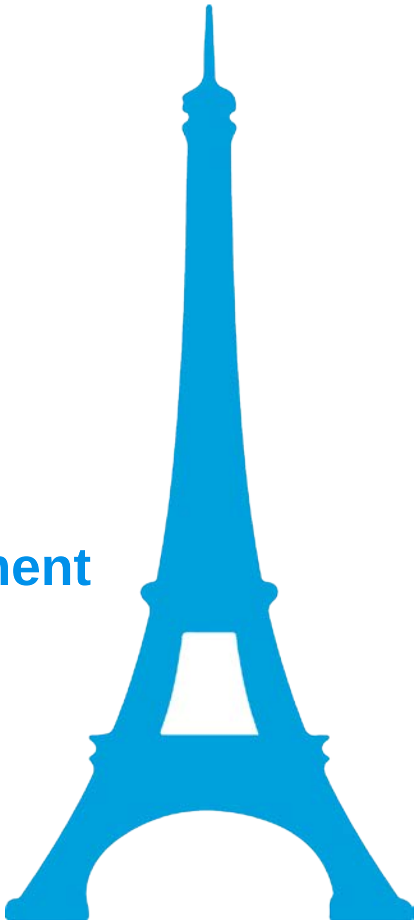
Microfluidic Diodes

ENME416 | Final Project
Conference Presentation
Team 5

Eiffel Studios

Microfluidic Research Department



John Hardies
Marcus Martin
Vineet Padia
Reid Poluhovich
Jaskeerat Singh

AGENDA

- Project Scope
- Designs & Discussion
- Results
- Lessons Learned
- Conclusions

Project Scope

- Design a new fluidic diode (on the *mezo* scale)
- Print with two materials on the Object Connex3
- Promote inflow and prevent backflow
- Gather data on design performance

Design Goal:

Diodicity

The ratio of ‘allowed’ versus ‘obstructed’ fluid flow through our diodes

Designs & Discussion

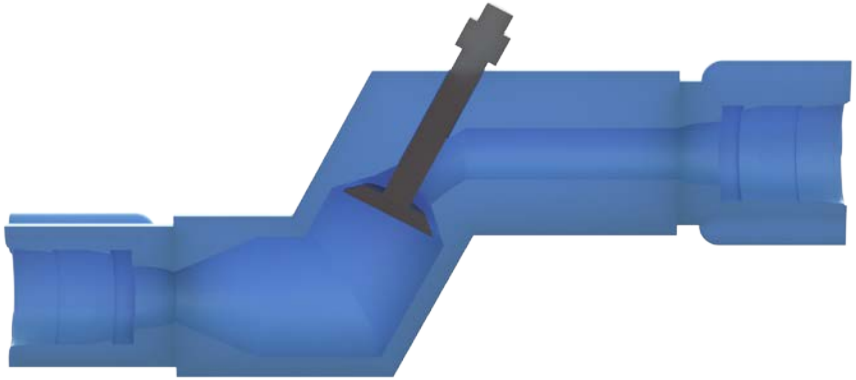
- Concept
- Renderings
- Performance

“

“I have not failed. I've just found 10,000 ways that won't work.”

- Thomas Edison -

Plunger Valve



Dynamic plunger raised and lowered in a rigid entry path that allows forward flow while closing for backflow.

Positive

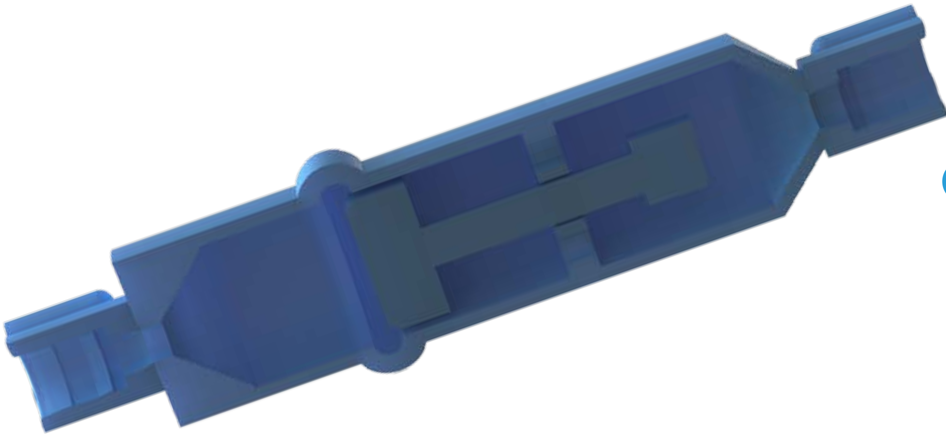
- Support material removal
- Structural integrity
- Compact design

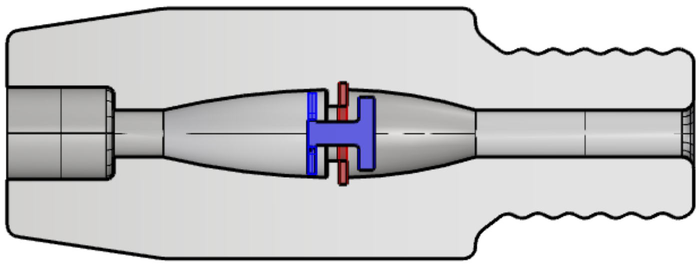
Limitations

- Feature size too small
- Diodicity of 1

Outcome: *Rubber plunger was too small, dissolved away.*

Plug Valve





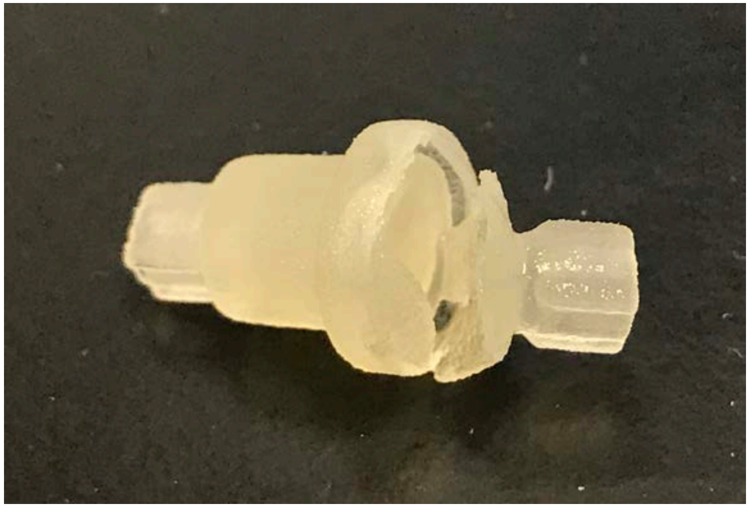
Plug inspired design that utilizes narrow internal gate to slowly allow forward flow while resisting backflow.

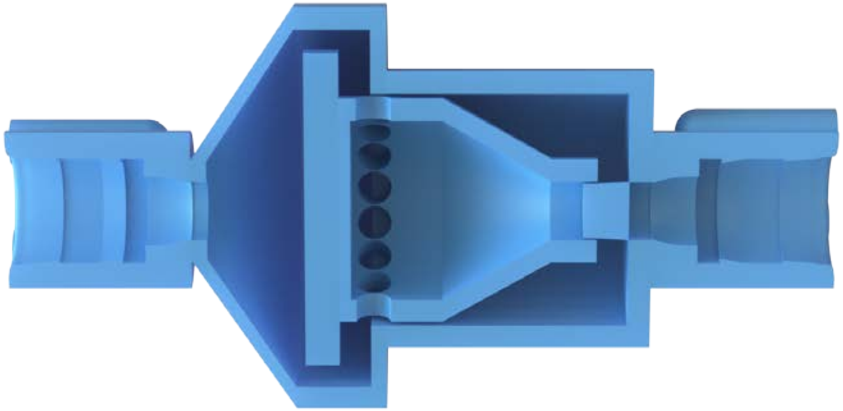
Limitations

- Repeated cracking from printing process
- Difficult support material removal
- No flow allowed in either direction

Outcome: *Inaccessible, large cavities didn't allow support material to escape*

Perforated Valve





Large, perforated, plunger-like valve translates when pressure is applied in the forward direction and allows fluid flow through the perforations.

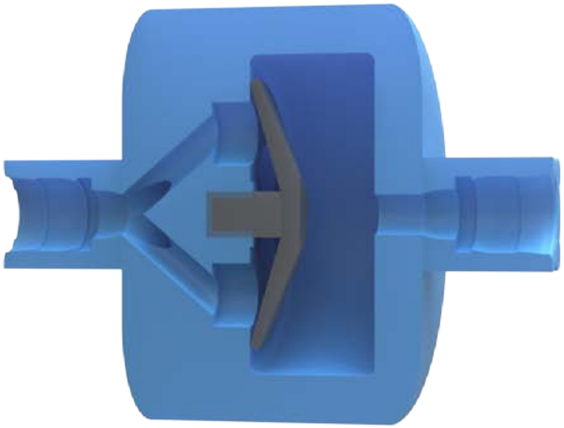
Positive

- New diode design
- Does not require rubber

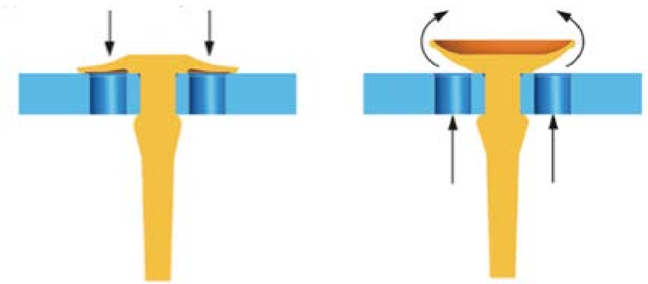
Limitations

- Cavity space is too large
- Support material was trapped
- Failure point at thin wall

Outcome: *Fracturing occurred consistently, support material remained.*



Umbrella Valve



Rubber umbrella valve that utilizes pressure difference to deform and allow forward flow to pass, while backflow is closed off.

Positive

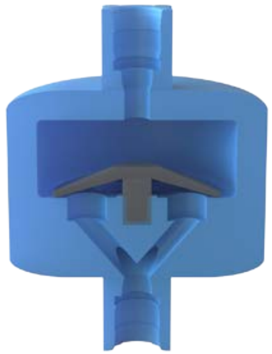
- Durable Design
- Withstands high pressure

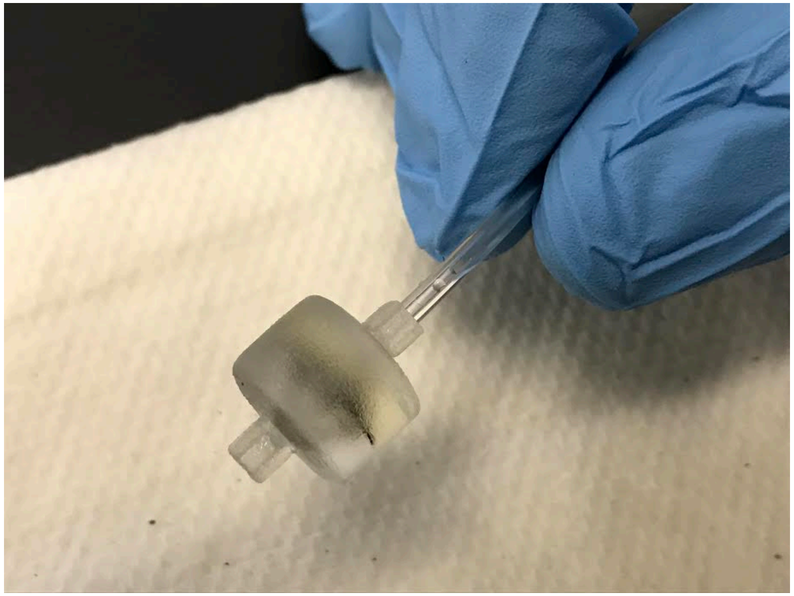
Limitations

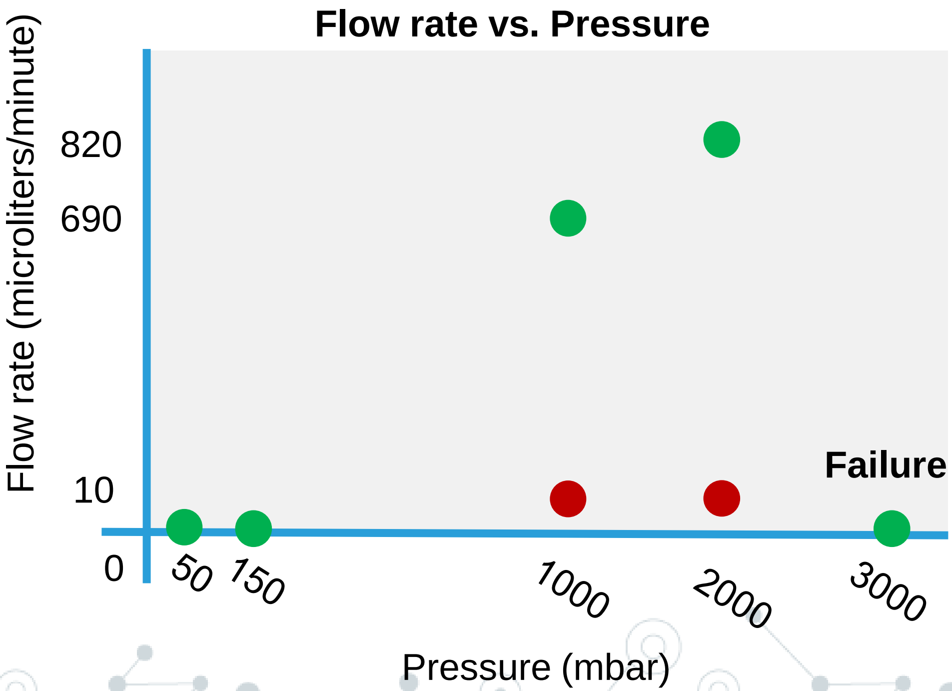
- Large, low accessibility cavity space
- Requires high pressures to function

Outcome: *Support material wasn't removed, only functioned under high pressure.*

Results





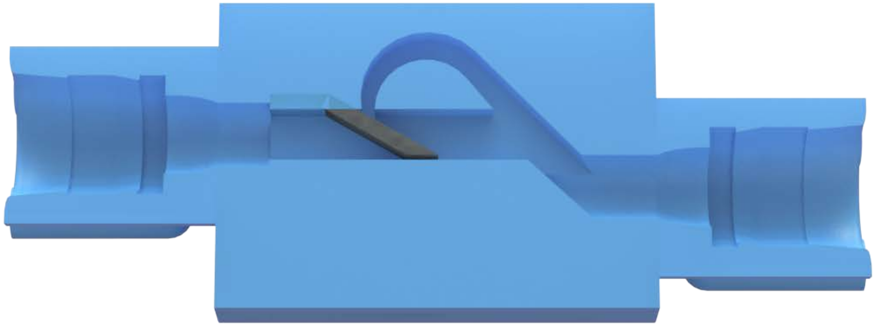


$$\text{Diodicity} = \frac{R_{backflow}}{R_{inflow}} = \frac{10mbar}{820\ mbar} = 0.0122$$

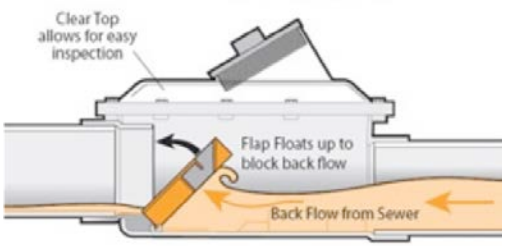
$$\Delta P = R * q \qquad R_{diode} = 1.539$$

Where R_t at 2000 mbar is assumed to be 0.9 and R = (Rt+Rd)

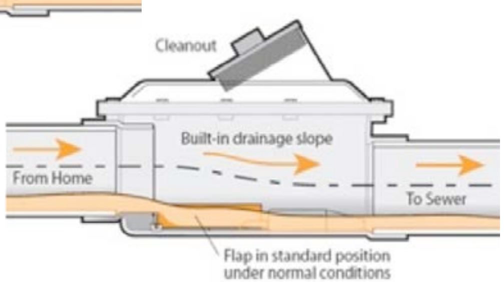
- **Inflow** (green)
- **Backflow** (red)



Tesla Flap



Drainage inspired diode utilizing dynamic rubber door adjusting to encourage forward flow while inhibiting backflow.



Positives

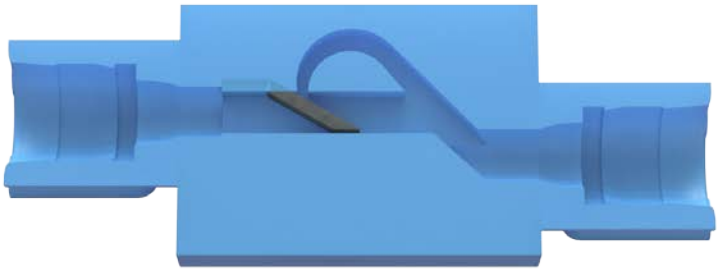
- High diodicity
- Limited cavity space
- Support material dissolved out

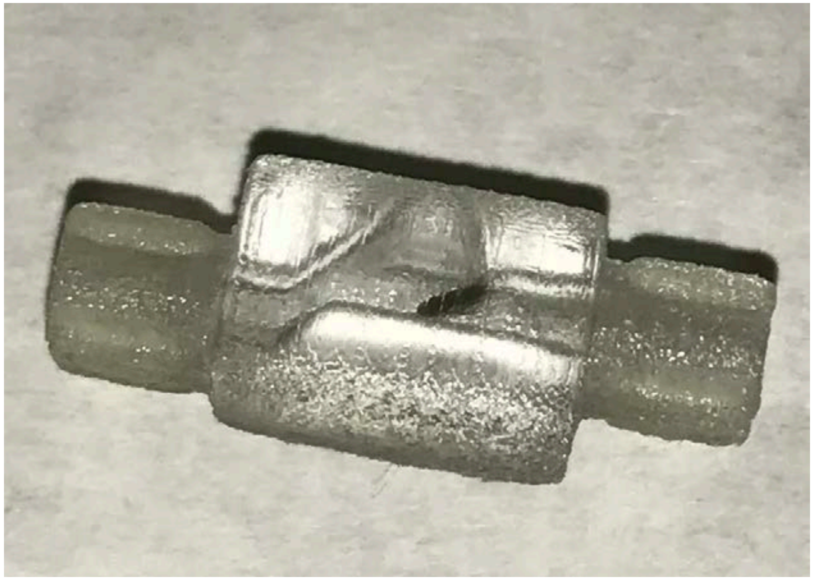
Limitations

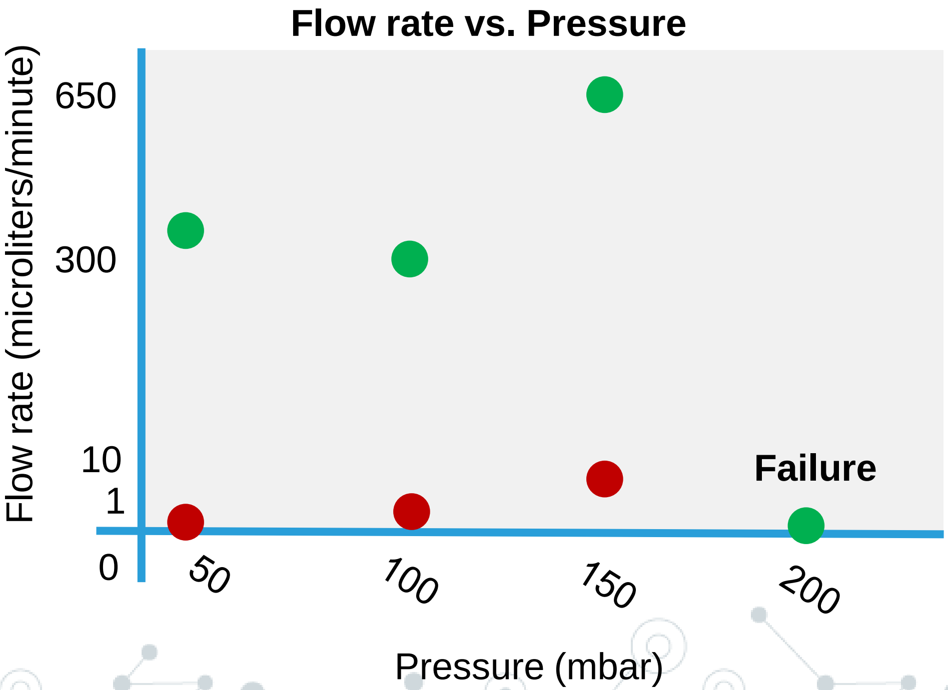
- Consistent point of failure
- Flap failure under high pressures (above 200 mbar)

Outcome: **Hinged rubber design succeeded, could be scaled for strength**

Results







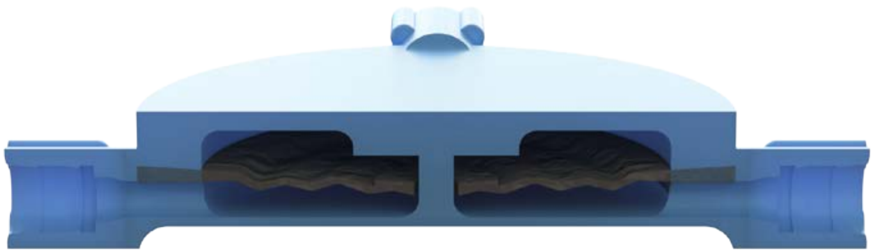
$$\text{Diodicity} = \frac{R_{backflow}}{R_{inflow}} = \frac{1\ mbar}{350\ mbar} = 0.00285$$

$$\Delta P = R * q \qquad R_{diode} = 0.0168$$

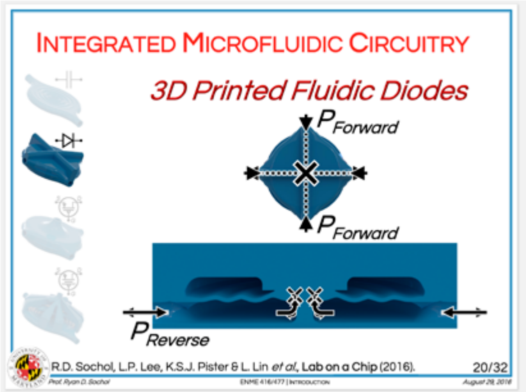
Where R_t at 50 mbar is found to be 0.126 and R = (Rt+Rd)

- **Inflow** (green)
- **Backflow** (red)

Flexible Diaphragm



'Control' design inspired & based upon on Dr. Sochol's fluidic diode utilizing high pressures to deform rubber & prevent backflow. This design was intended for a proof of concept.



Positive

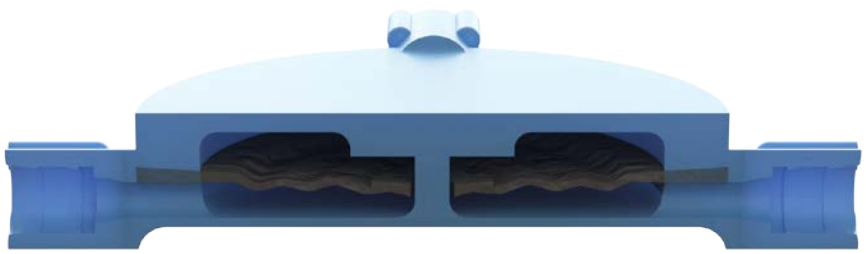
- High diodicity
- Structurally sound

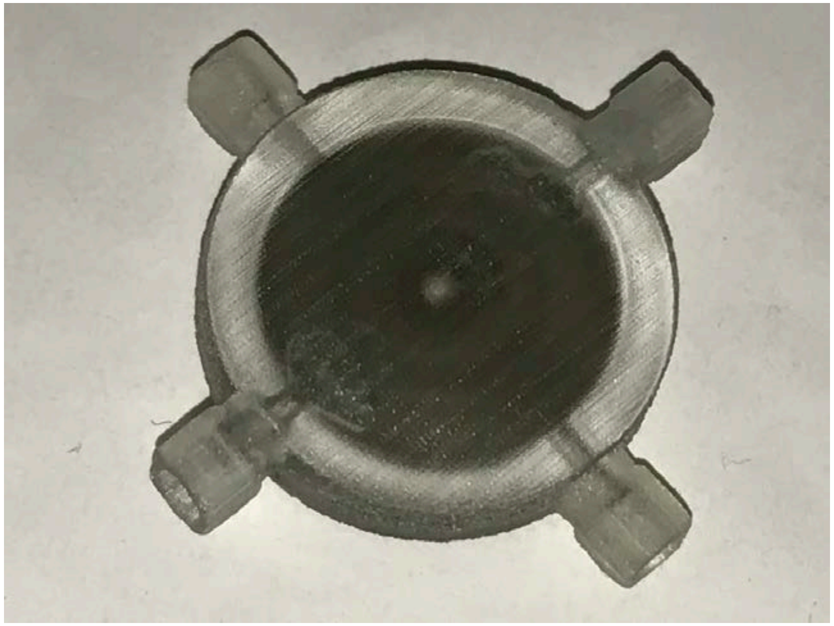
Limitations

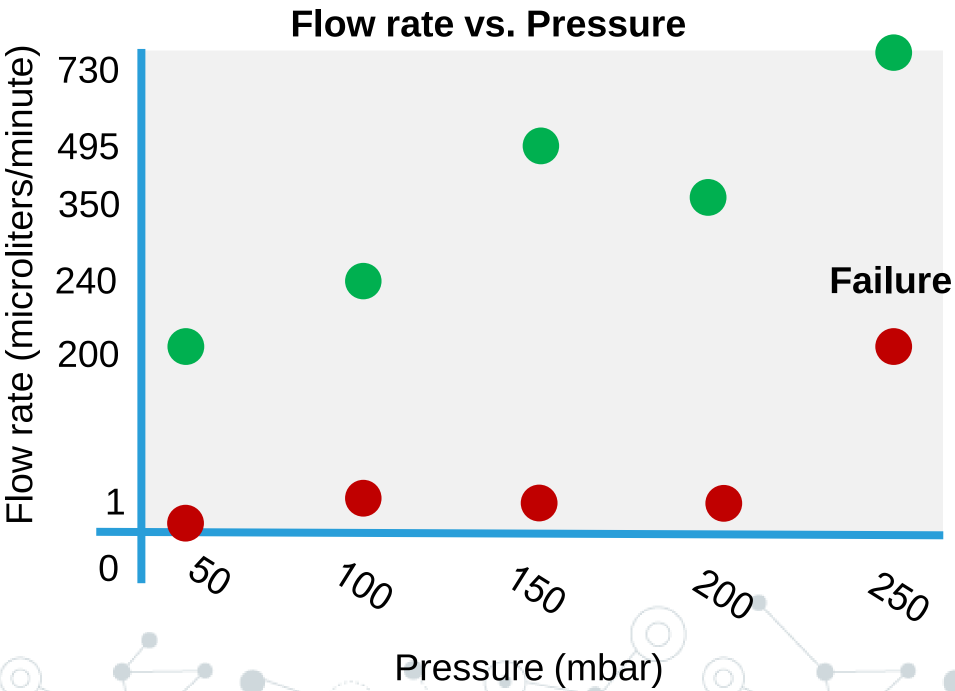
- 'Leaking' backflow system
- Larger design takes up build plate space & material

Outcome: *High diodicity in low pressures, our design failed under high pressure*

Results







$$\text{Diodicity} = \frac{R_{backflow}}{R_{inflow}} = \frac{1\ mbar}{200\ mbar} = 0.005$$

$$\Delta P = R * q \qquad R_{diode} = 0.125$$

Where R_t at 50 mbar is found to be 0.126 and R = (Rt+Rd)

- Inflow
- Backflow

Results

Minimum diodicity ratios

Diode Design	Inflow rate (microliters/min)	Backflow rate (microliters/min)	Diodicity Ratio
Tesla Flap	350	1	0.00285
Umbrella Valve	820	10	0.0122
Flexible Diaphragm	200	1	0.005

Lessons Learned

Printing Considerations

Avoiding thin dissolvable feature size components

Feature size ‘limits’

Support material removal considerations
(i.e. more open ports)

Microfluidic Design

Avoiding ‘large’ cavities with poor accessibility

Utilizing ‘flowing’ design i.e. avoid 90º corners

Hinged vs. ‘free-floating’ components

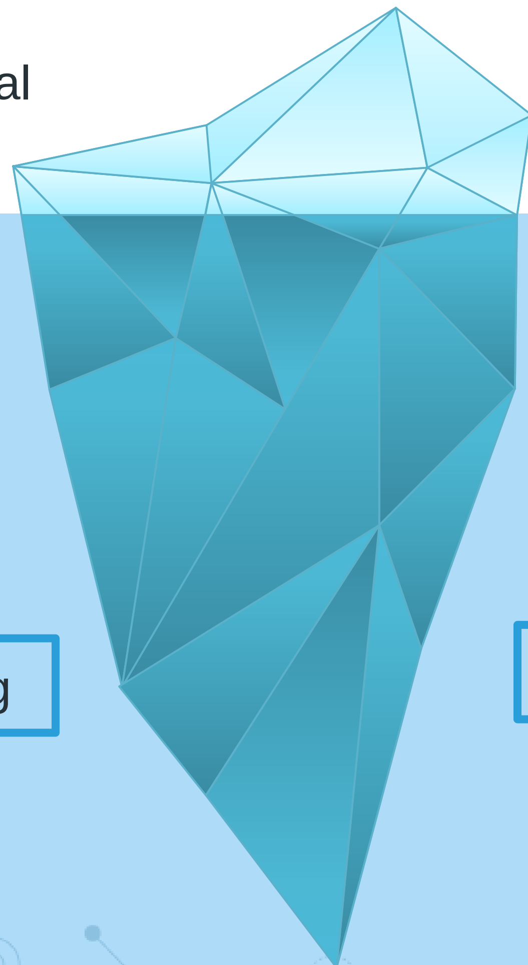
3D Printing

at *mezo* scale or *any* scale

Material versatility

Manufacturing unconventional shapes and prototypes

Significantly faster mold and prototype development



File formatting

Size limitations

Post-processing

Support Material

Print failures

Resolution

Part strength

Material inconsistency

Moving Forward

Failure analysis on three designs

Microfluidic simulations: COMSOL or Mathematica

Iterate & Improve

THANK YOU!

Special thanks to Parth Desai for the lab help and Dr. Sochol

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