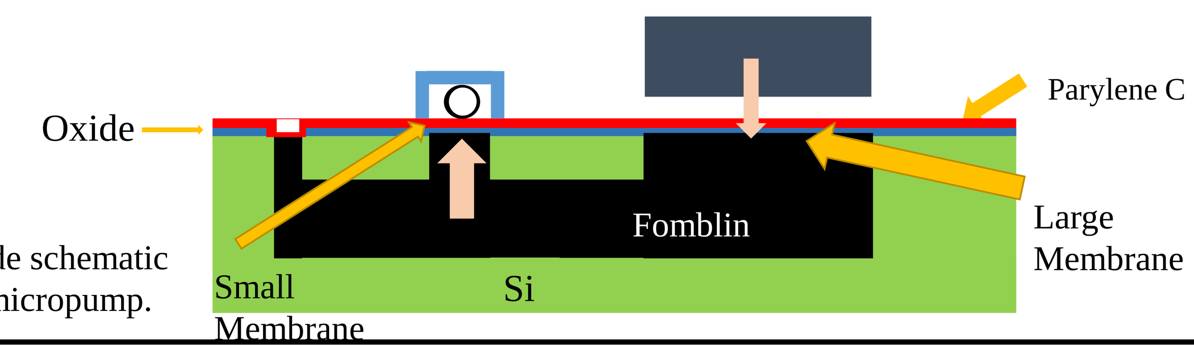

Fig 9. Side schematic view of micropump.