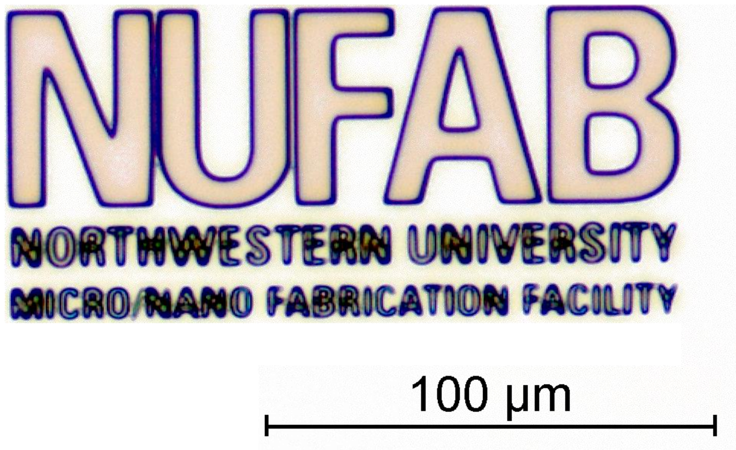
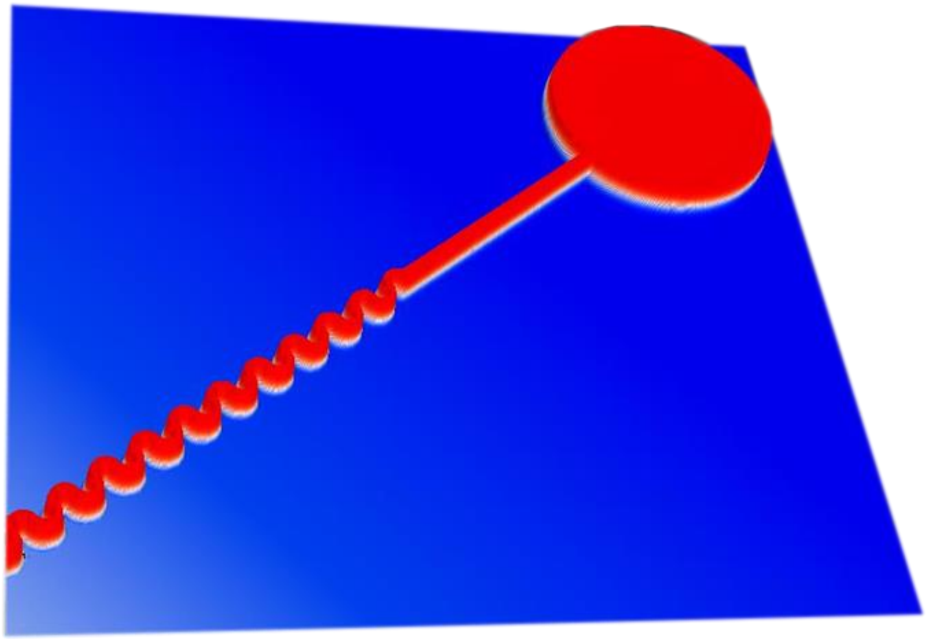
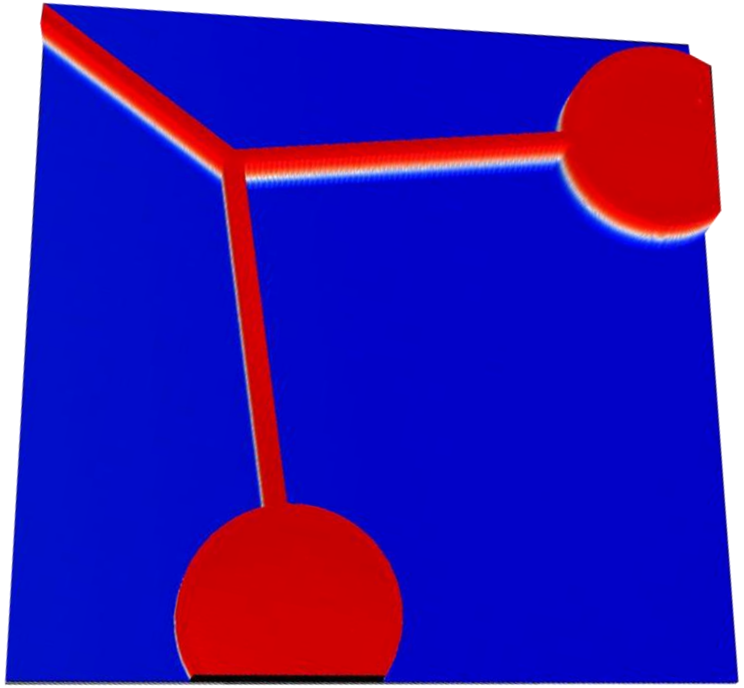
Enabling Microfluidics @



Serkan Butun and Suhwan Choi





In this talk…

- What is microfluidics and why we use it?
- See types and applications of this technology

- What kind of methods NUFAB provides for fabricating microfluidic devices?

What is microfluidics?

- Microfluidics: Study of fluid flows and design of components that are geometrically constrained to a small scale (micrometer, µm) at which surface forces dominate volumetric forces.
- Interdisciplinary field: engineering, physics, chemistry, biology, materials science.
- Smaller length scale – different physics (ex, capillary action).

Diameter:	1d	10^{-1}d	10^{-2}d	10^{-3}d
Surface Area:	1A	10^{-2}A	10^{-4}A	10^{-6}A
Volume:	1V	10^{-3}V	10^{-6}V	10^{-9}V
Weight:	1kG	1g	1mg	1ug
Surface/Volume:	1	10	10^{2}	10^{3}

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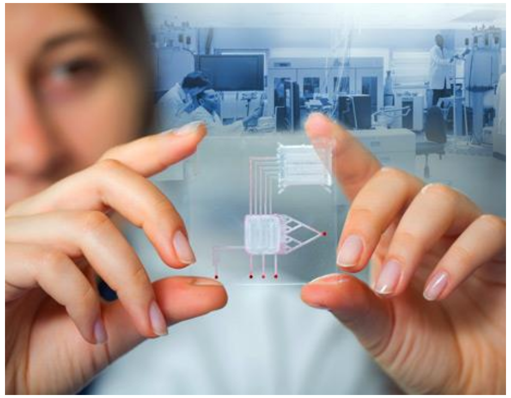
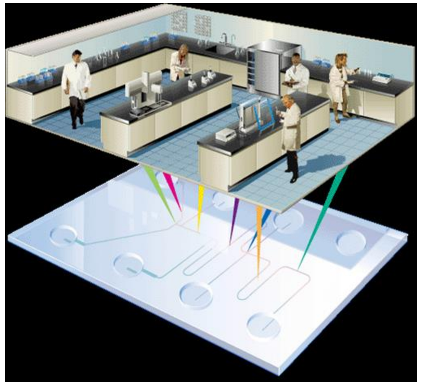
Why microfluidics?

Low sample volume	→	Reduce cost
Parallelization		High throughput experimentation
Small physical		Economic footprint
Batch fabrication		Quantitative benefit
Automation		Compact



Advantages of microfluidics: Lab on a chip



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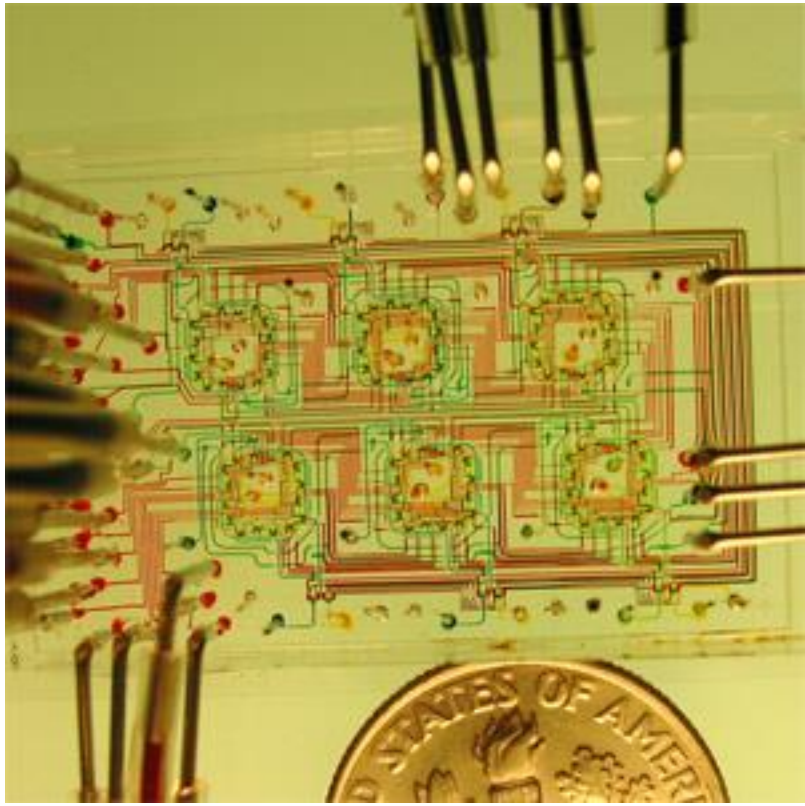
Continuous-flow microfluidics

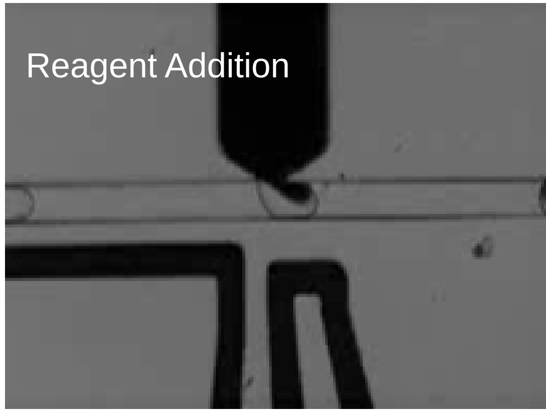
- Manipulation of liquid flow through fabricated microchannels without breaking continuity.
- Syringe pumps are typically used to pump in your reagents.
- A variety of applications including micro- and nanoparticle separators, particle focusing, chemical separation as well as simple biochemical applications.

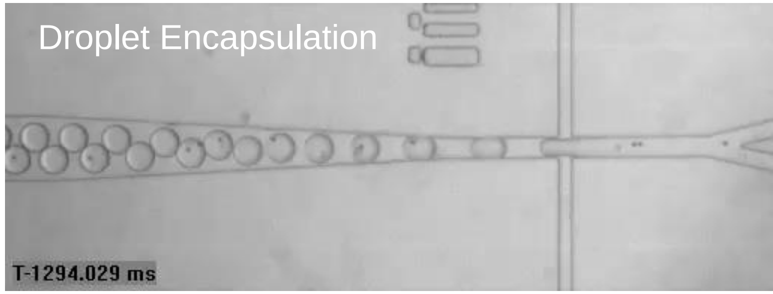


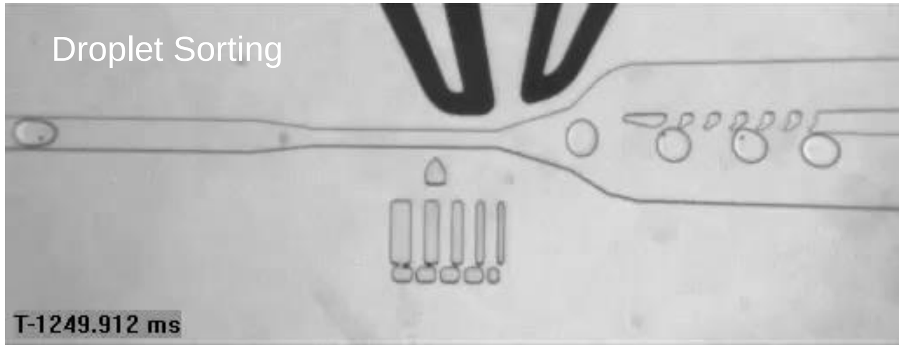
(Quake lab, Stanford)

Droplet-based microfluidics

- Manipulates discrete volumes of fluids in immiscible phases with low Reynolds number and laminar flow regimes.
- Microdroplets allow for handling miniature volumes (µl to fl) of fluids conveniently.
- Provide better mixing, encapsulation, sorting, and sensing, and suit high throughput experiments.
- Requires a deep understanding of droplet dynamics such as droplet motion, droplet sorting, droplet merging, and droplet breakup.

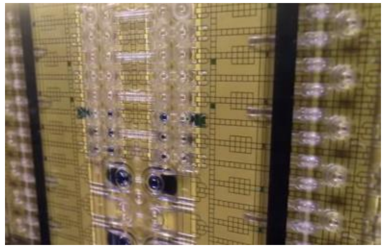




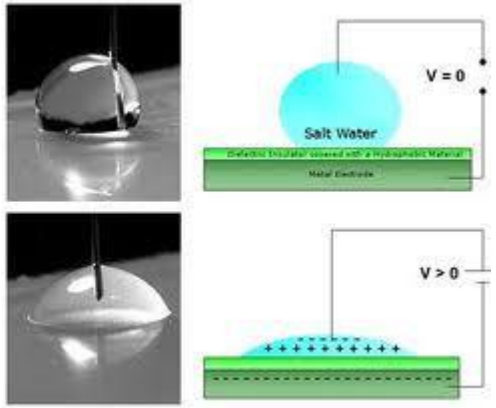


(Weitz lab, Harvard)(Abate lab, UCSF)

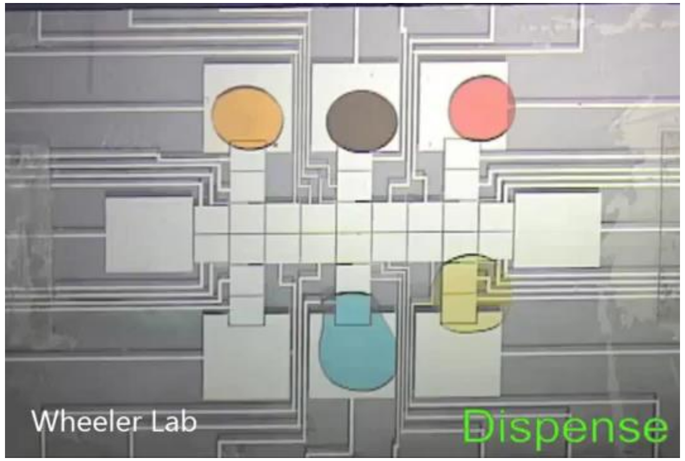
Digital microfluidics



- An advanced fluid-handling technology that precisely manipulates droplets on a substrate using electrowetting.



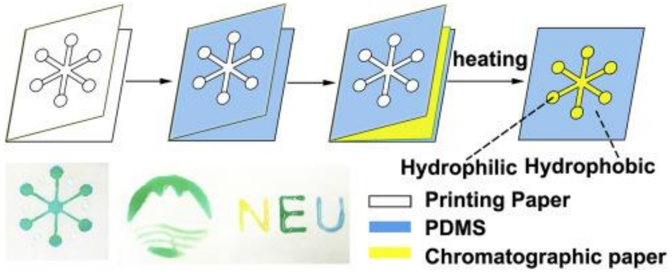
- “Electrowetting” refers to the ability of an applied voltage to modulate the “wettability” of a surface.
- Harnesses electrowetting to control droplets.
- Electrical signals are applied to an array of electrodes to define the size and position of each droplet.



- Droplets are moved by turning the voltage on and off in succession across adjacent electrodes.

Paper-based microfluidics

- Paper based microfluidics rely on the phenomenon of capillary penetration in porous media.
- Hydrophobic barriers on hydrophilic paper passively transport aqueous solutions to outlets where biological reactions take place.
- Current applications include portable glucose detection and environmental testing, with hopes of reaching areas that lack advanced medical diagnostic tools.



(https://doi.org/10.1016/j.aca.2018.12.001)

(mrnok/shutterstock.com)

Photolithography @ NUFAB

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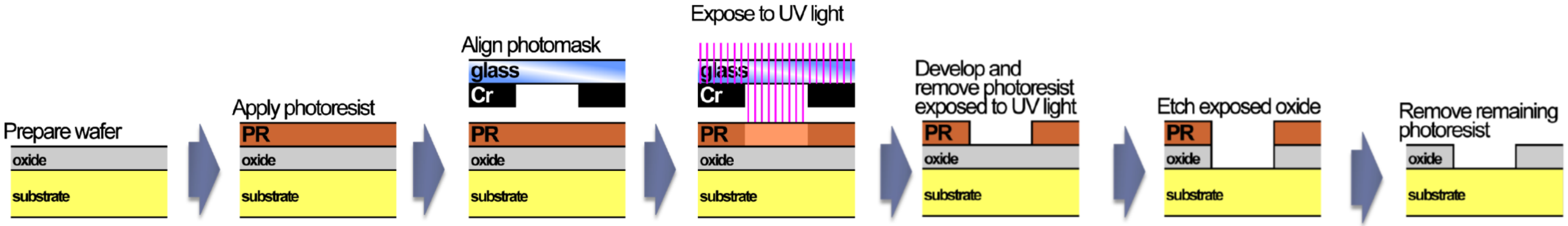
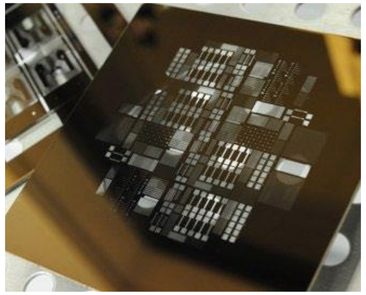
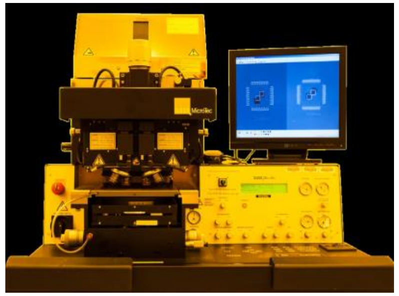
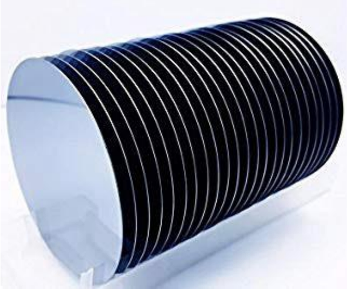
Procedure



Required tools


Masks: Cr or Iron oxide plates


Mask aligner


Substrates


Photoresists

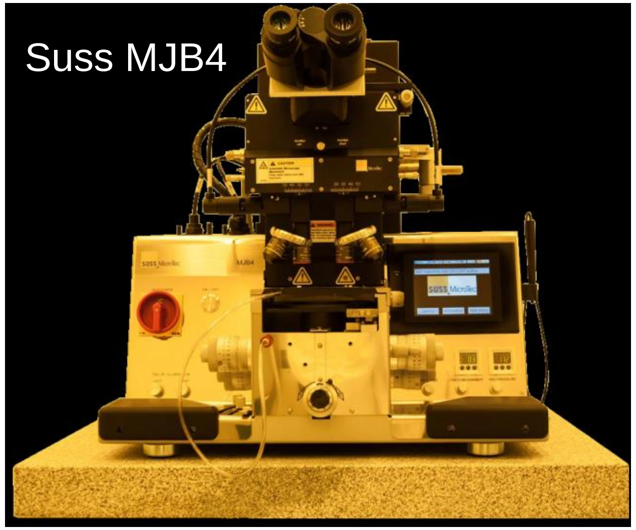
Developers


Spinner

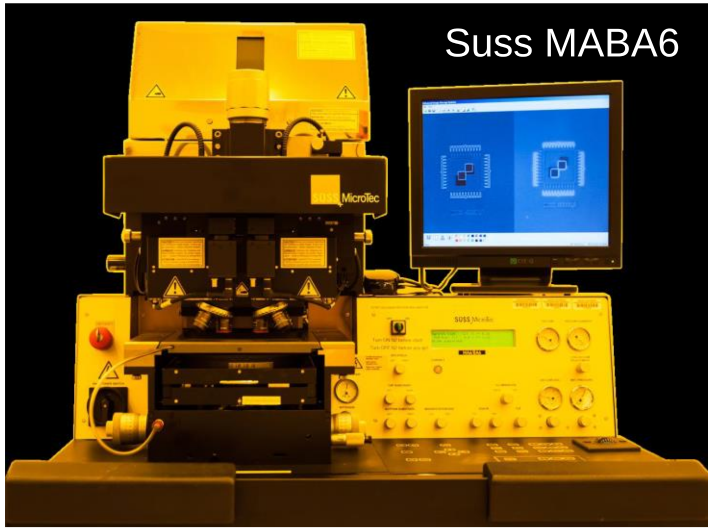
Photolithography Aligners @ NUFAB

Contact Aligner

- ➢ Advanced contact modes
- ➢ UV lamp –365 nm (i-line)
- ➢ Up to 6 inch wafer process
- ➢ Backside alignment



Suss MJB4



Suss MABA6

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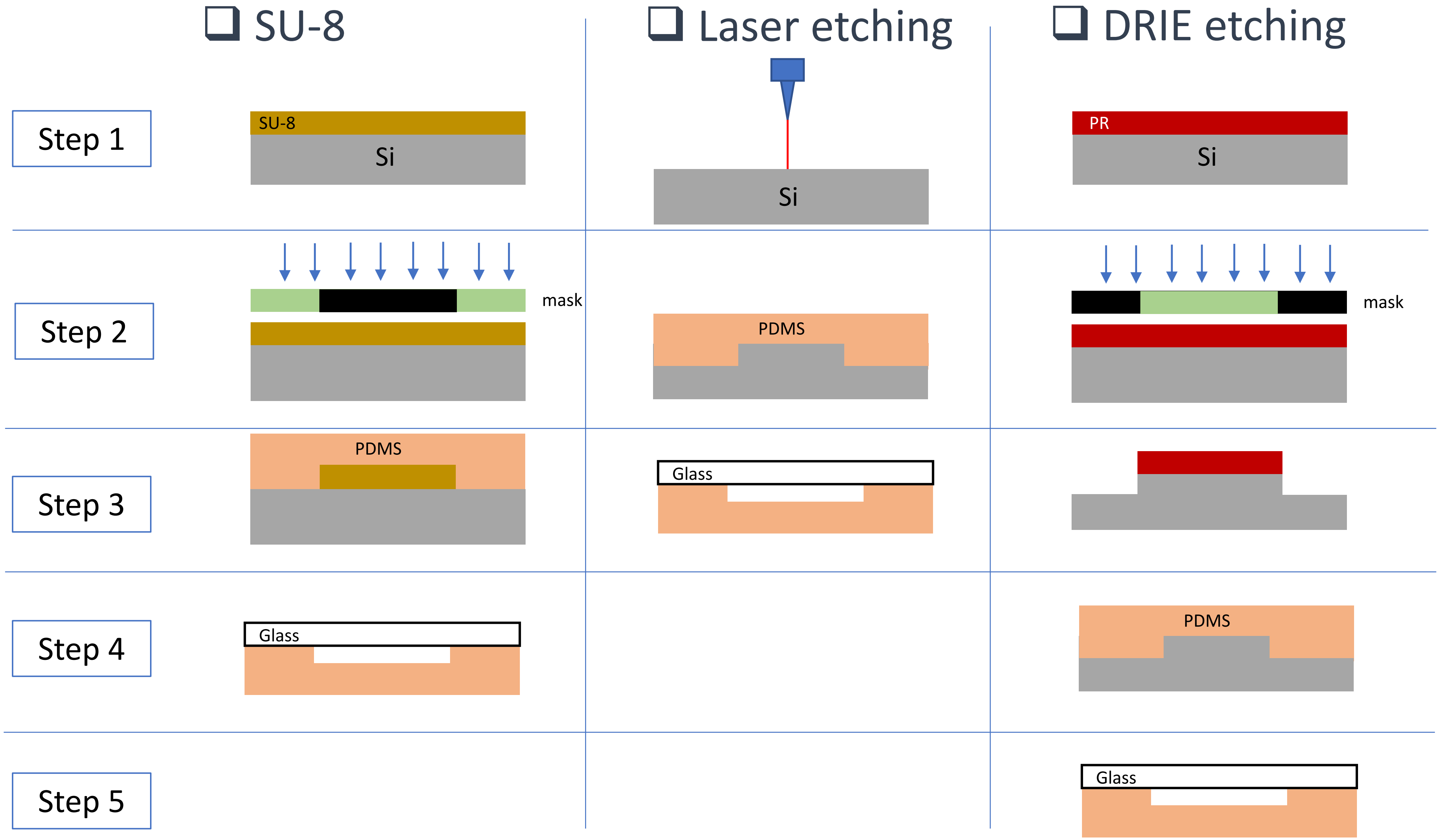
Maskless Aligner

- ➢ 375, 395 and 405 nm lasers
- ➢ Up to 150 x 150 mm writing area
- ➢ Backside alignment

Heidelberg uPG 501

Heidelberg MLA150

Microfabrication - Mold



SU8 Properties

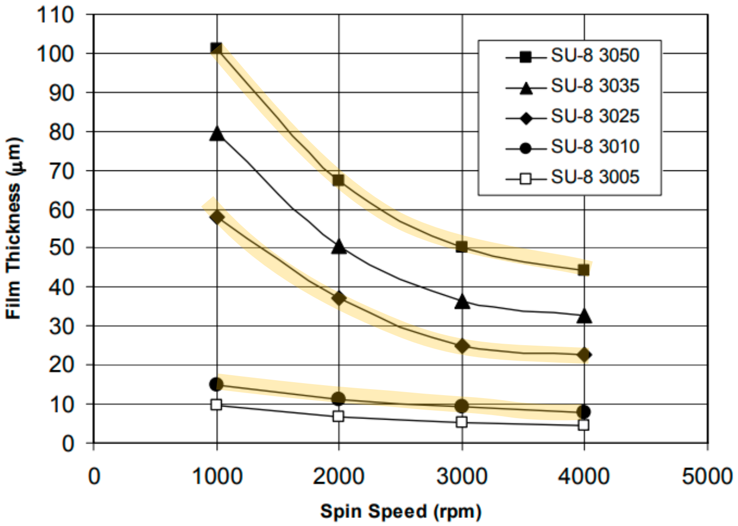
Pros

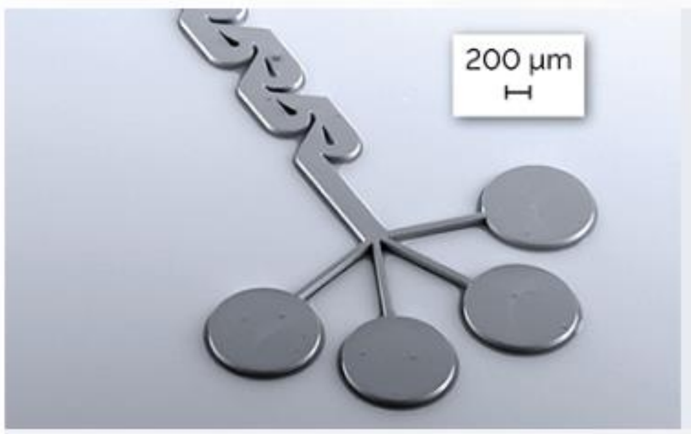
- Permanent Epoxy Resist
- Very Stable – Chemically/Physically
- Wide range of thickness
- High Aspect Ratio

Cons

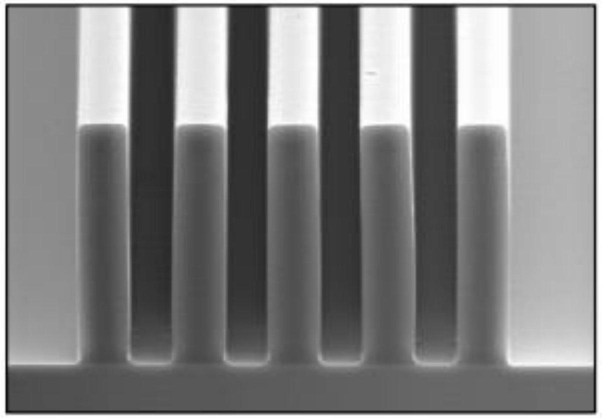
- Impossible to remove
- Exhausting to work with
- Difficult film stress control
- Adhesion is poor

*Also have: SU8 2002



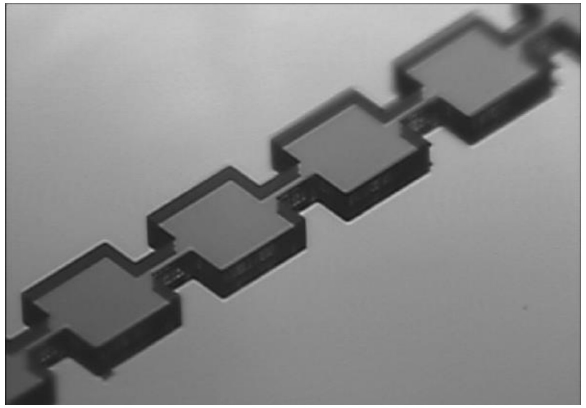


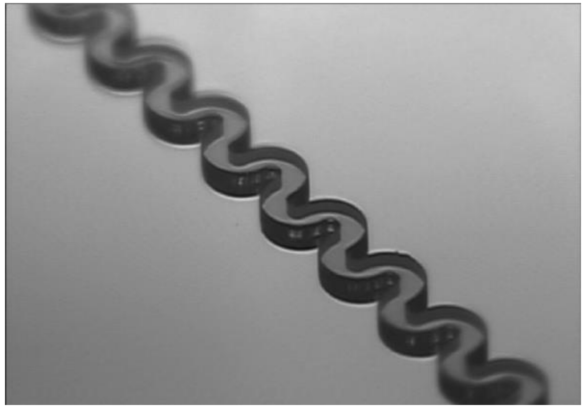
MLA150 375 nm laser exposure

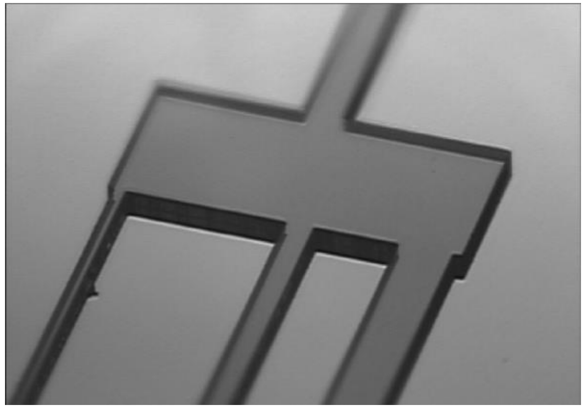


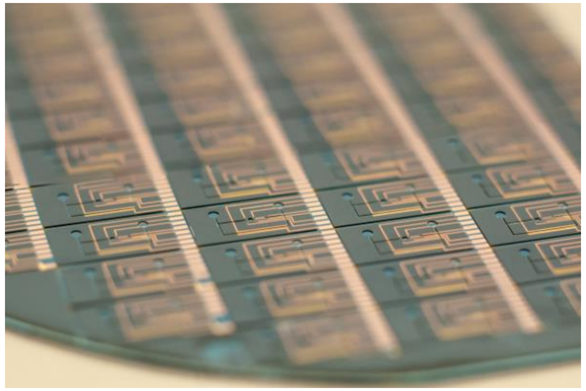
Contact aligner exposure
10 um features, 50 um SU-8 3000 coating

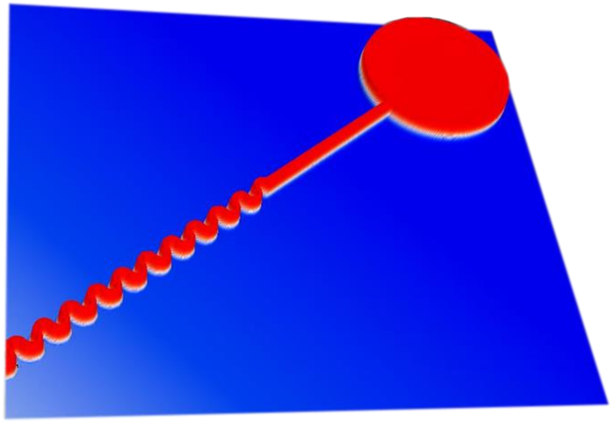
Some SU8 molds fabricated in NUFAB

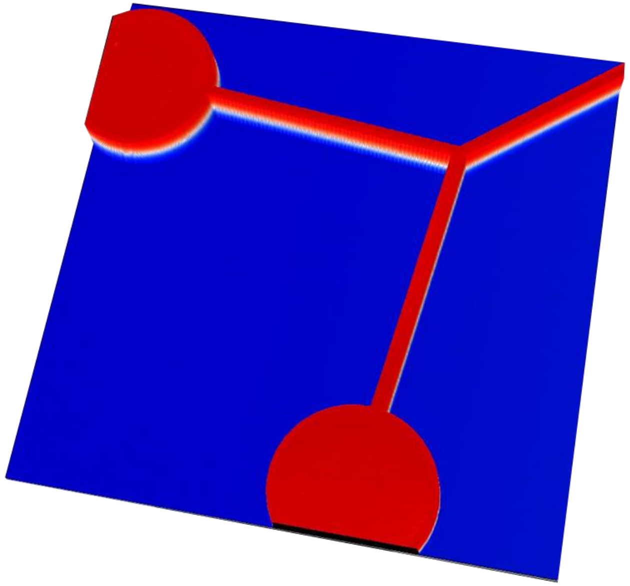






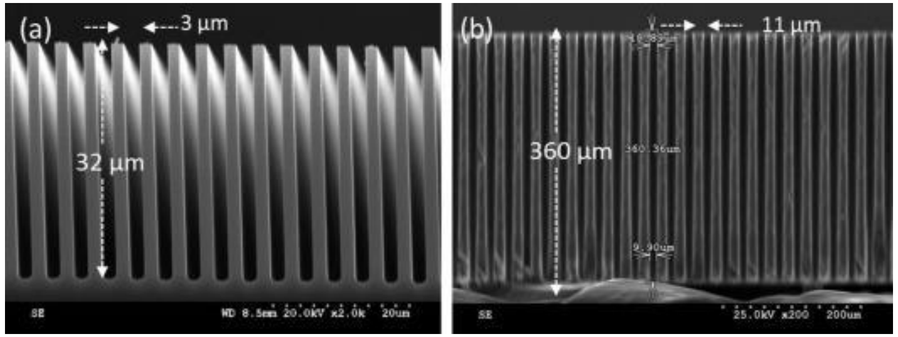






DRIE Etching @ NUFAB

- Bosch process alternating etch and passivation cycles.
- Straight side wall, highly anisotropic.
- Feature depth hundreds nanometers to 1mm.
- Highly automated machine, easy to operate, but need careful pattern layout design for desired etch profile.



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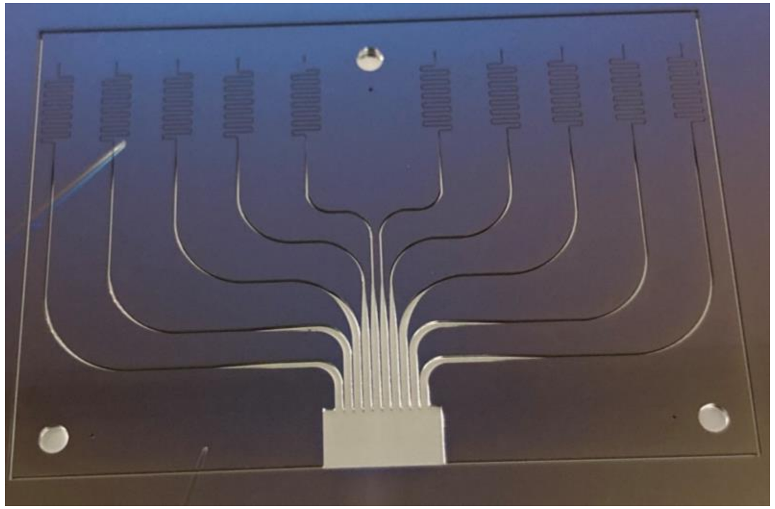
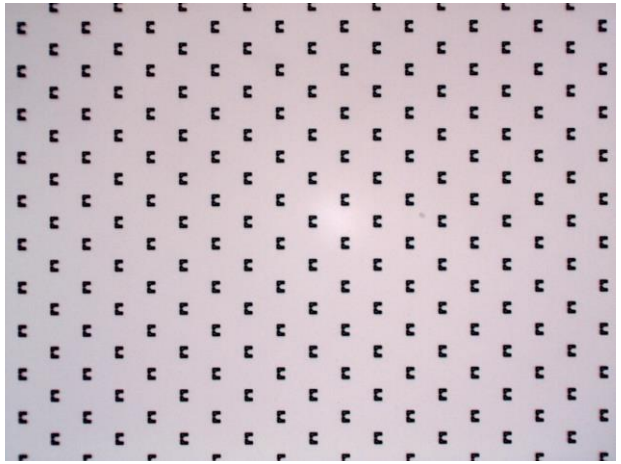
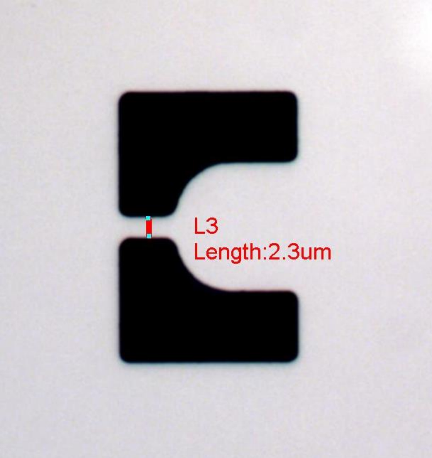
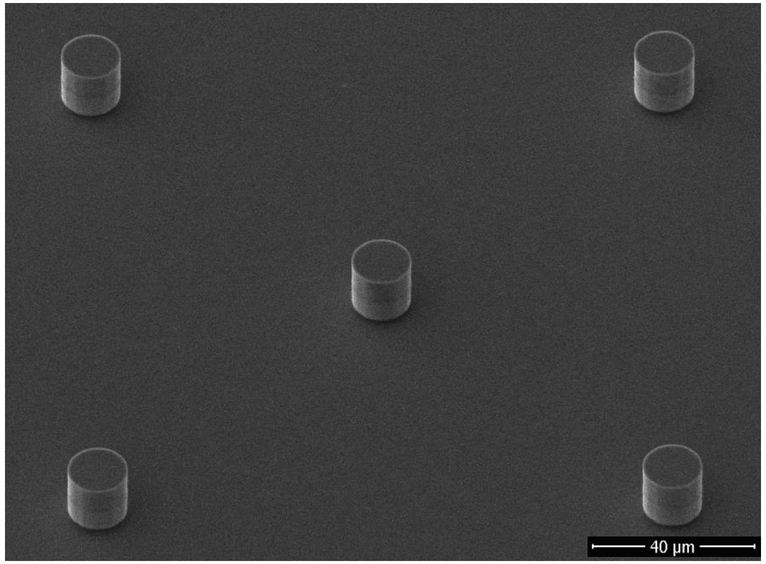
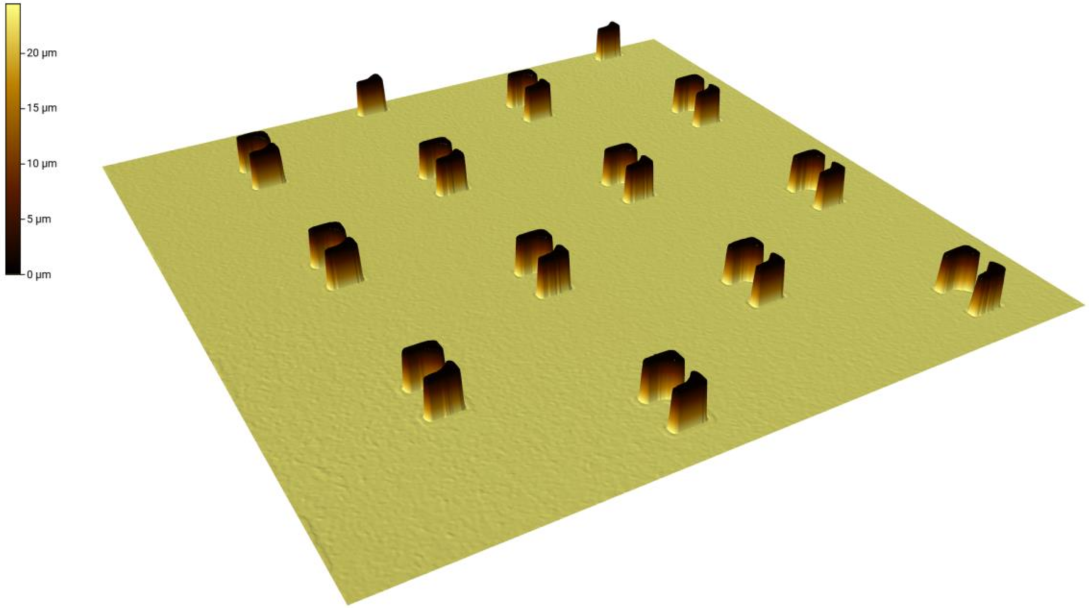
High Aspect ratio devices can be easily made











DRIE bonus – PTFE deposition

- Most high aspect ratio patterns require some form of surface modification for easy detachment of PDMS from the mold.
- Typically, a chemical treatment is used.
- DRIE has a built-in PTFE deposition cycle at the end of etching that makes a highly hydrophobic non-stick surface coating.
- Easy to use, very effective.

Laser cutter @ NUFAB

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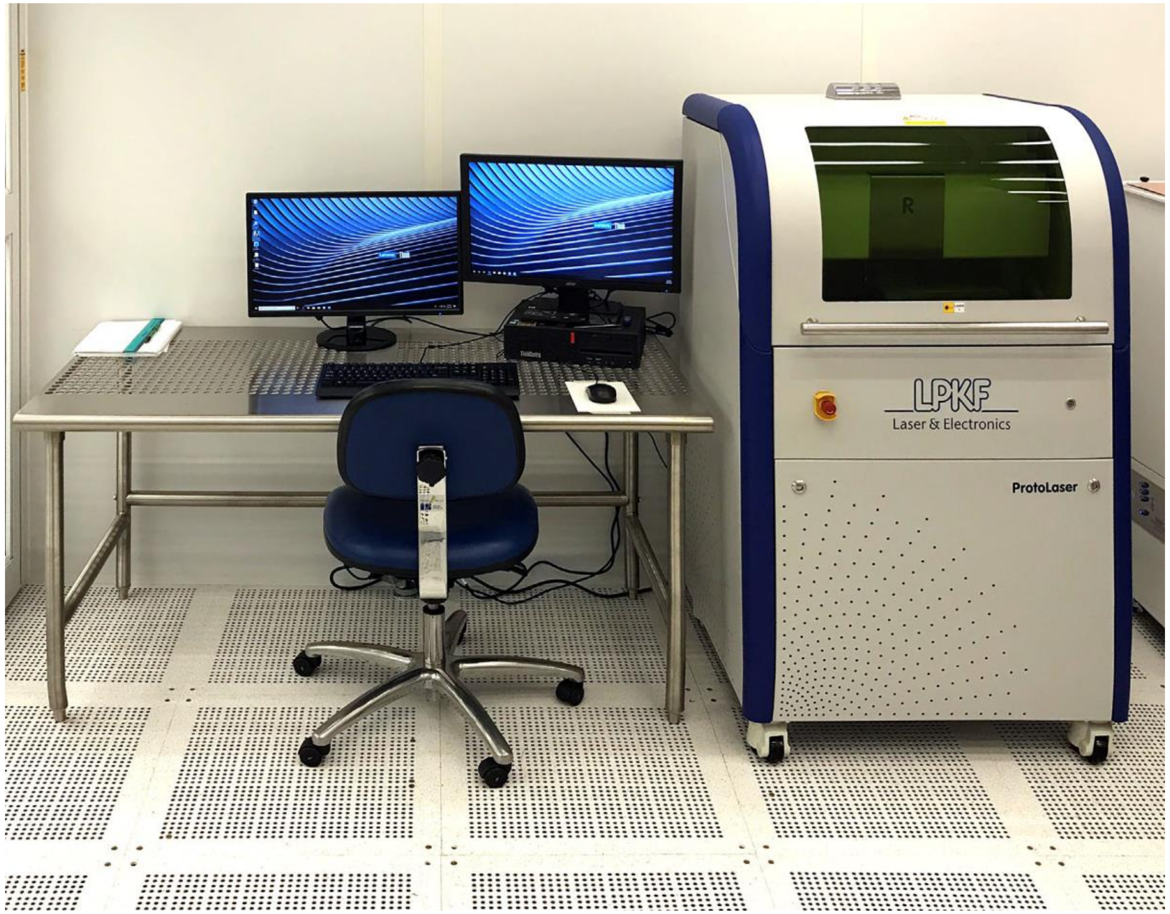
- Virtually anything can be engraved or cut.
- ~20 um spot size.
- 15 um lines can be engraved or cut depending on the material thickness.

LPKF R Protolaser



Laser cut microfluidic mold fabrication approaches

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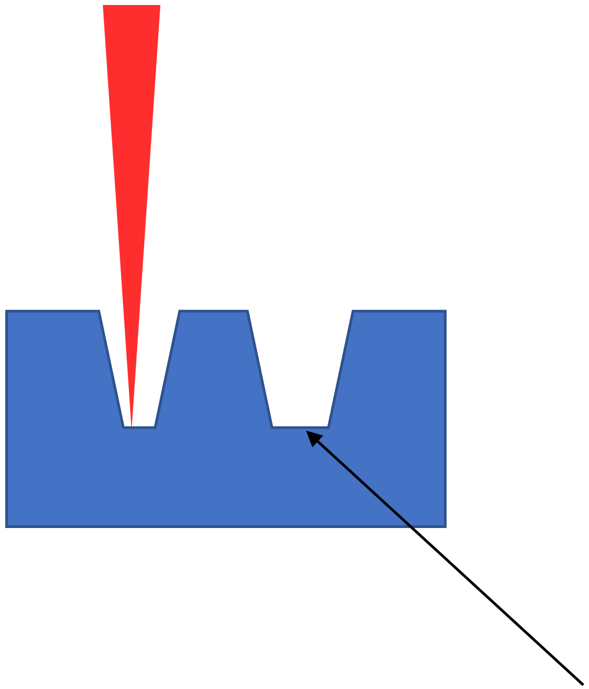
1. Making Grooves on the substrate



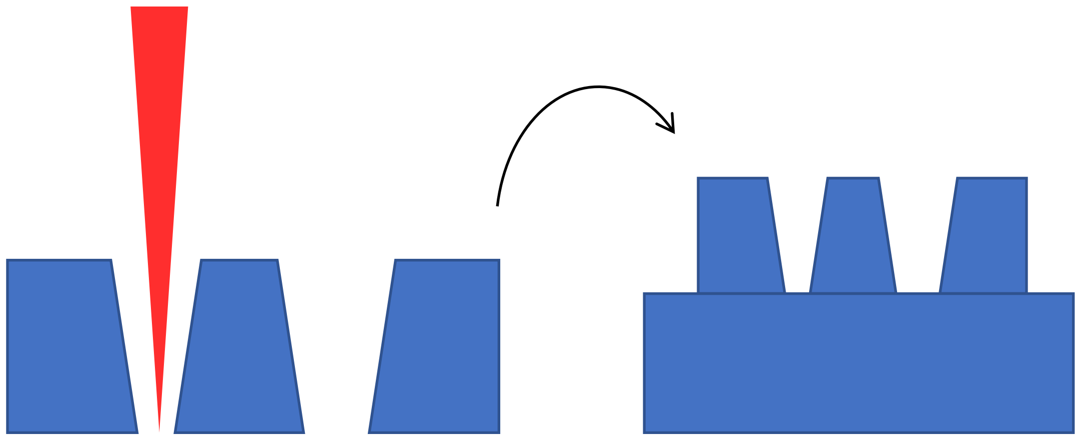
2. Full depth cut

Laser cut microfluidic approaches

1. Making Grooves on the substrate

Rough surface

2. Full depth cut

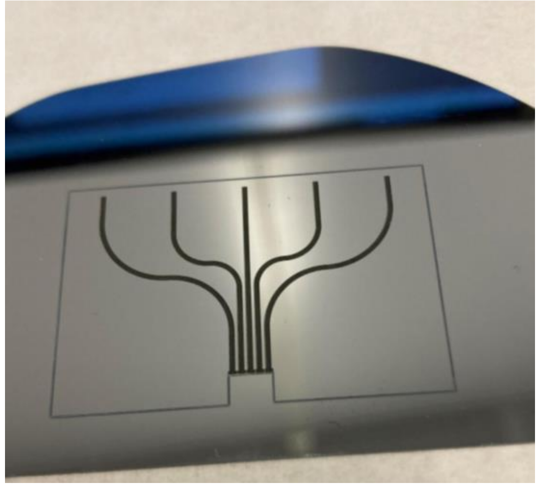


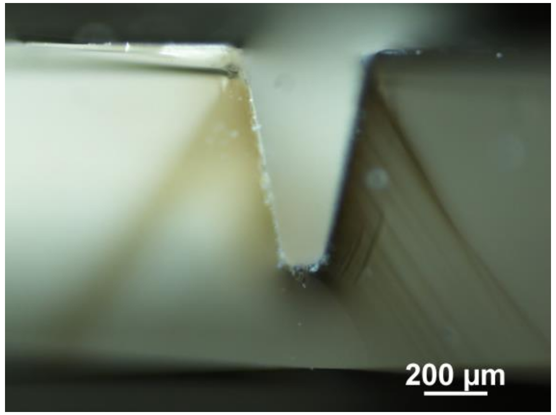
Cut the substrate all the way

Bond the piece to another substrate

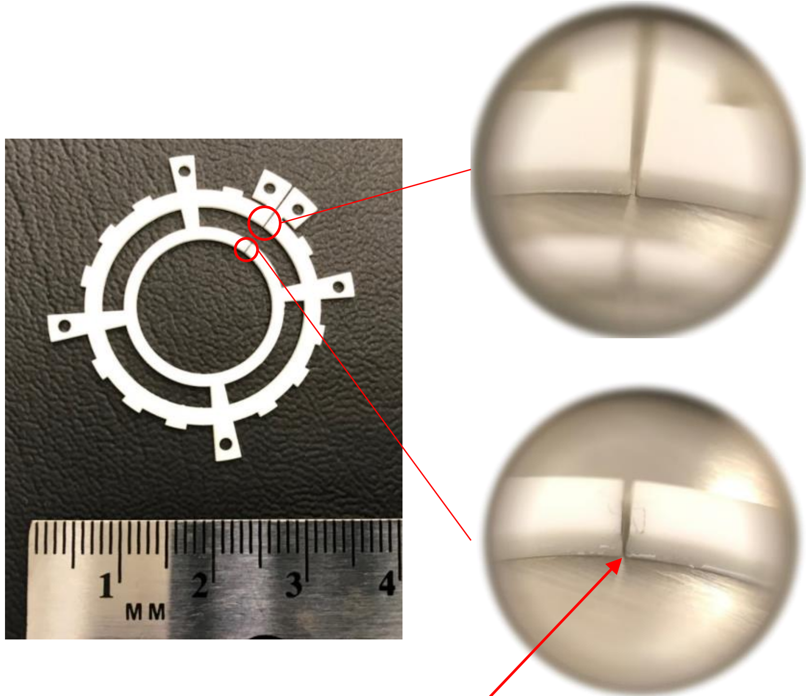
Laser cut microfluidic approaches

1. Making Grooves on the substrate



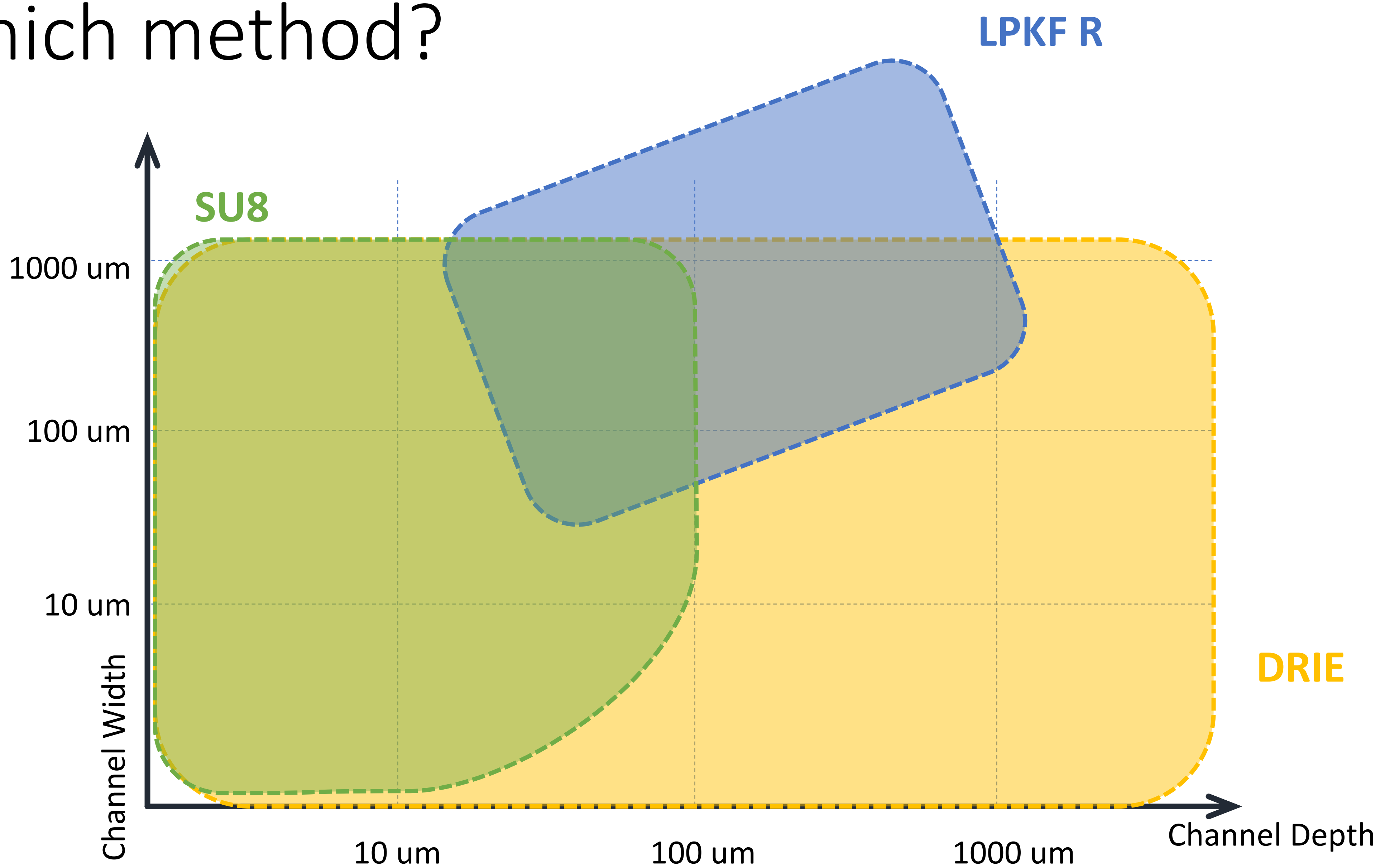


2. Full depth cut



10 um gap at the bottom

Which method?



Comparison

	SU8	LPKF R	DRIE
Min feature size	1 – 10 um	20 – 100 um	<1 um
Aspect Ratio	~ 5	4	>10
Effort	3	1	2
Typical process time	3 hours active – including photomask making	30 min Active – actual cut time varies	1.5 hours Active
# trainings required	2 – 4 MLA150 Acid Bench SU8 Spinner Contact Aligner	1 LPKF R	3 Spinner MLA150 DRIE

Conclusion

- Microfluidics has high-throughput, quantitative, and small-scale benefits for engineering, physics, chemistry, biology, materials science, and biotechnology.
- NUFAB has a wide variety of utilizing tools for microfluidic fabrications.
- We are working hard to serve micro/nano fabrication in research.
- Please feel free to contact staff for your application questions or process development for microfluidics system.

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Thank you!

Questions?

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