

# SIMPLE IMPLANTABLE DRUG DIFFUSION DELIVERY DEVICE

BY  
**BENJAMIN  
MCDERMOTT**  
UNIVERSITY OF VIRGINIA  
ADVISOR:  
**DR. G. ATKINSON,**  
VCU

1 [http://www.centrasight.com/img/img\\_pat\\_eye\\_callouts.jpg](http://www.centrasight.com/img/img_pat_eye_callouts.jpg); 2 Dr. Gary Atkinson, VCU

## ABSTRACT

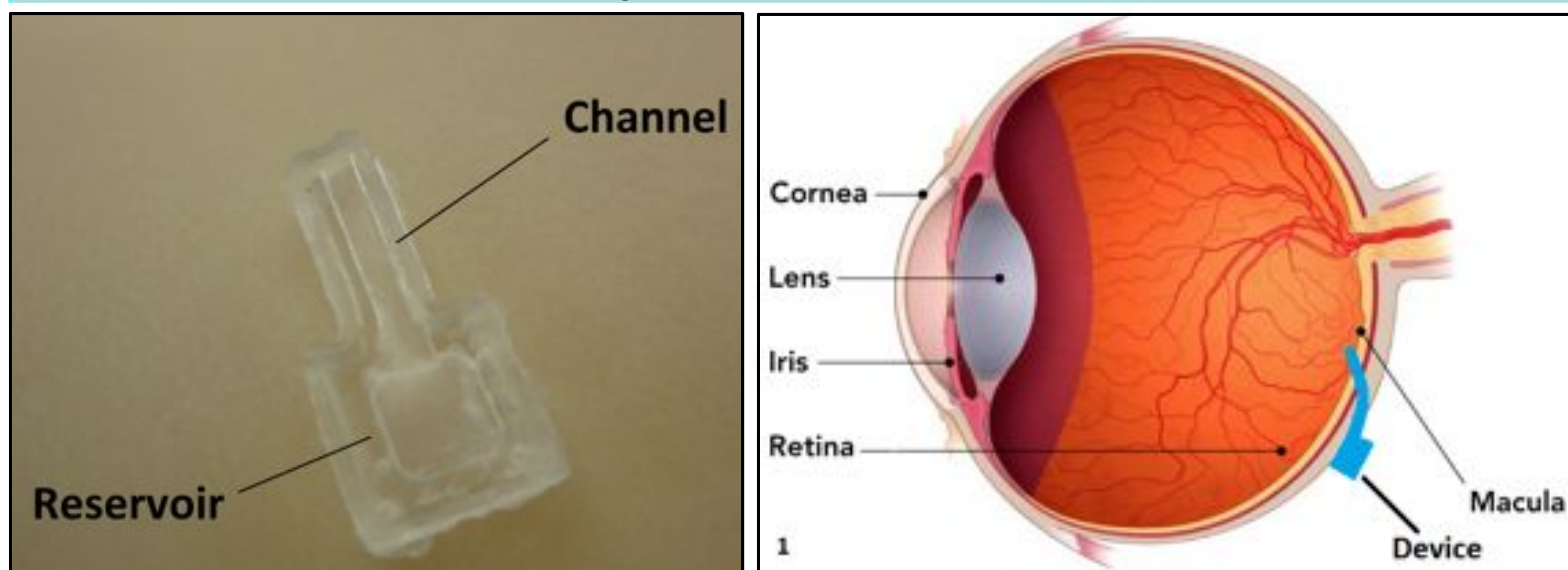
Alternatives have long been sought after to replace the conventional monthly direct eye injections for treating macular degeneration. Designing, building, and testing one such alternative was the goal of the 2011 VMEC project at VCU. By borrowing knowledge and techniques from numerous fields of study such as Rapid Prototyping, Microfluidics, and of course, Microelectronics, I was able to obtain some promising results.

## ADVANTAGES

- Medicine diffuses onto the area that needs it most over a long period of time.
- Only one surgery is needed.
- Device can be refilled by injecting medicine into it.
- Device is entirely made of polydimethylsiloxane (PDMS), making it very flexible.

## HOW IT WORKS

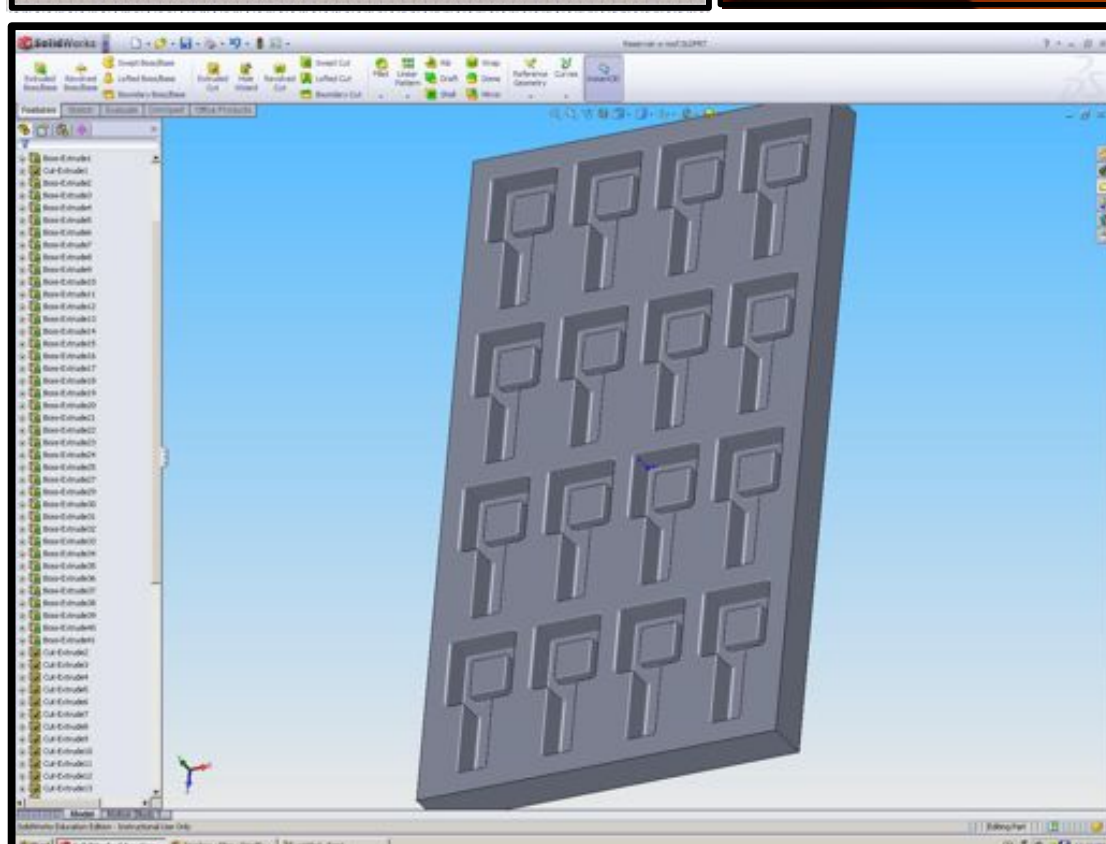
After the medicine is injected with a non-coring needle, the PDMS seals the puncture hole automatically. The device can now be surgically attached to a human eye. Fluid in the reservoir will diffuse through the channel and onto the area to be treated.



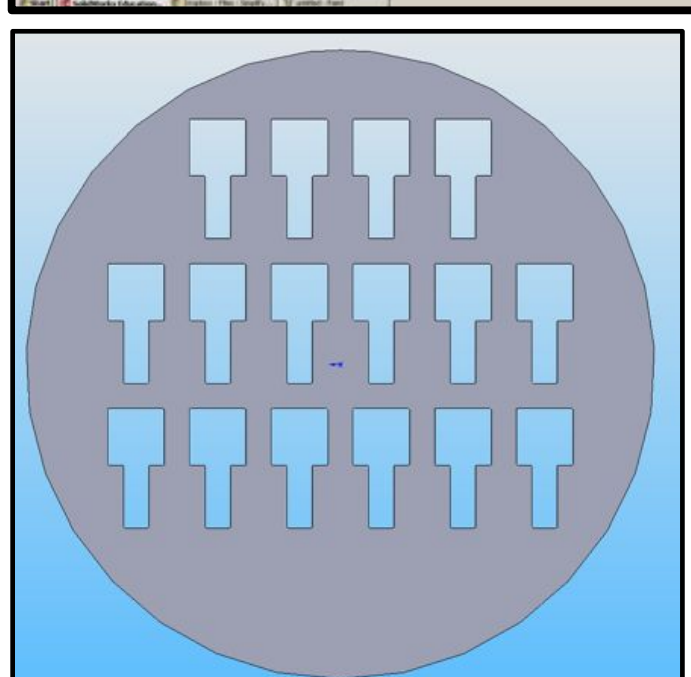
## DESIGN LAYOUT



Mentor Graphics IC-Station was used to design a mask for the lithography process.



A CAD program known as SolidWorks was used to make 2 rapid prototypes. This tray was used to mold the PDMS into reservoir pieces.



This prototype was used as a "fence" to enclose the PDMS when it was poured onto a silicon wafer.

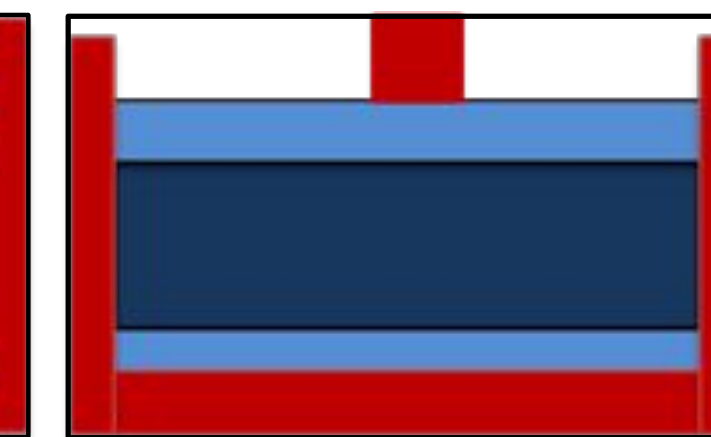
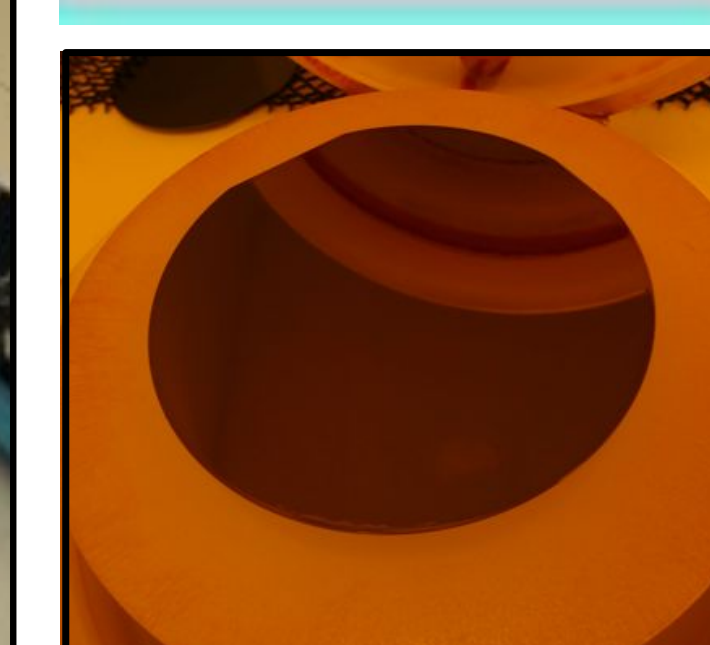
## DEVICE FABRICATION



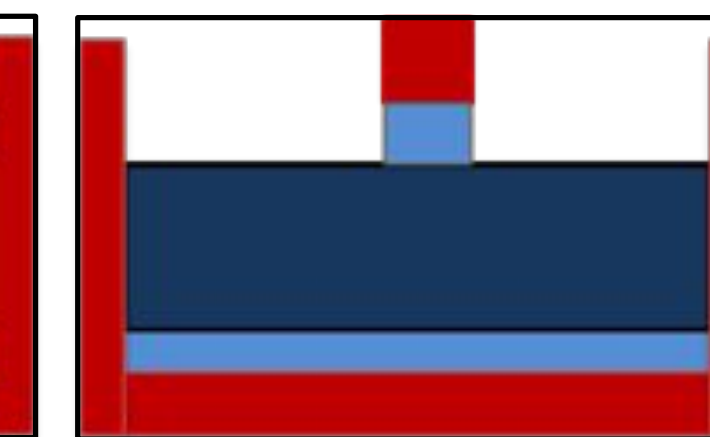
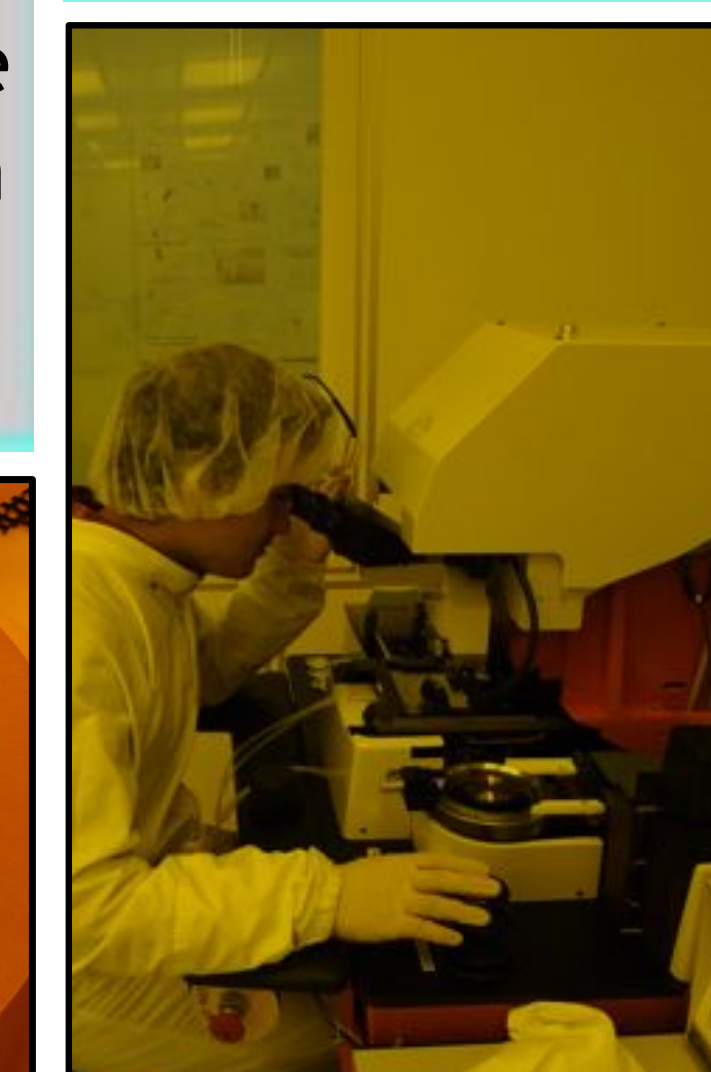
**Wet Oxidation**  
The silicon wafer is placed in the Bruce Furnace for 6 hours at 1000 °C. As a result, an oxide layer of about 12000 Å thick grew on each wafer.



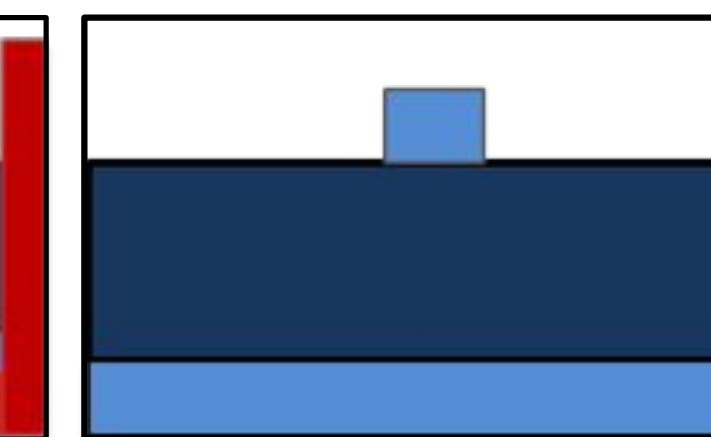
**Resist Application**  
A thick photoresist (AZ4620) is spun on the back of the wafer. The wafer is then hardbaked on a hot plate for 2 minutes at 125 °C. After this, a thinner photoresist (SPR3012) is spun on the front. This is then hardened by prebaking the wafer in an oven at 90 °C for 10 minutes.



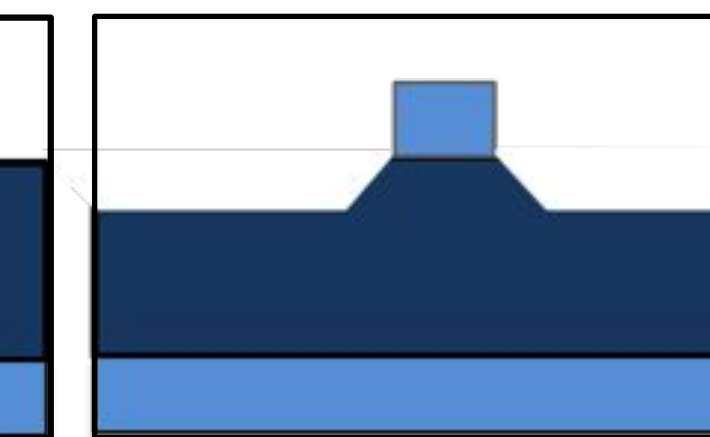
**Channel Mold Lithography**  
The wafer is exposed to the pattern on the mask made by the μPG 101 and then placed in developer to remove the exposed photoresist. After rinsing and drying, the wafer is postbaked in an oven at 125 °C for 10 minutes.



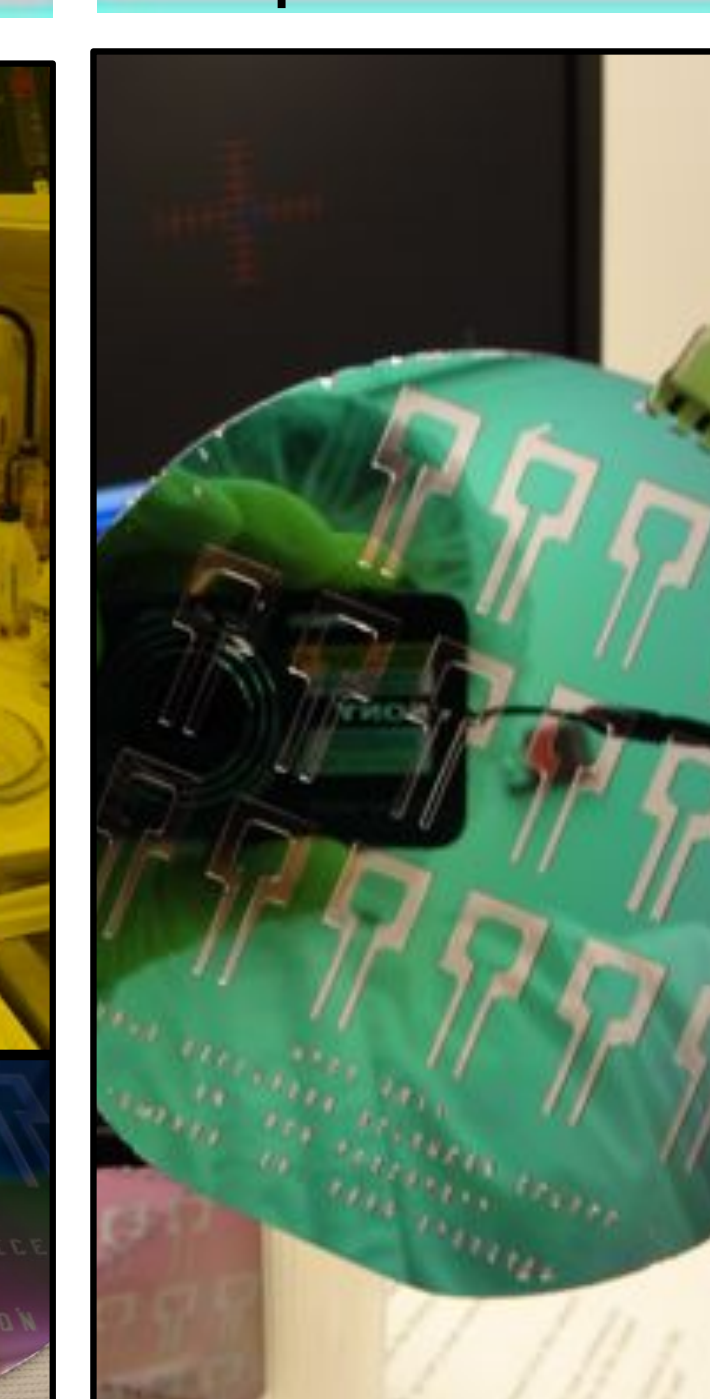
**Oxide Etch**  
The wafer is placed in a hydrofluoric acid bath in order to remove the oxide that was exposed during the Lithography process. The amount of time it is in the bath depends on the etching rate (typically 50-75 nm/min) and the thickness of the oxide.



**Resist Strip**  
After rinsing and drying the wafer, the remaining photoresist is removed by submerging the wafer in acetone and then isopropyl alcohol. The wafer is then rinsed and dried.



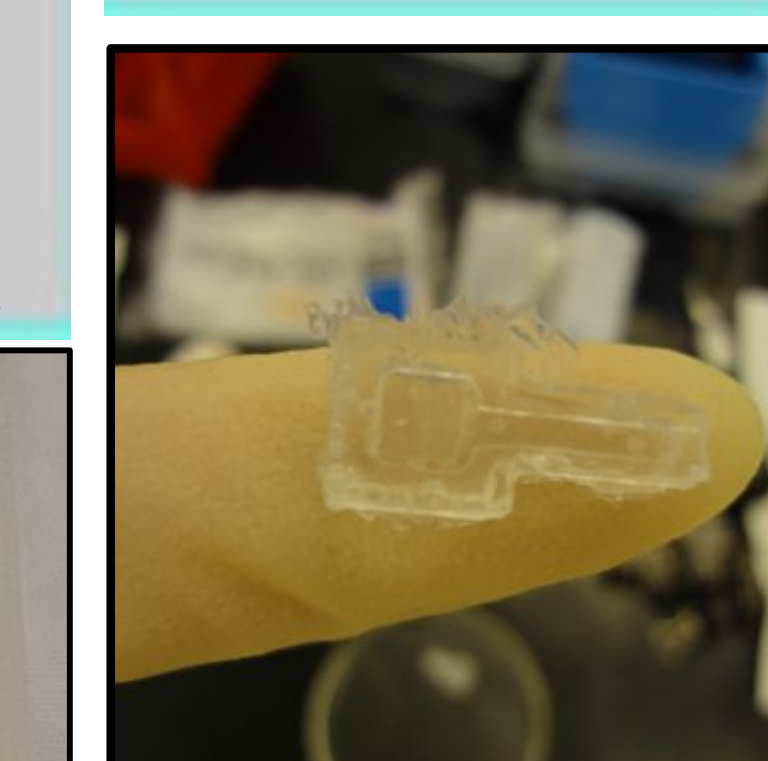
**KOH Etch Wafer**  
is submerged in potassium hydroxide in order to etch a trapezoidal-shaped groove into the exposed silicon. The depth of the groove depends on the time, rate, and temperature.



**Molding PDMS (all parts)**  
The PDMS was a mixture of Sylgard 184 elastomer base and its curing agent. The mass ratio was 10:1. Before pouring the PDMS onto the wafer with the fence fitted over it and into the reservoir tray, a coating of Liqui-Nox was applied to both as a surfactant. Once the PDMS was poured in, it could simply be left out to cure in about 2 days.



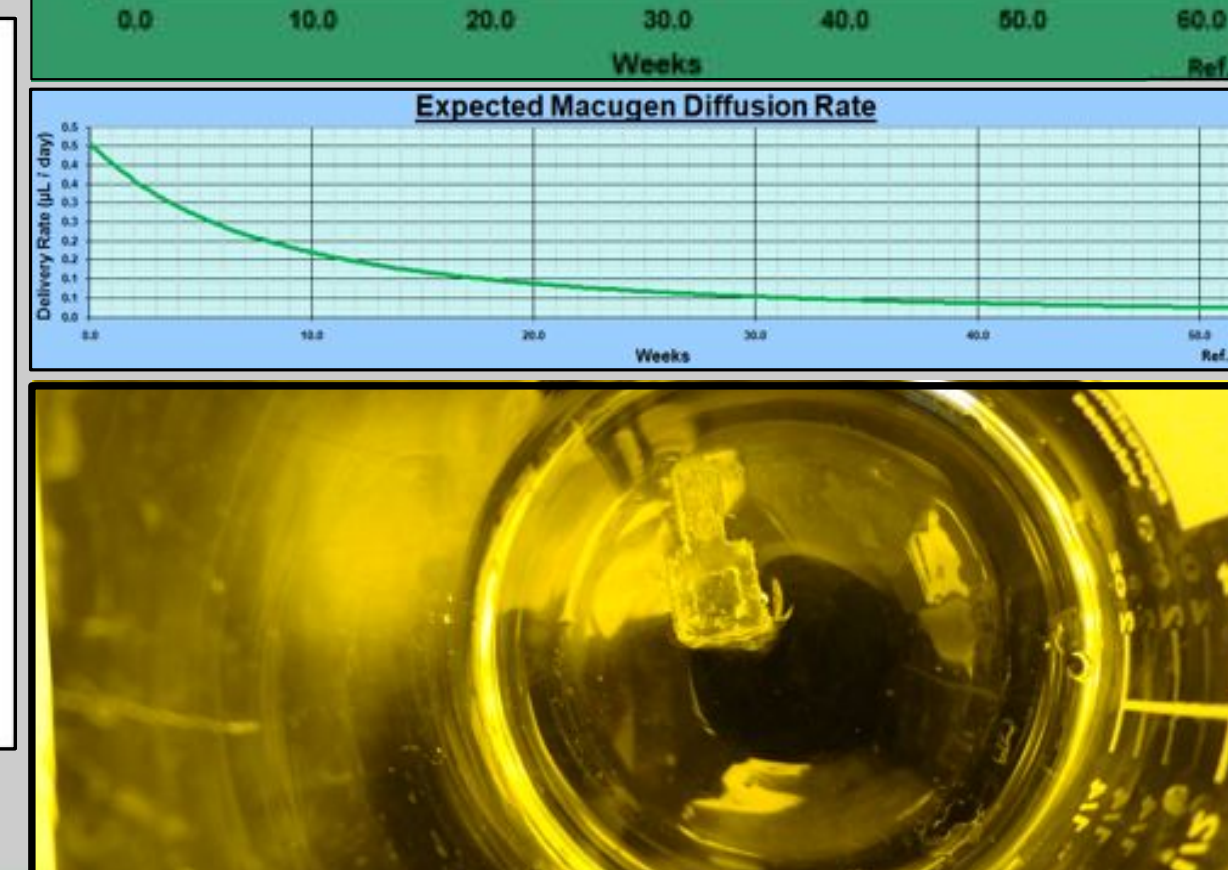
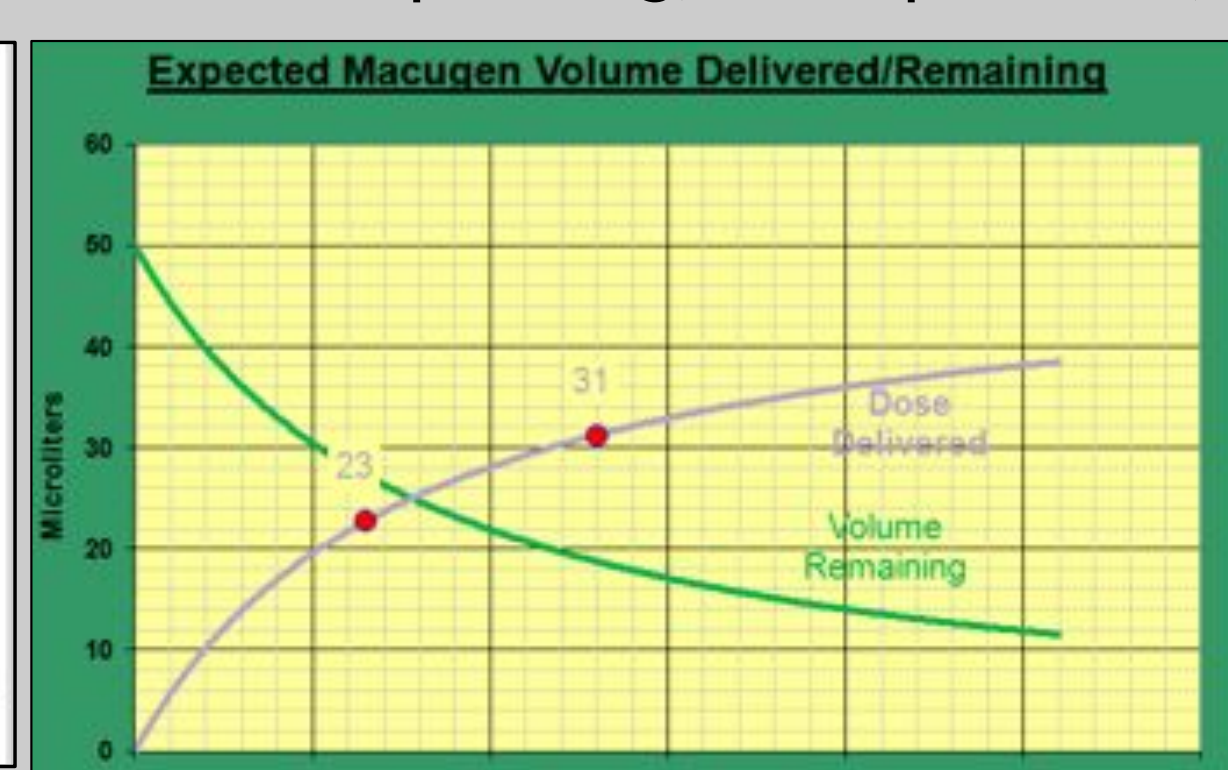
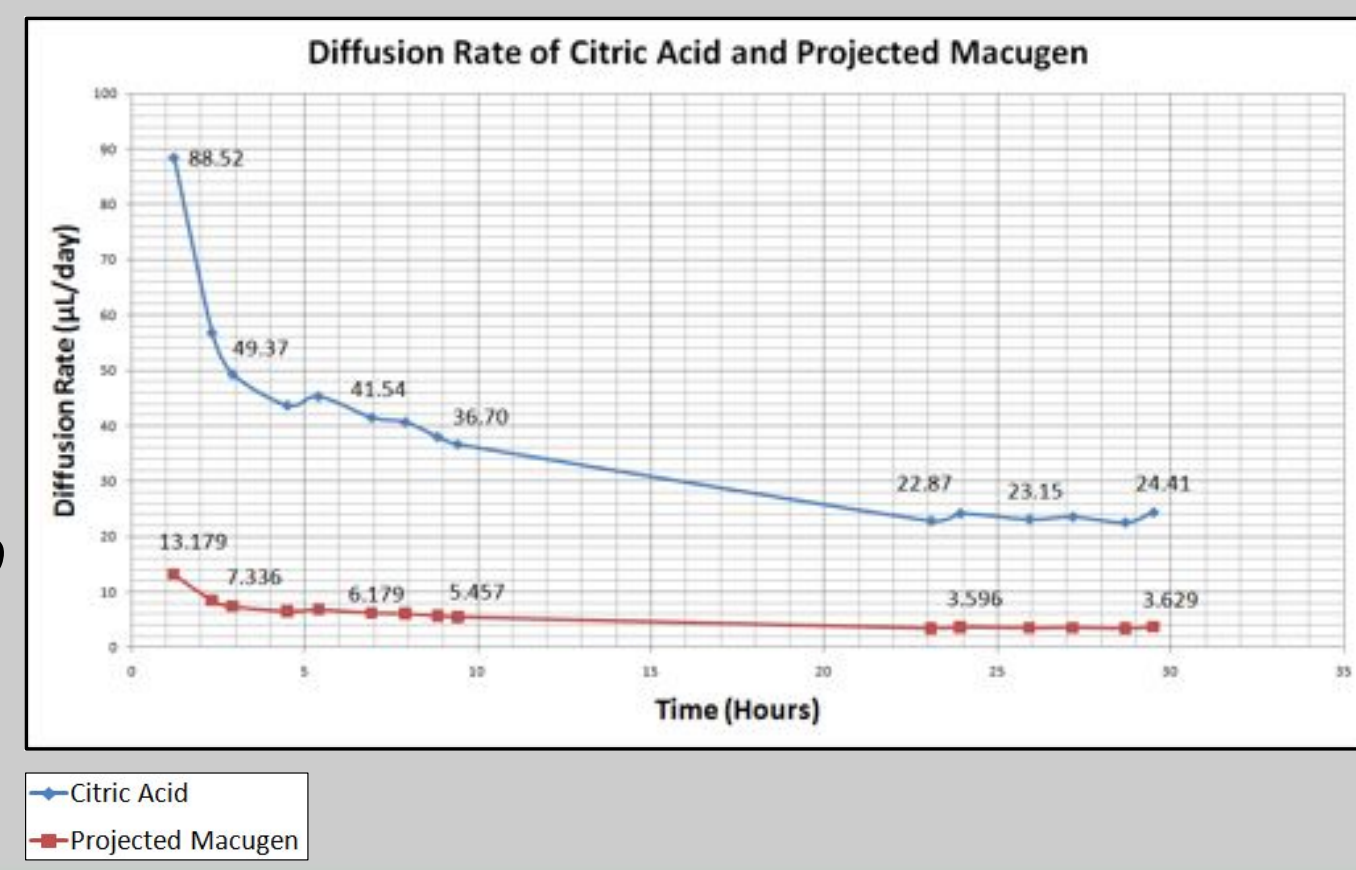
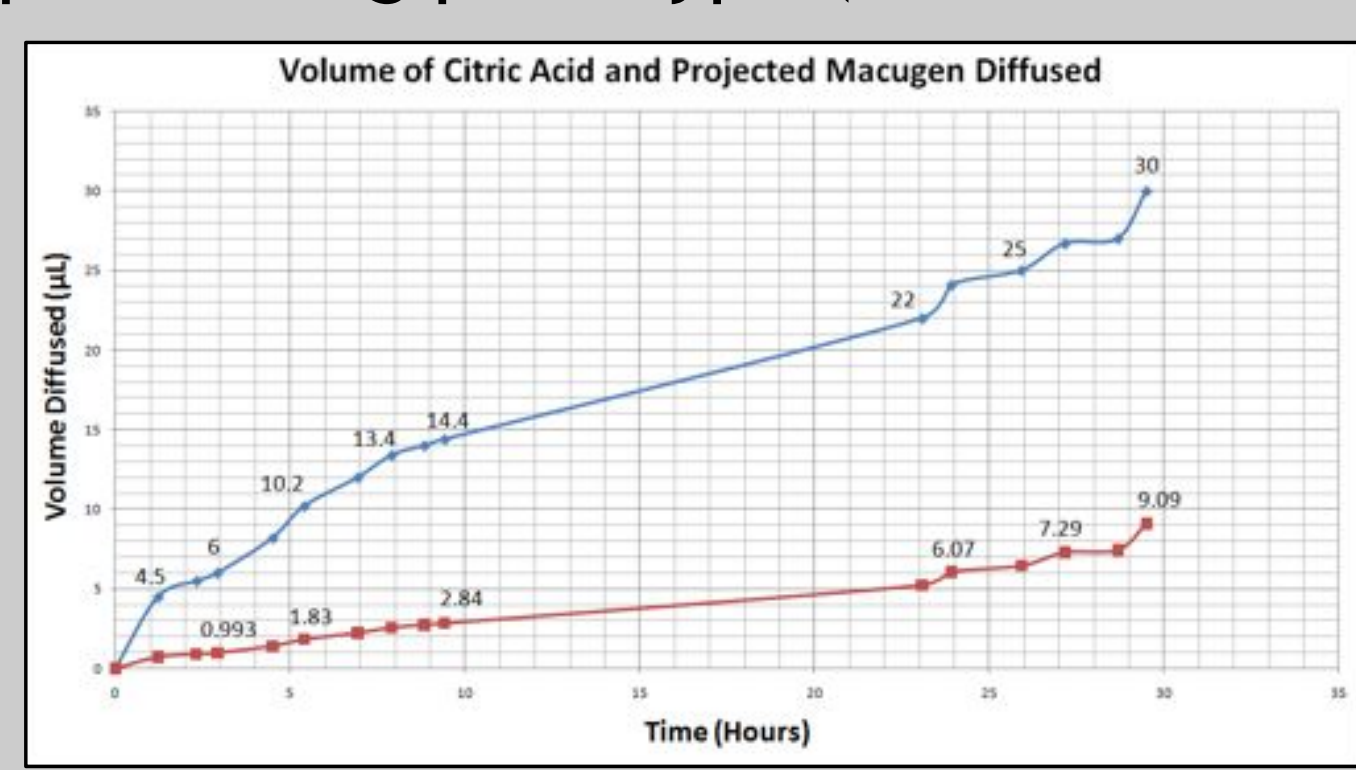
**Plasma Bonding/ PDMS glue**  
Once the PDMS cured, the pieces were scooped out and cleaned with acetone. The next step was O<sub>2</sub> plasma bonding at 20 Watts and 600 mTorr for 30 seconds, but this did not work. So instead, the channel and reservoir pieces were glued together using some more PDMS.



## TESTING AND RESULTS

The device was tested by injecting it with 50 μL of citric acid and placing it in a beaker of 50 mL tap water and recording the pH level over time. The pH level of another 50 mL of tap water was recorded every time a drop from 50 μL of citric acid was added in order to derive the diffusion rate of the device if it were filled with Macugen, a medicine for macular degeneration. Below are the results of the best performing prototype (channel dimensions=12000 μm long, 2250 μm wide, 300 μm thick):

*The prototype testing process lasted about 29.5 hours. About 20 μL of citric acid were left in the reservoir, translating to about 40.91 μL of Macugen left. The diffusion rate of the citric acid started off quite high but leveled off in a few hours, translating to an ending Macugen diffusion rate of 3.629 μL/day.*



*The actual and projected results differ drastically from these expected ones, leading to the conclusion that gluing the device together with PDMS probably did not fully seal the device.*

## CONCLUSION

The prototype could have given adequate doses of medicine for 2-3 weeks. This short lifespan is due to the inherent imprecision in attempting to glue the pieces together. This could be fixed by producing smoother rapid prototypes, resulting in PDMS molds that could be plasma bonded. While the lifespan was much shorter than the desired three months, I was left feeling optimistic about the device. It worked quite well, given the circumstances. If the plasma bonding problem was addressed, this device could be a legitimate alternative to monthly eye injections.

## THANKS!

Thank you to VMEC for giving me the chance to participate in this project. I also want to thank Dr. Gary Atkinson and the employees of the Wright Virginia Microelectronics Center for helping me through the whole process.