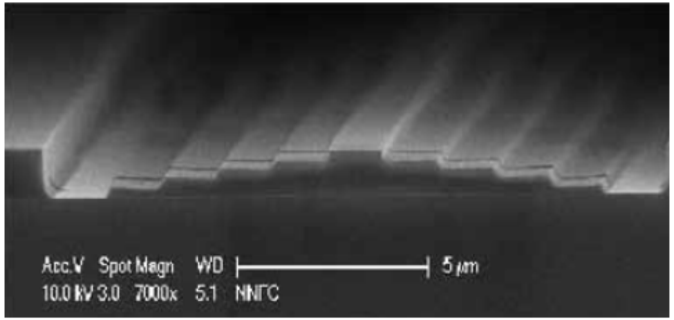
Final Presentation

Grayscale lithography and resist reflow for parylene patterning

Charmaine Chia & Joel Martis

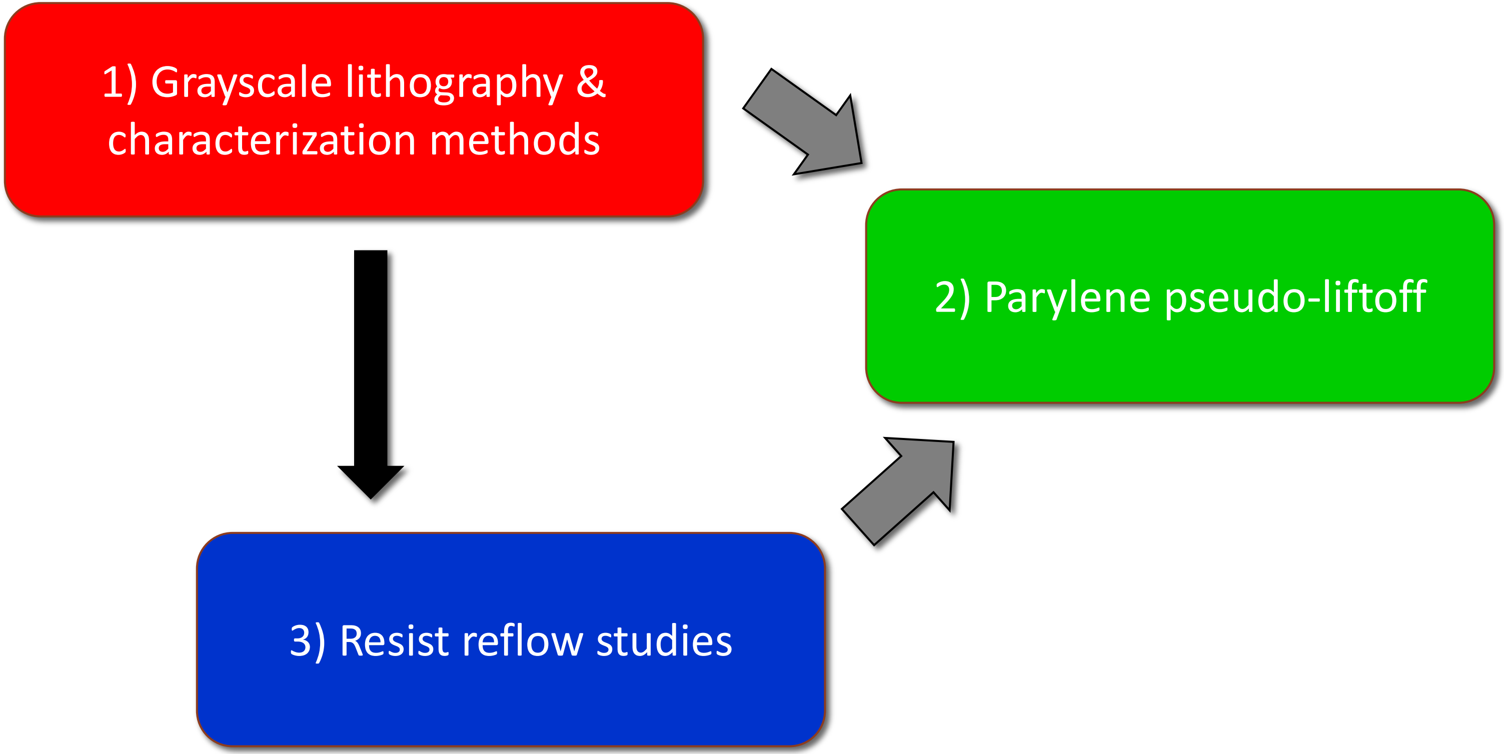


http://www.eng.auburn.edu/~sylee/gray.html

Staff Mentors:
Swaroop Kommera
Michelle Rincon

External Mentor:
Michael Robles

Overview



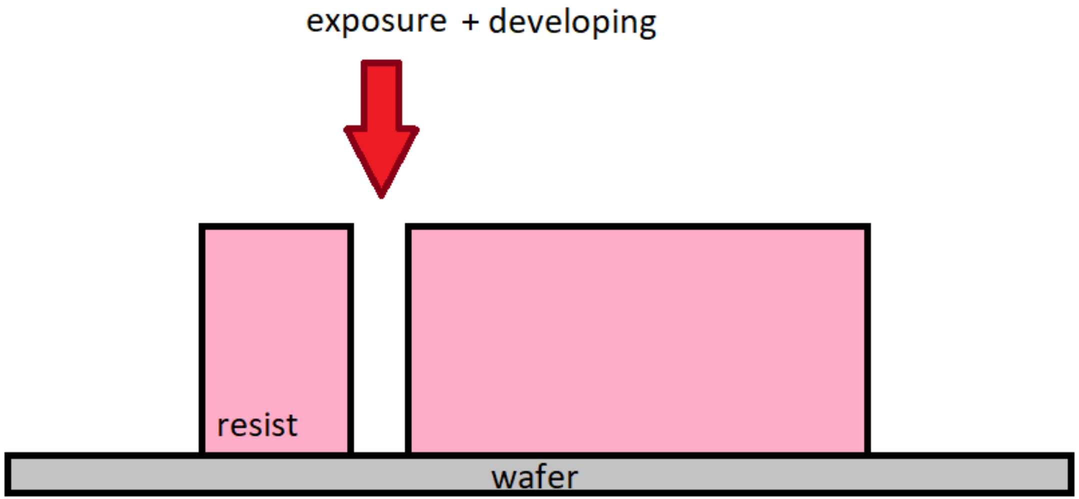
1) Grayscale lithography & characterization methods

2) Parylene pseudo-liftoff

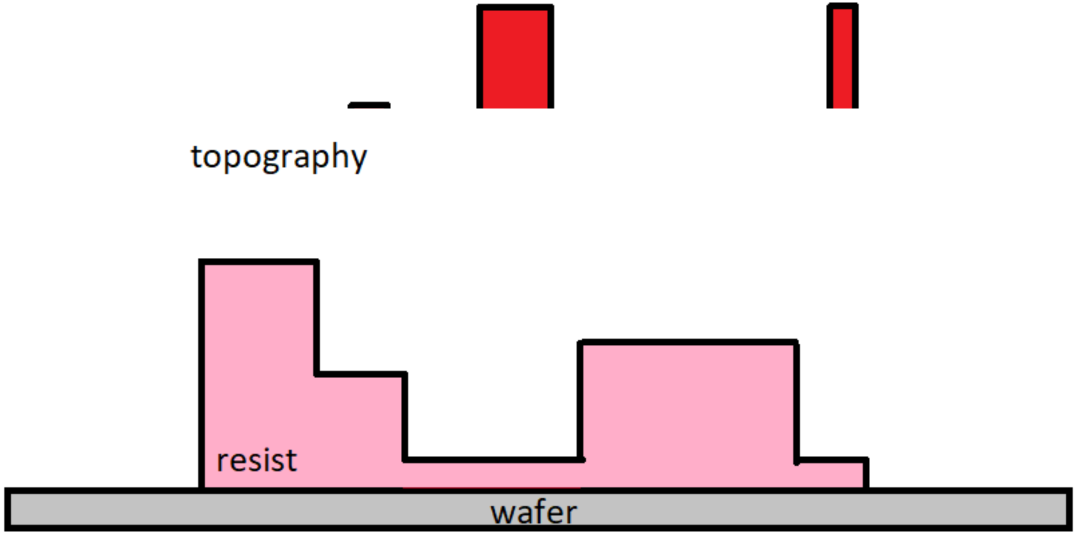
3) Resist reflow studies

Grayscale lithography

Grayscale lithography overview

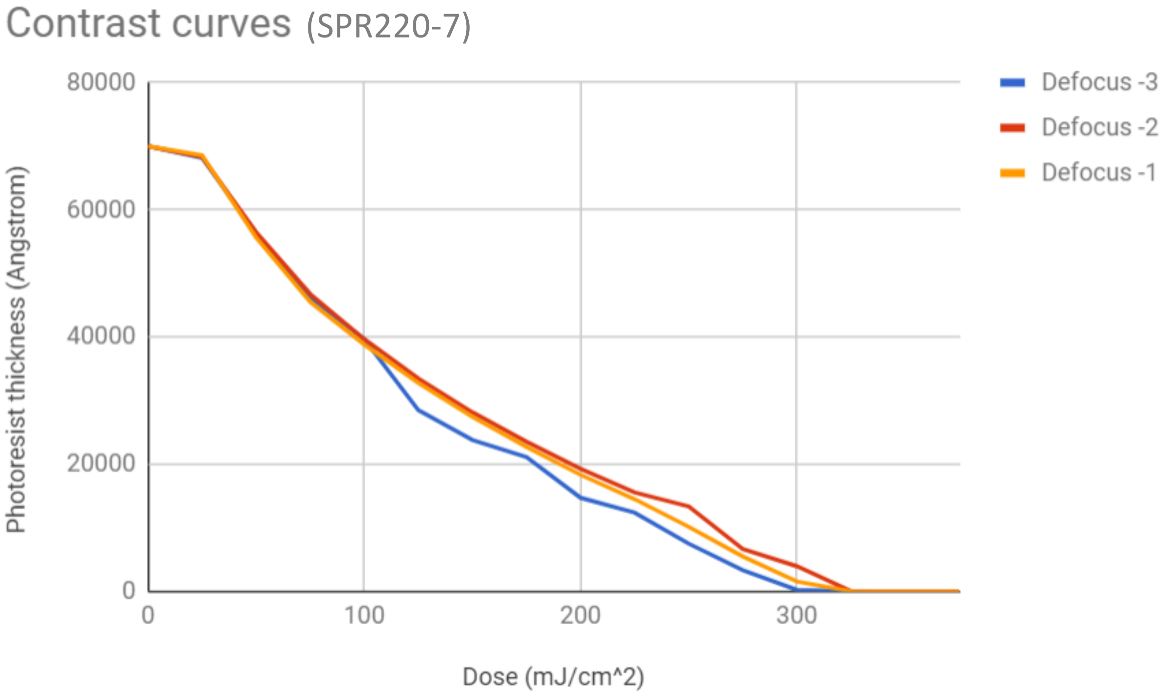


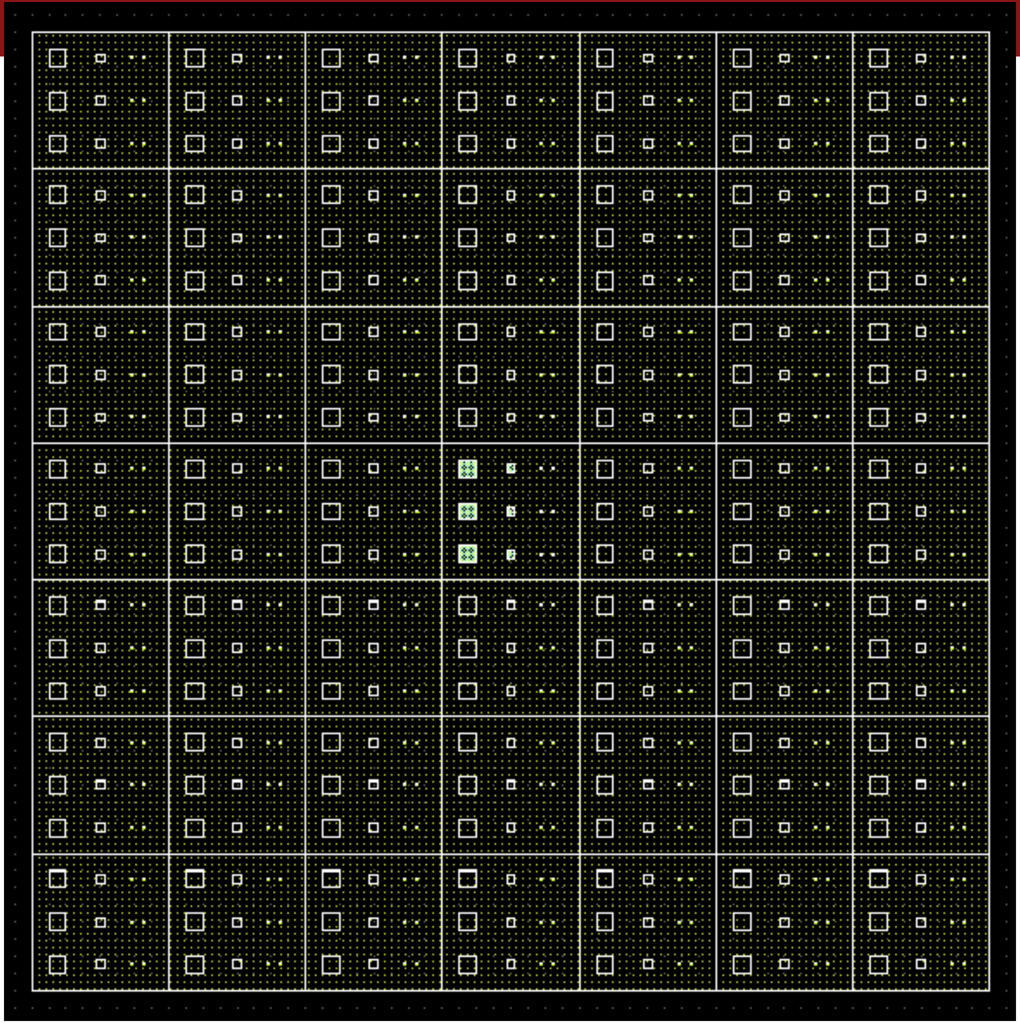
Grayscale lithography overview



How

- O CUS EXPOSURE
- U





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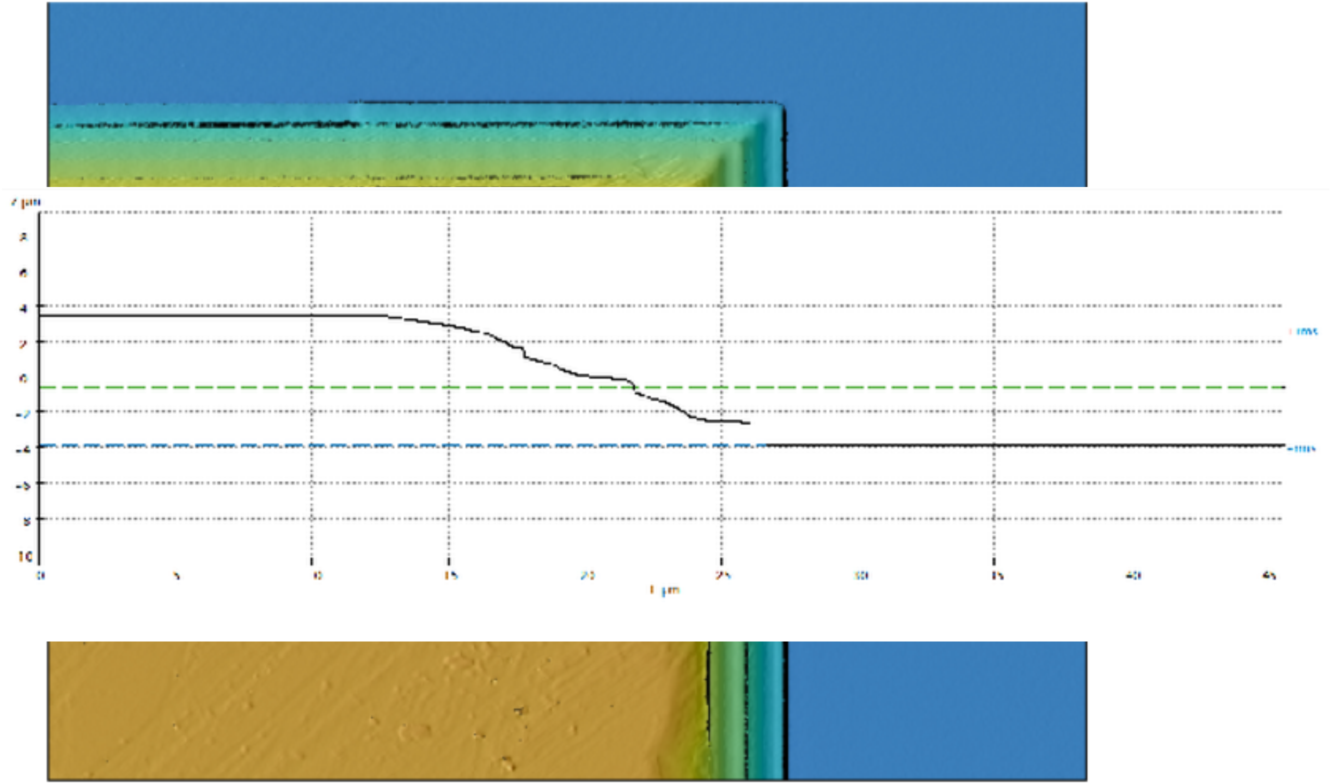
Overview of imaging/characterization methods

- OPTICAL IMAGING – ORDINARY MICROSCOPE, S-NEOX, KEYENCE
- PROFILOMETRY - DEKTAK
- SEM

Optical images

S-neox



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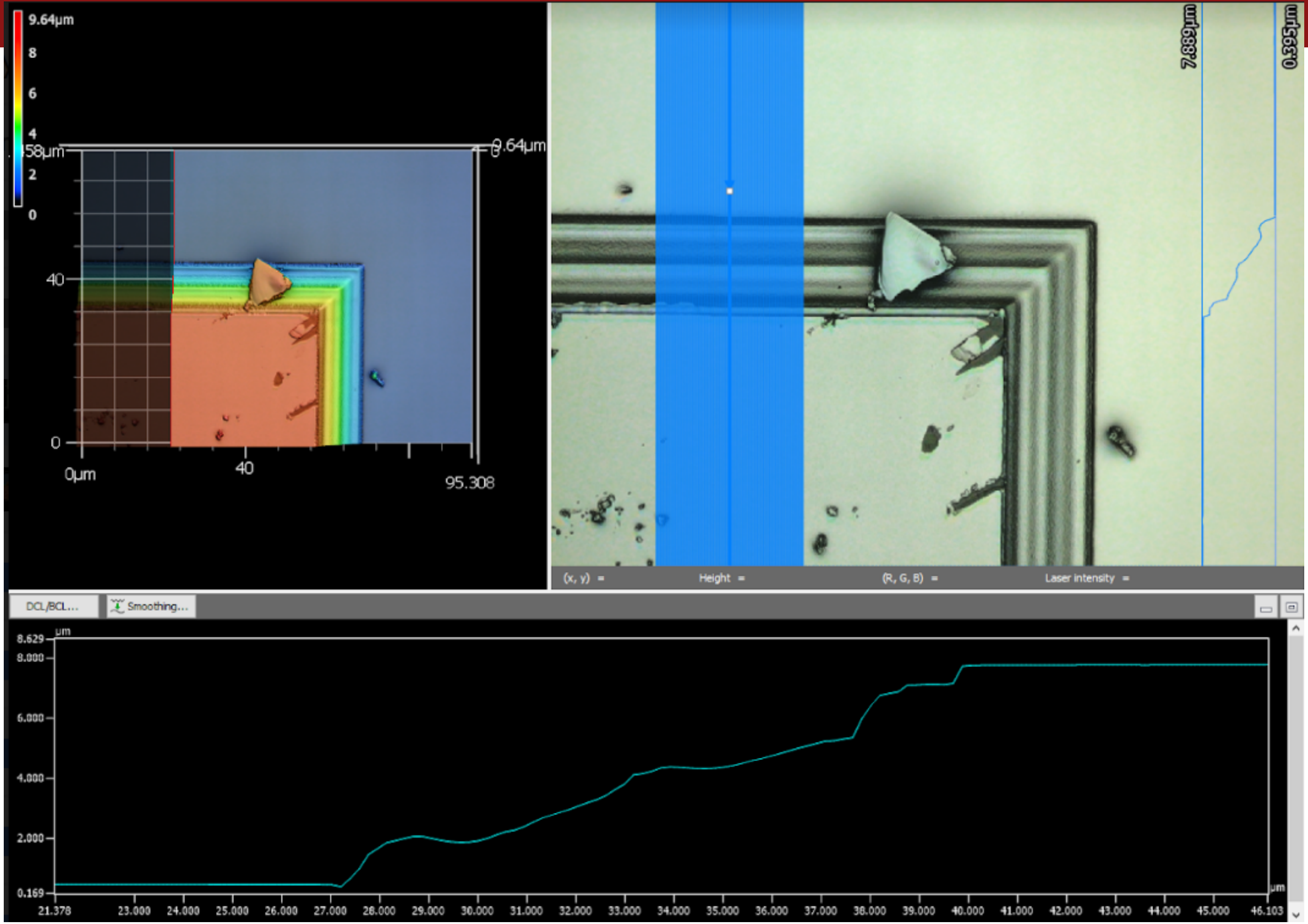
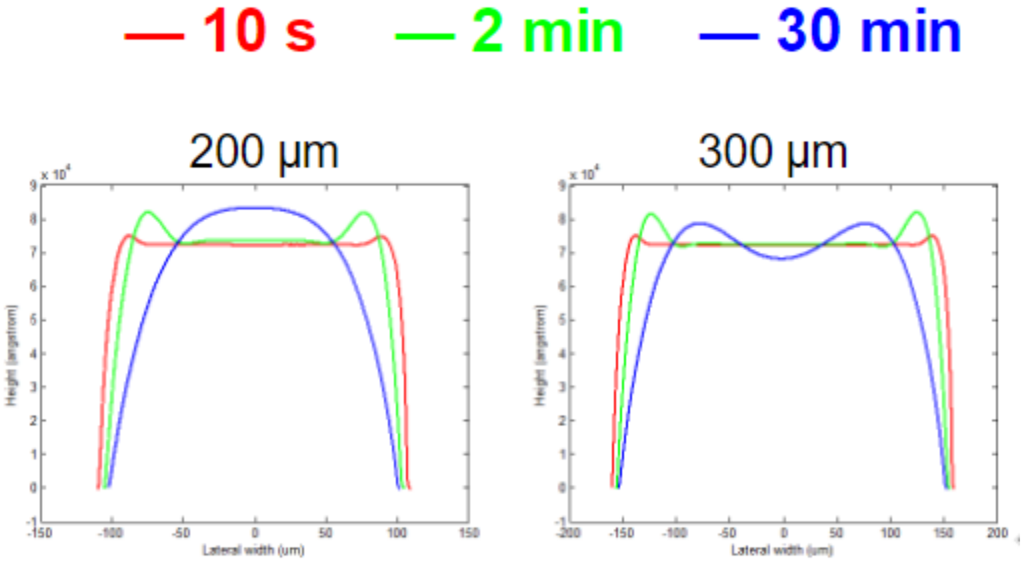
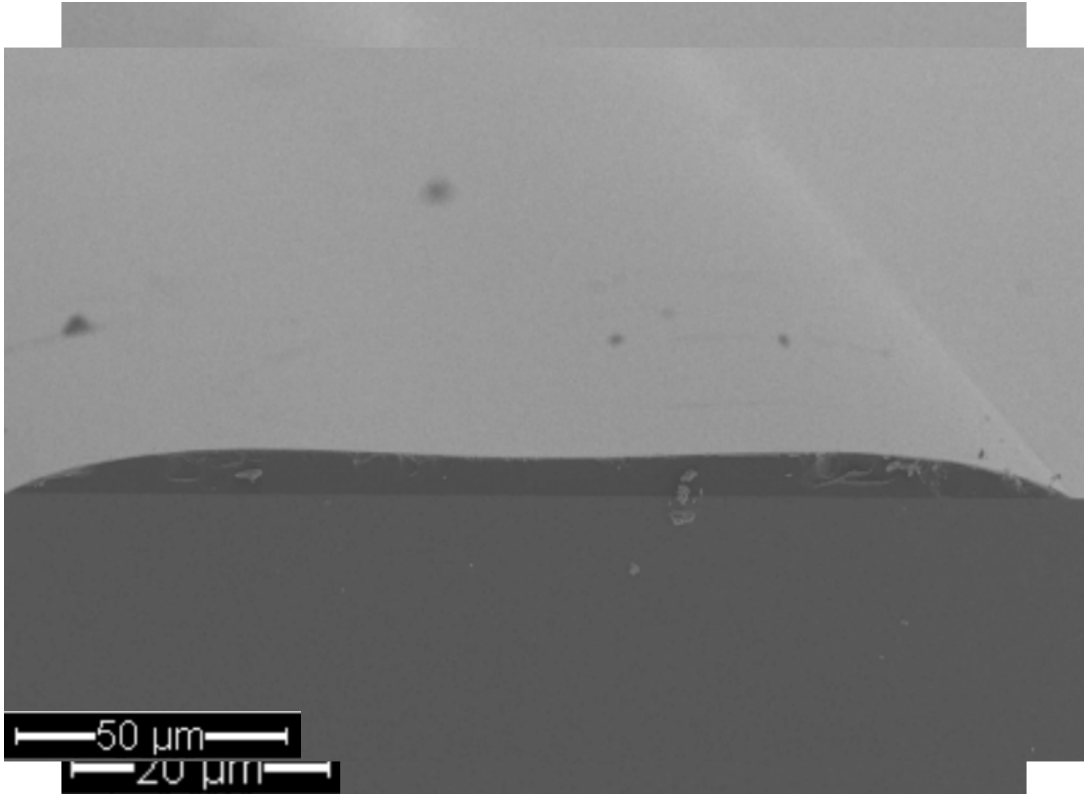

9.64µm
8
6
4
2
0
58µm
9.64µm
40
0
0µm
40
95.308
7.889µm
0.395µm
(x, y) =
Height =
(R, G, B) =
Laser intensity =
DCL/BCL...
Smoothing...
µm
8.629
8.000
6.000
4.000
2.000
0.169
21.378
23.000
24.000
25.000
26.000
27.000
28.000
29.000
30.000
31.000
32.000
33.000
34.000
35.000
36.000
37.000
38.000
39.000
40.000
41.000
42.000
43.000
44.000
45.000
46.103
µm

Dektak profilometer

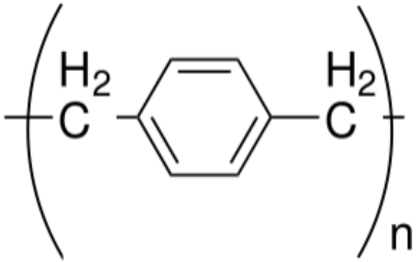


SEM



Parylene pseudo-liftoff

Motivation



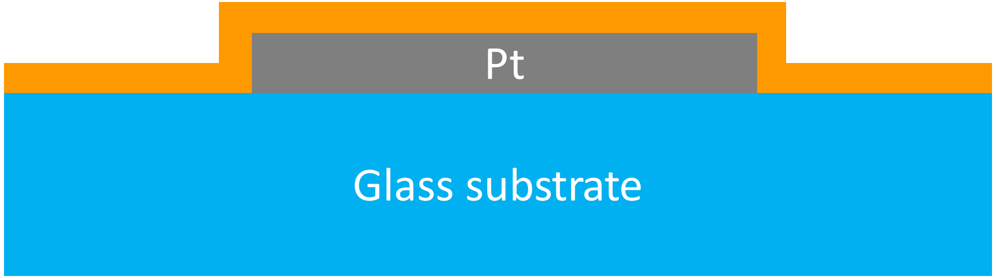
The main method of patterning parylene is uses oxygen plasma

Sensitive regions of the substrate may get damaged due to the plasma etching / oxidation

Goal:

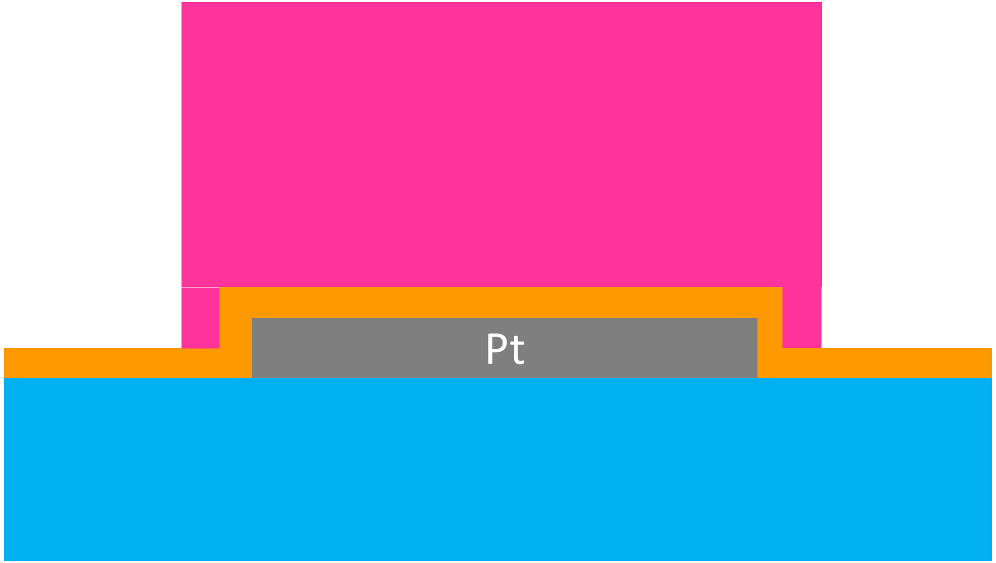
Develop a method of patterning parylene that does not expose the underlying area to oxygen plasma

Process flow



1. Spin 7 um of photoresist (SPR 220-7)

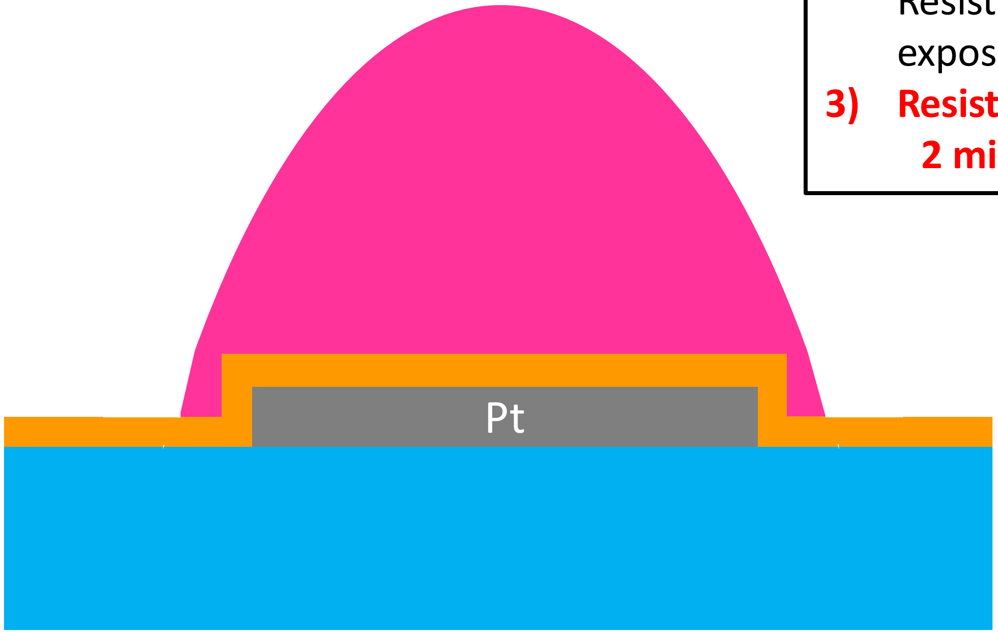
2. Pattern PR to expose parts where parylene is to be deposited



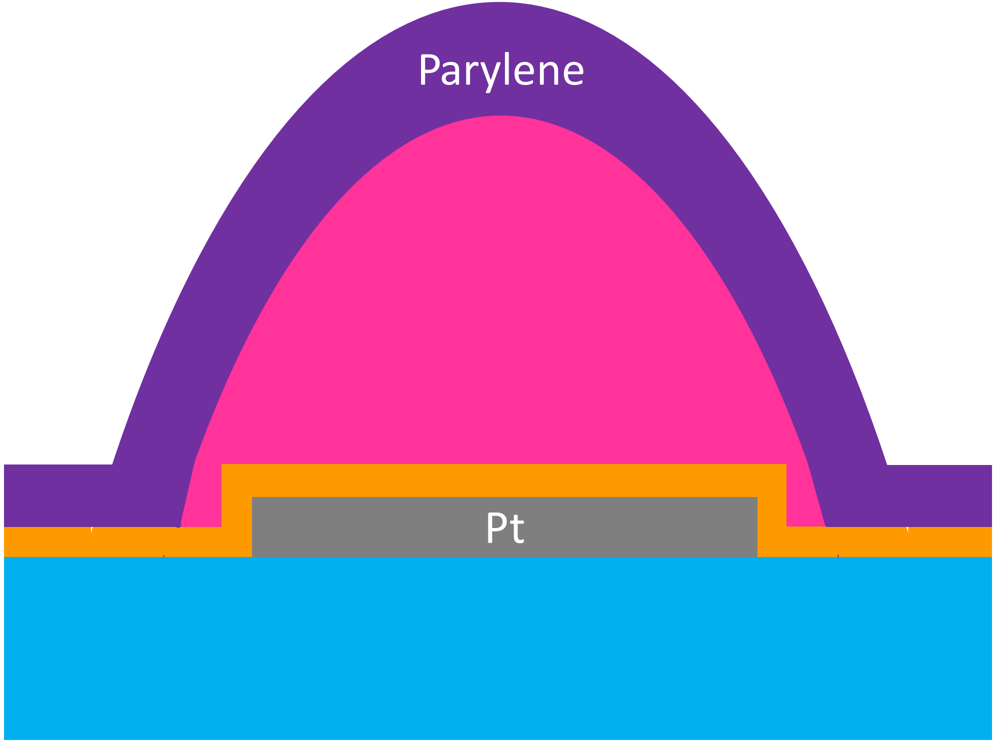
3. Process PR to get sloped sidewalls

Explored:

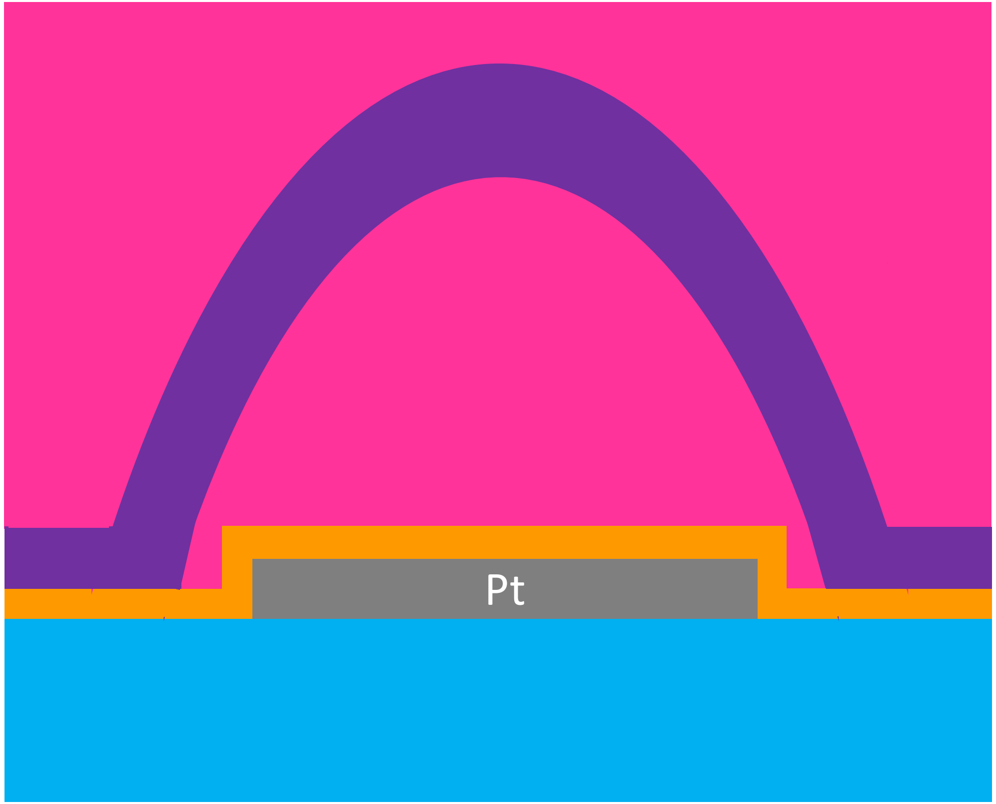
1) Grayscale patterning
2) Immersion in IPA ➔ Resist washed off after exposure to light
3) **Resist reflow: 2 min @ 180 C**



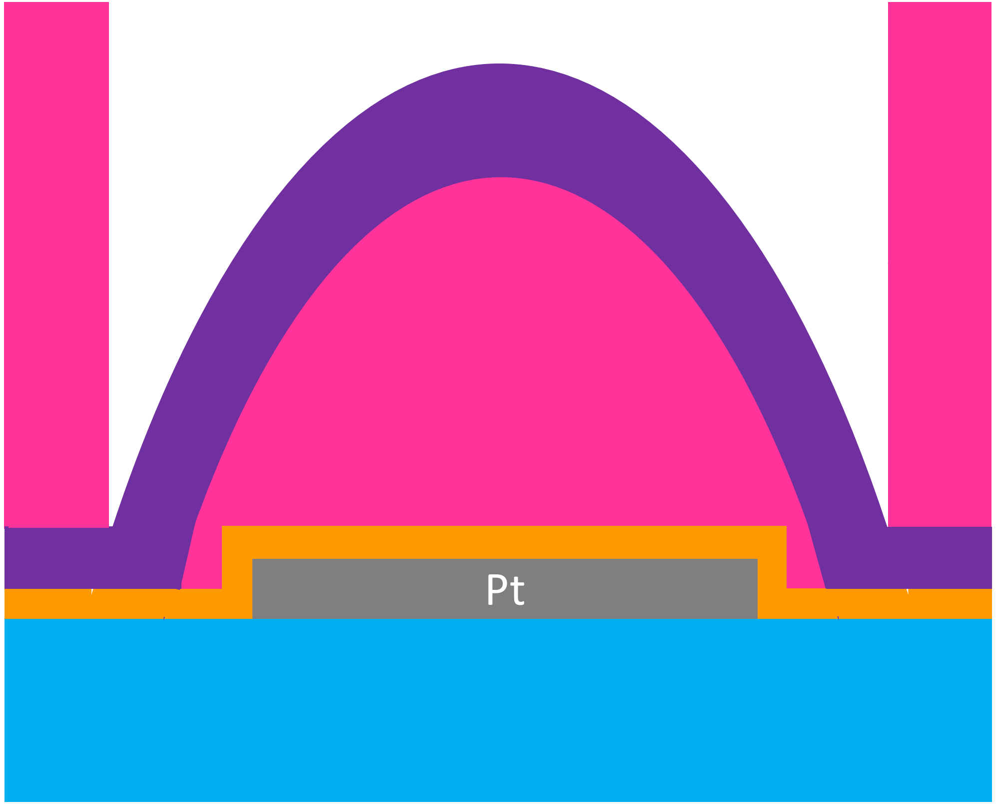
4. Deposit 1 um of parylene conformally using parylene coater



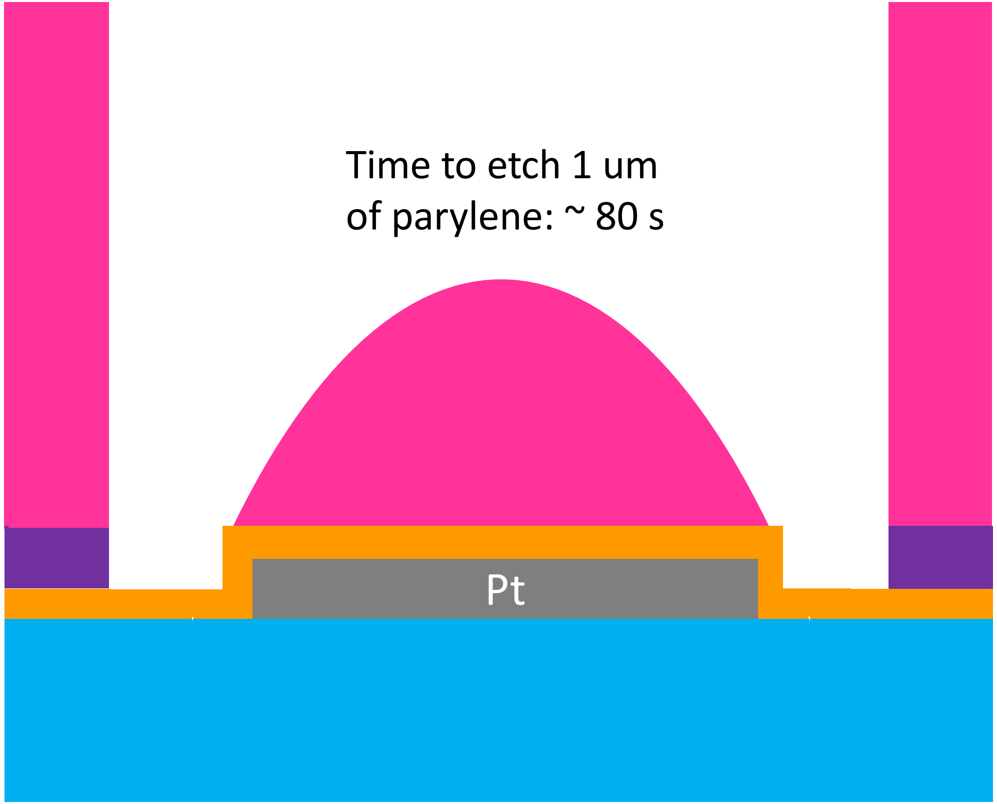
4. Deposit 10 um of photoresist (SPR 220-7)



5. Pattern PR to expose areas where parylene is to be removed

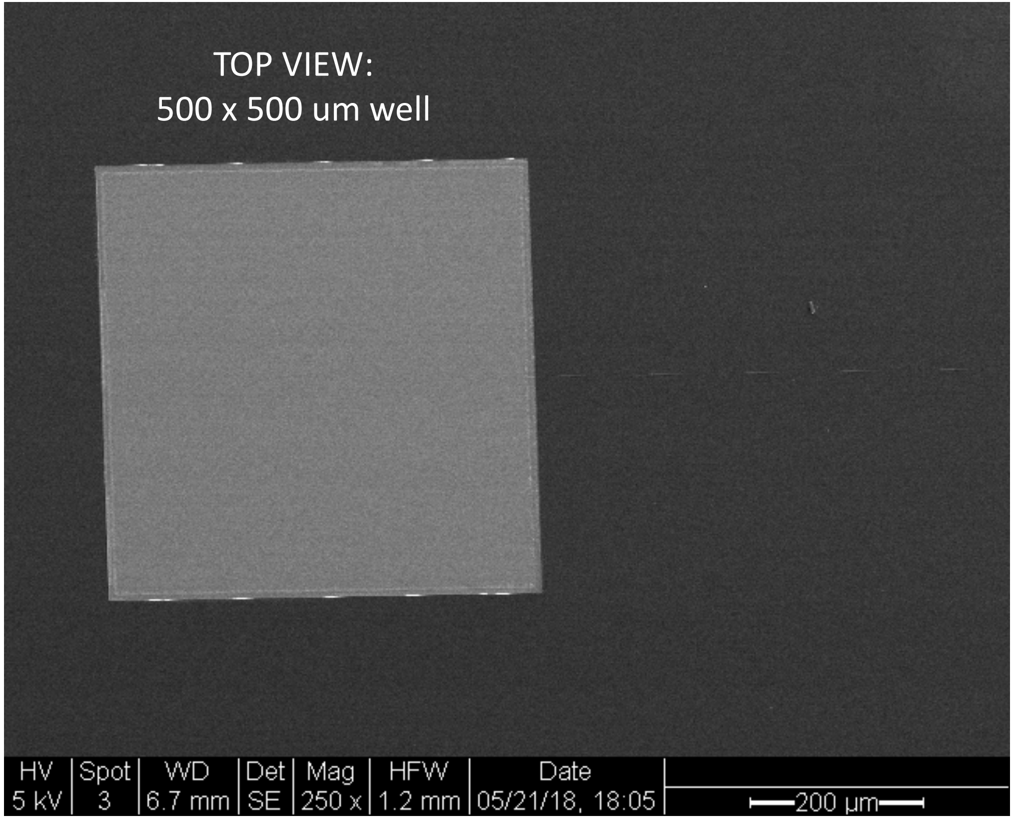


6. Etch exposed parylene with O2 plasma in Pt-Mtl (~12 min)

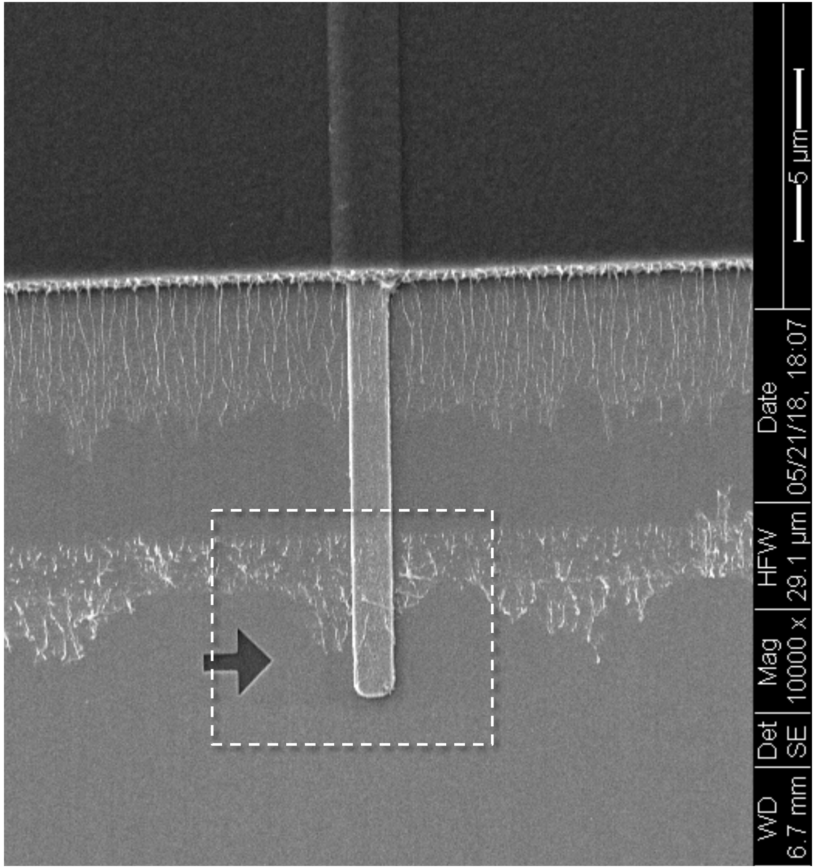


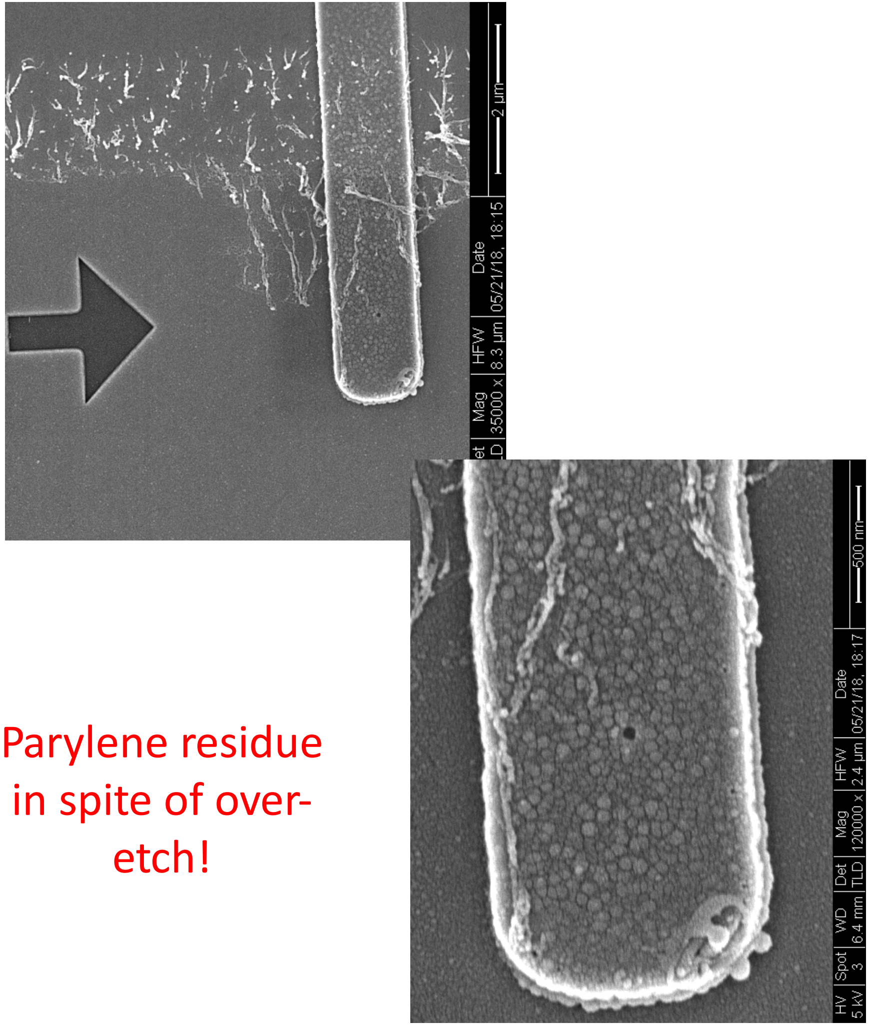
Time to etch 1 um of parylene: ~ 80 s

7. Remove photoresist with acetone / IPA rinse to leave behind patterned paryene



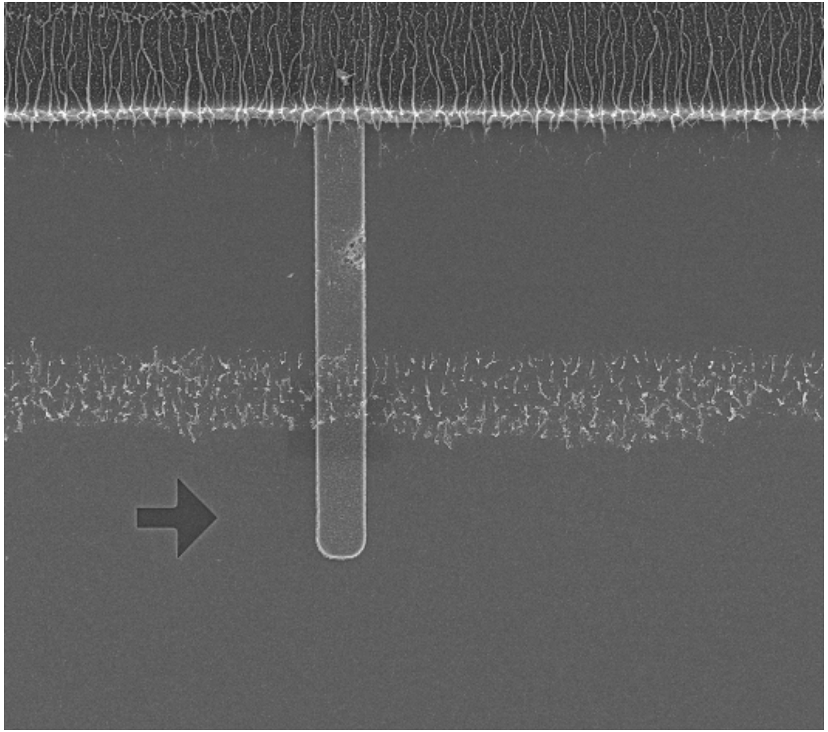
6 minute O_2 plasma etch

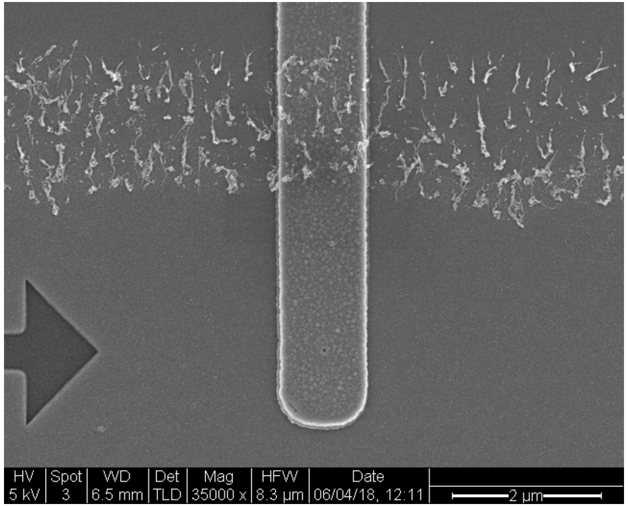


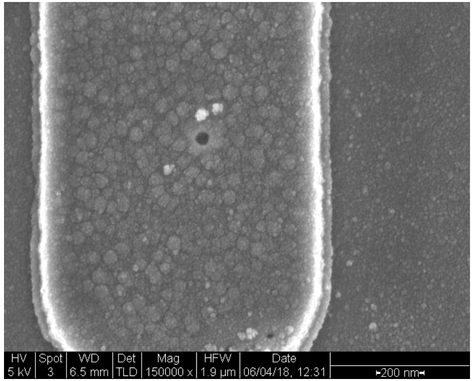


Parylene residue in spite of over-etch!

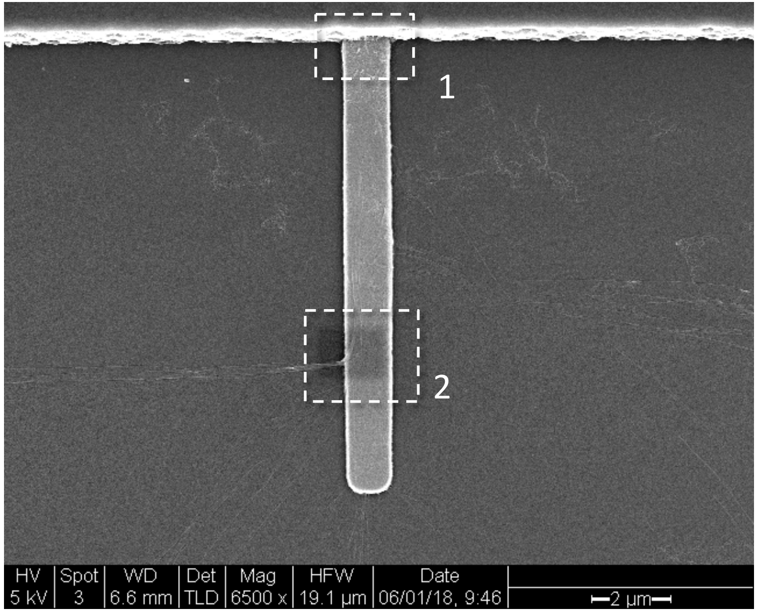
6 minute O_2 plasma etch → 5 min descum

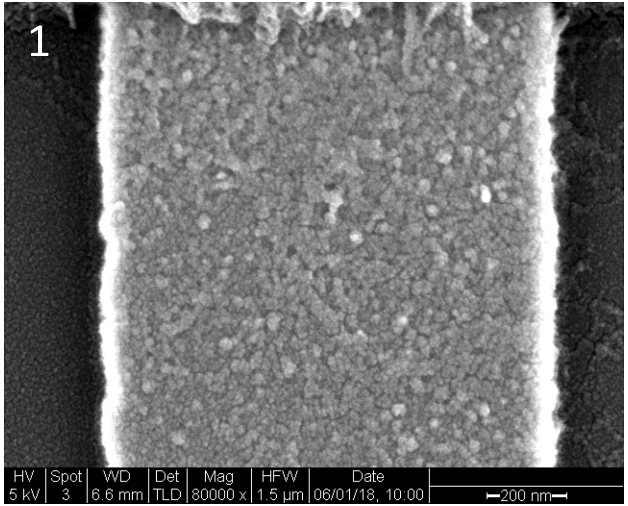


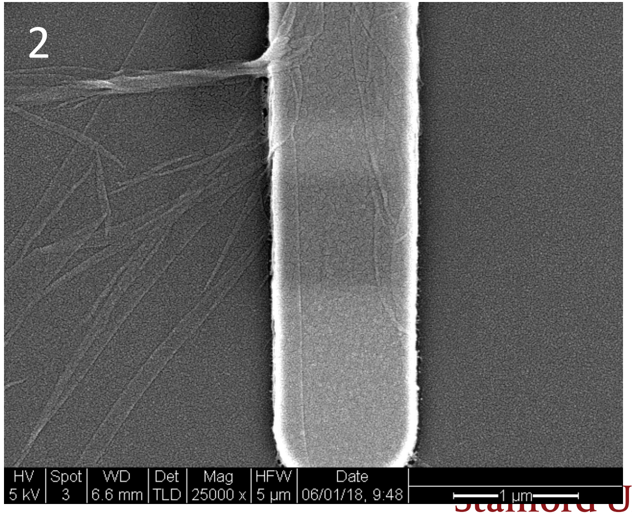




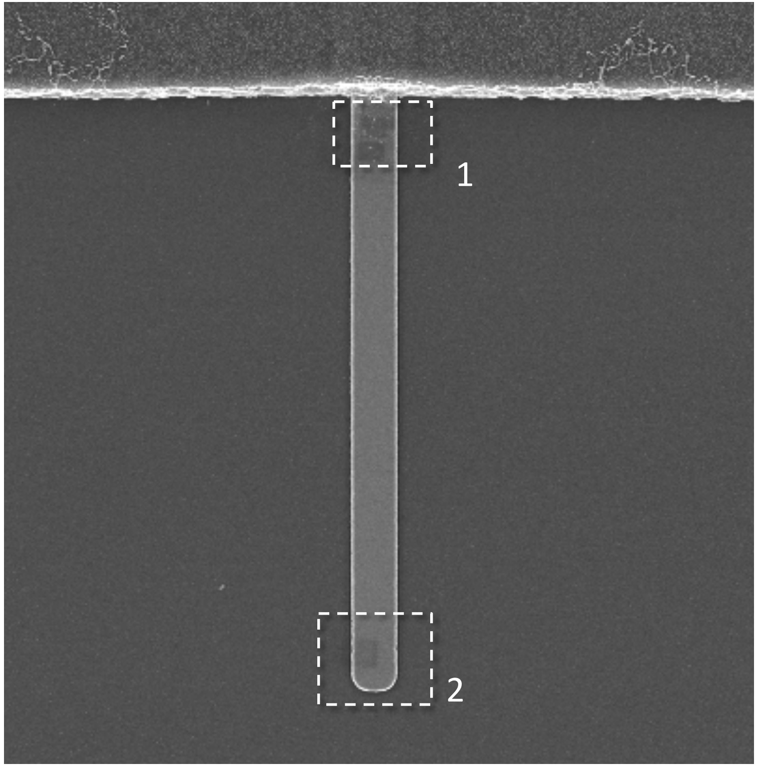
10 minute O_2 plasma etch

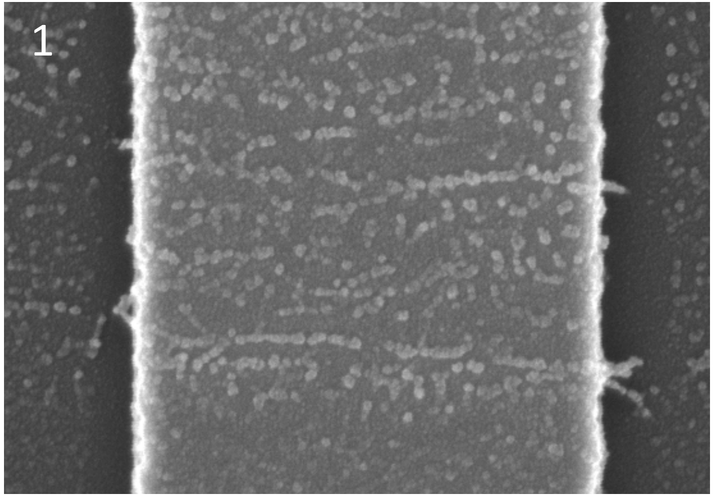


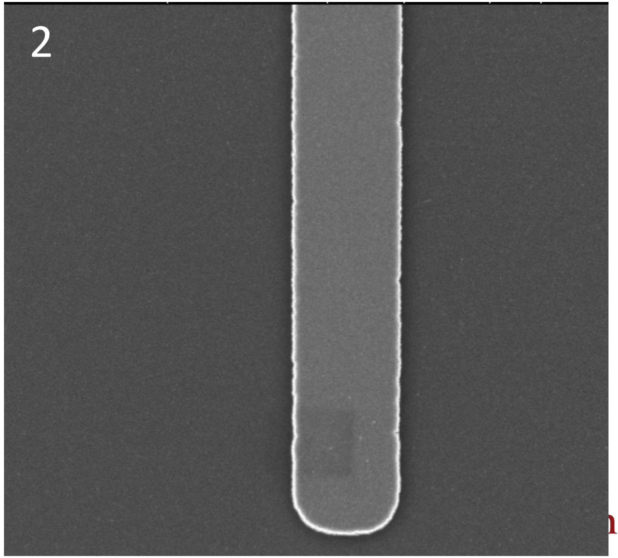




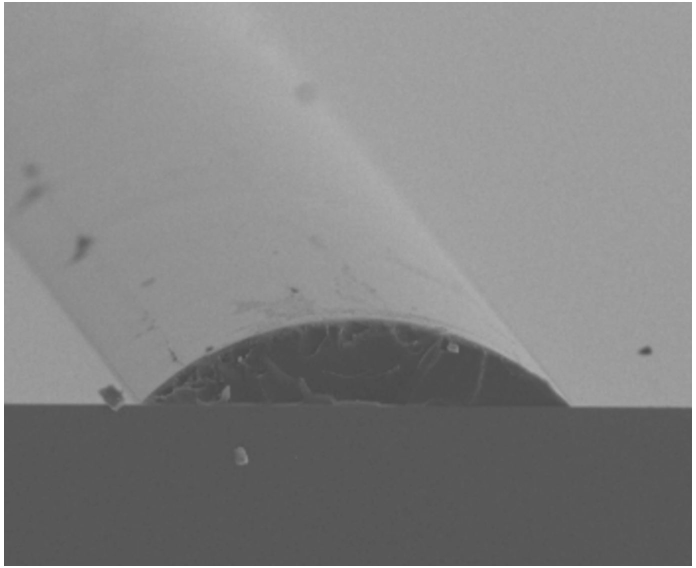
6 minute O_2 plasma etch → 5 min descum





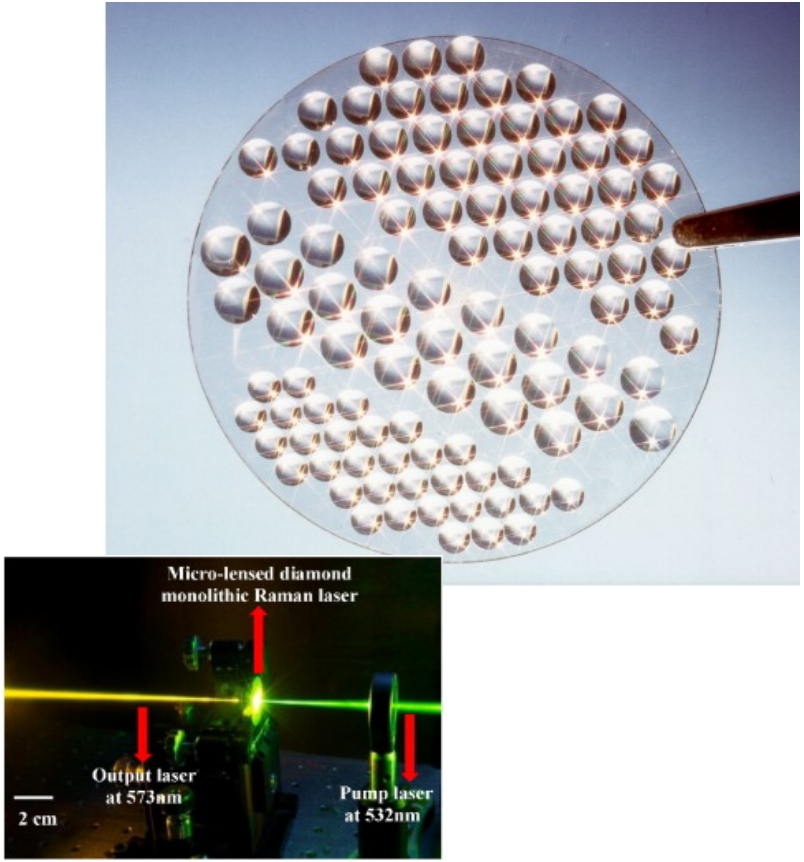


Resist reflow experiments

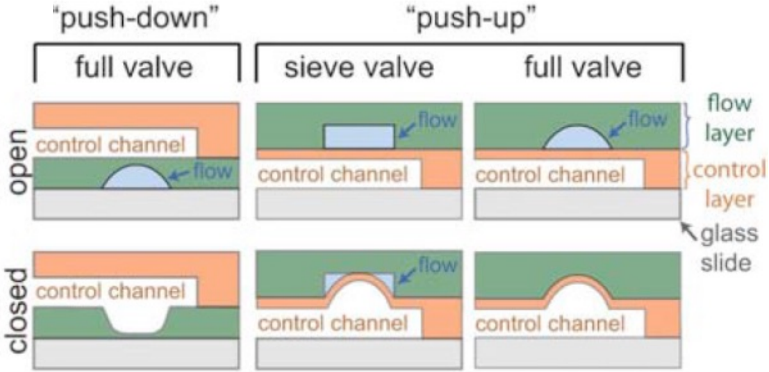


Motivation & applications

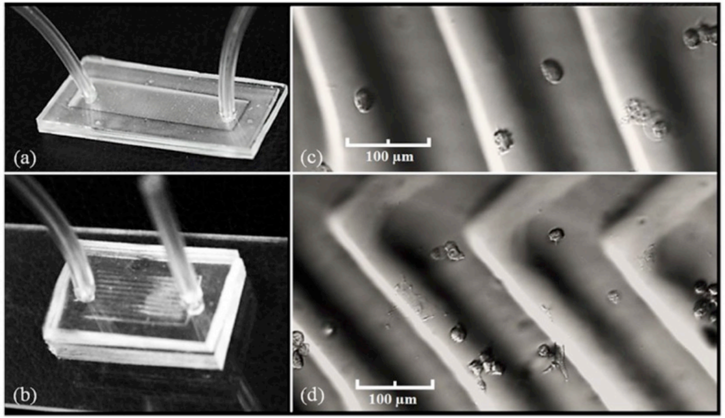
Microlenses



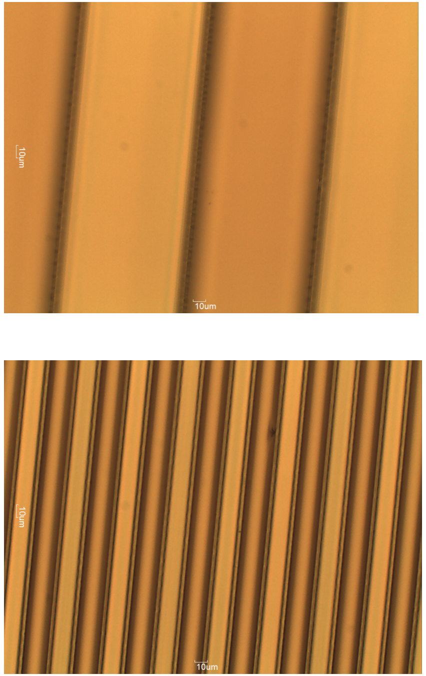
Microfluidic valves



Micro-wavy channels for cell capture



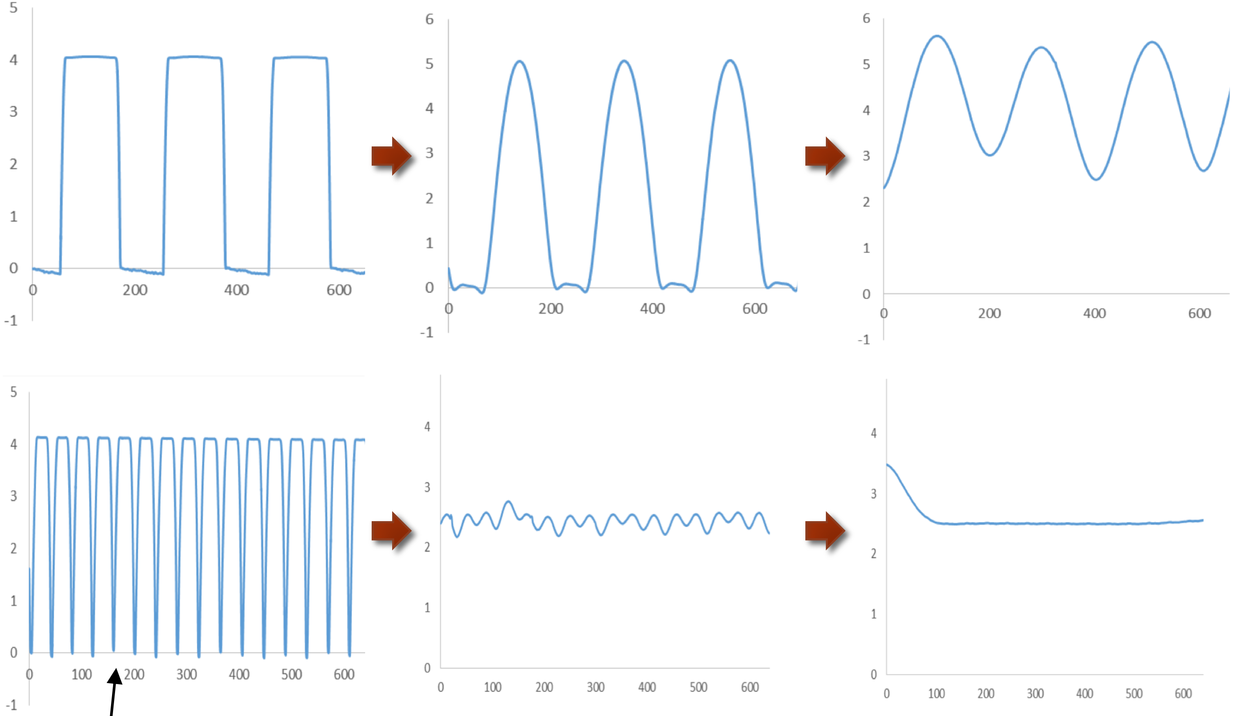
Some ‘gratings’ we’ve made…



No bake

2 min @ 120 C

2 min @ 180 C



Dektak resolution limit ~ 20 µm

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Physics of reflow

A number of physical mechanisms play a role in resist reflow. The dominant effects are:

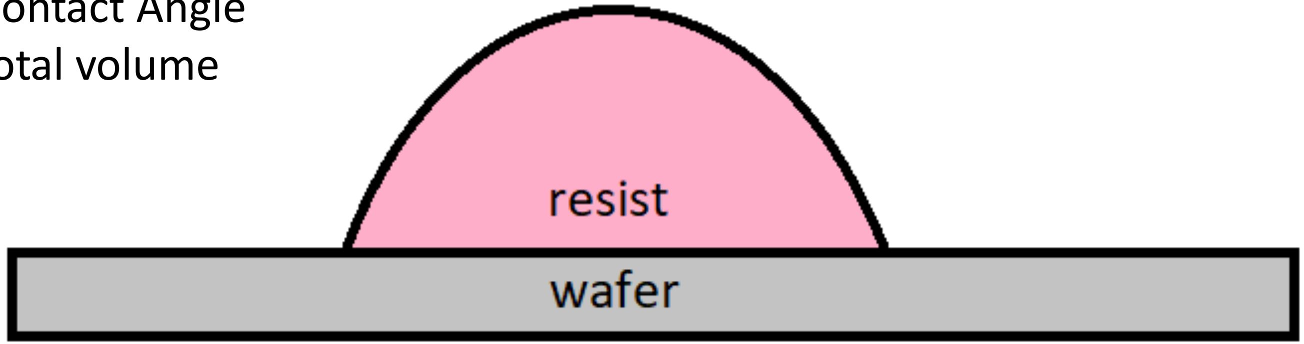
- Surface tension effects
- Edge stress effects

Physics of reflow – surface tension

Surface tension tends to minimize interfacial area to minimize energy.

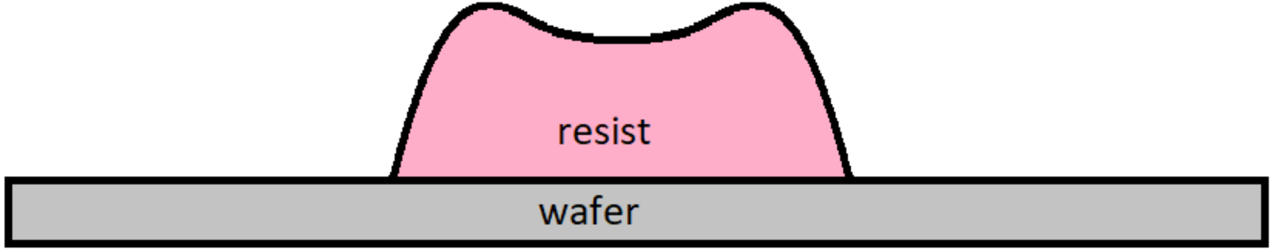
Constraints:

- Contact Angle
- Total volume



Physics of reflow – edge stress

The edges of a feature can be under a state of stress due to developing, spinning etc. When heated, the resist tries to relax…



Experimental Objectives & Splits

Can we predict the shape evolution of simple rectangular resist structures, given:
1) Initial dimensions, and 2) Reflow procedure

Independent variables (X)

Bake temp:
120 C
140 C
180 C

Bake time:
10 s
30 s
60 s
120 s
1800 s 3600 s 5400 s
7200 s

Width:
50 µm
75 µm
100 µm
200 µm
300 µm
400 µm
500 µm
600 µm
800 µm
1000 µm

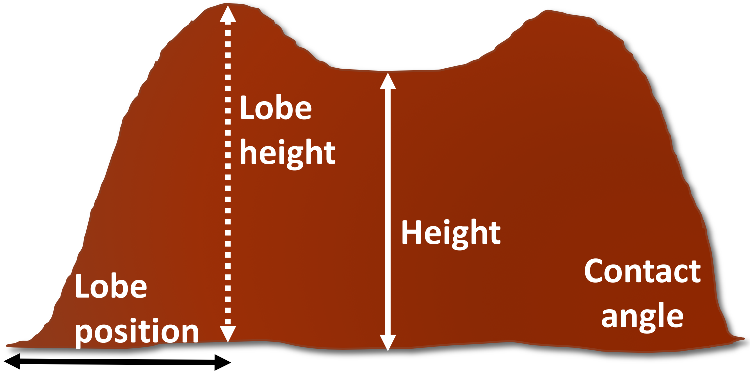
Shape:
Long
Square

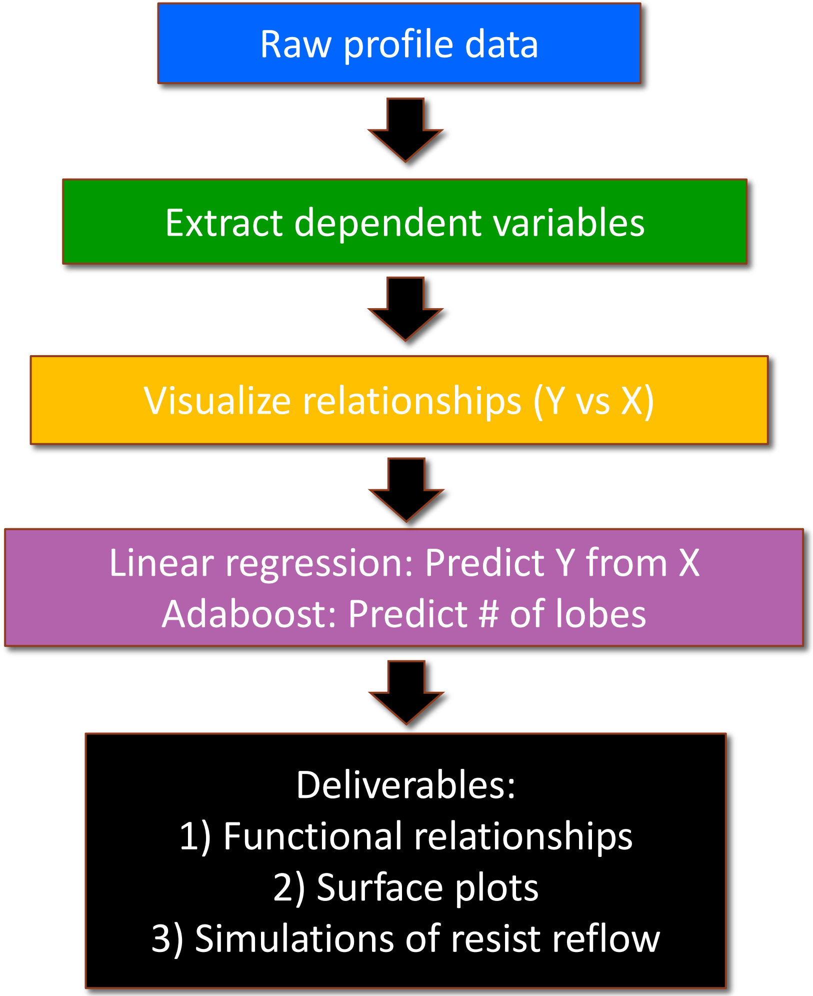
Analysis strategy

Dependent variables (Y)

Number of lobes (1 or 2)?

Cross-sectional area?





Raw profile data

Extract dependent variables

Visualize relationships (Y vs X)

Linear regression: Predict Y from X
Adaboost: Predict # of lobes

Deliverables:
1) Functional relationships
2) Surface plots
3) Simulations of resist reflow

Example use case

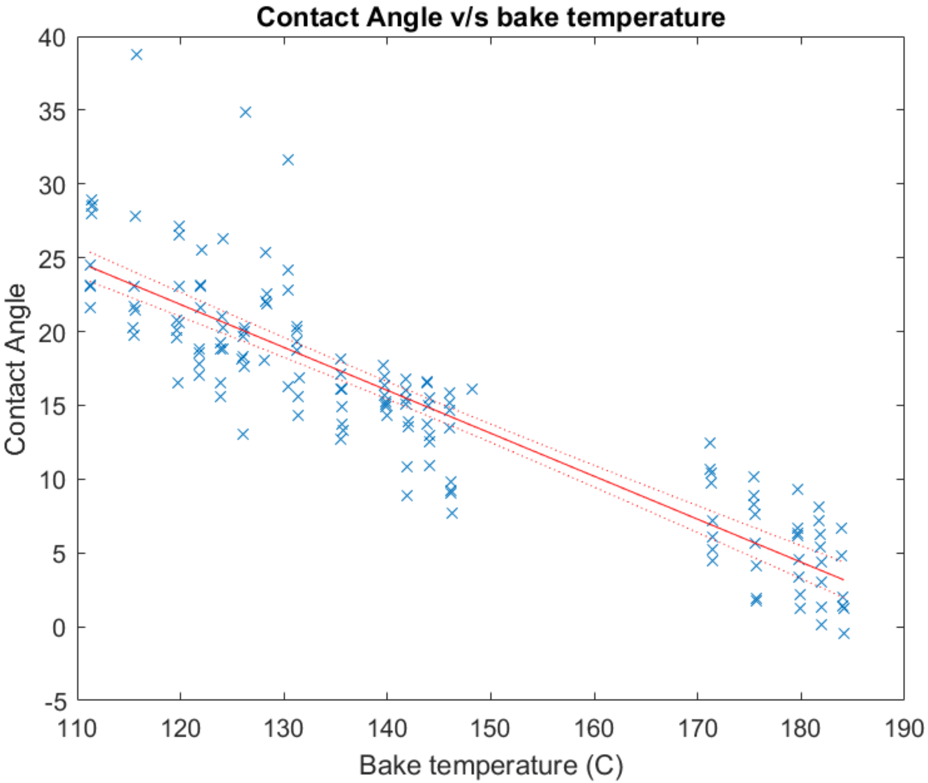
Suppose we have a long resist structure of width 300 μm and height 7 μm. The vertical aspect ratio is 0.0233.

We would like to achieve a contact angle of less than 20° and a rounded profile. What bake parameters should we choose?

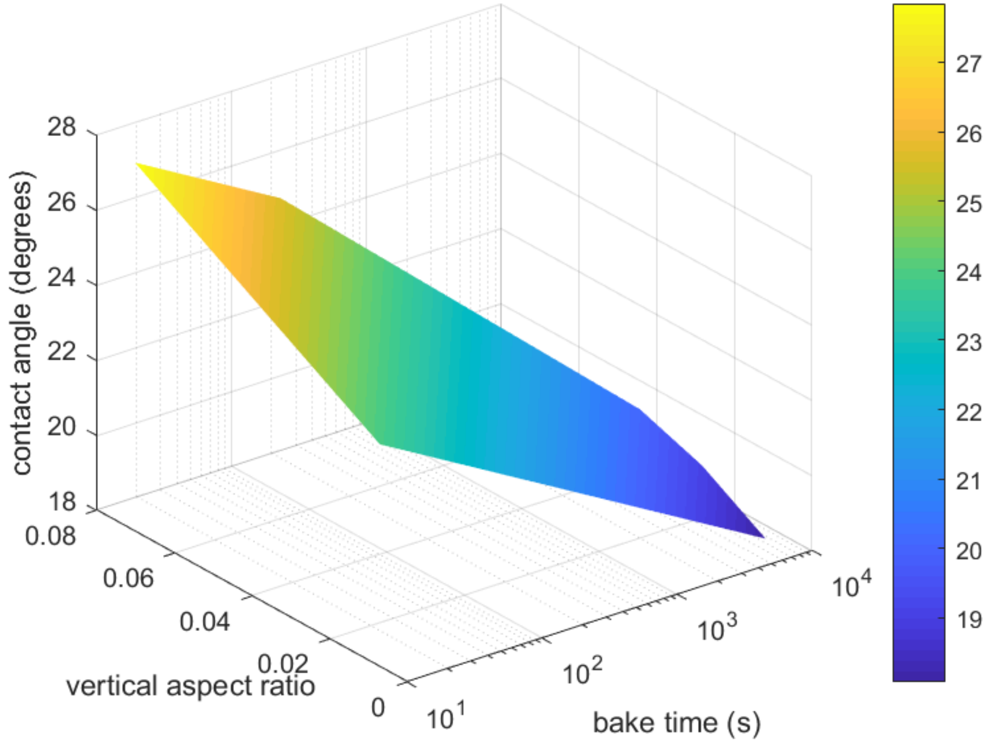
Plots of independent vs dependent variables

Contact Angle(y) v/s feature size(x_1), bake temperature(x_2) & log(bake time)(x_3)

$$y = 64.87 - 0.00176 * x_1 \; - 0.29 * x_2 \; - 2.8015 * x_3$$



Plots of independent vs dependent variables



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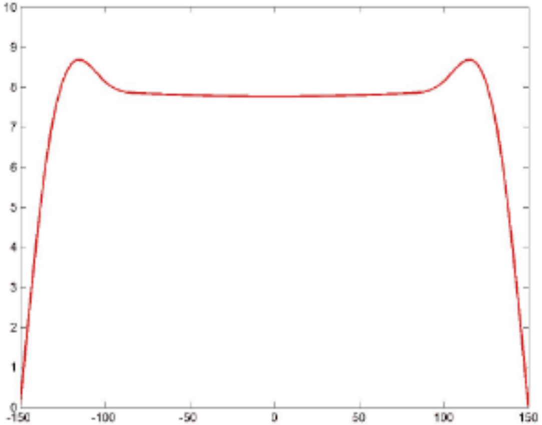
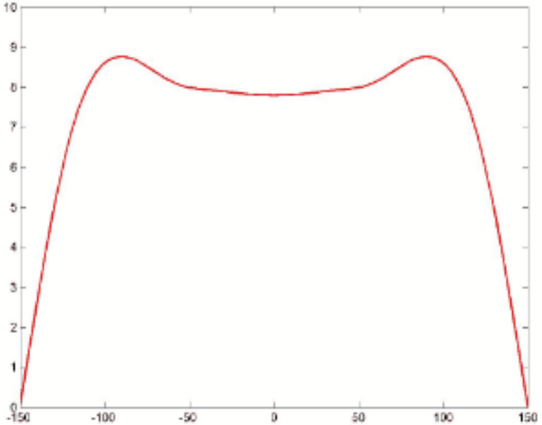
Simulating resist profile evolution (10 s → 2 h)

using **cubic spline interpolation** from $Y_{predicted}$: contact angle, height, lobe height & position

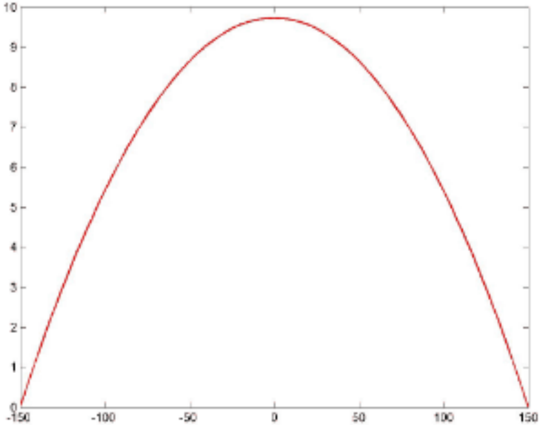
120 C



140 C



180 C



Conclusions

- Grayscale lithography for SPR220-7 is characterized
- Resist reflow is studied and data consolidated. Empirical relations and surface plots have been created for the benefit of future users
- A recipe for quasi-liftoff of parylene is developed with the help of the above knowledge

We would like to thank our mentors and SNF+SNSF staff who were very supportive!