

Deformation of Stamp Features with Slanted Walls during Microcontact Printing

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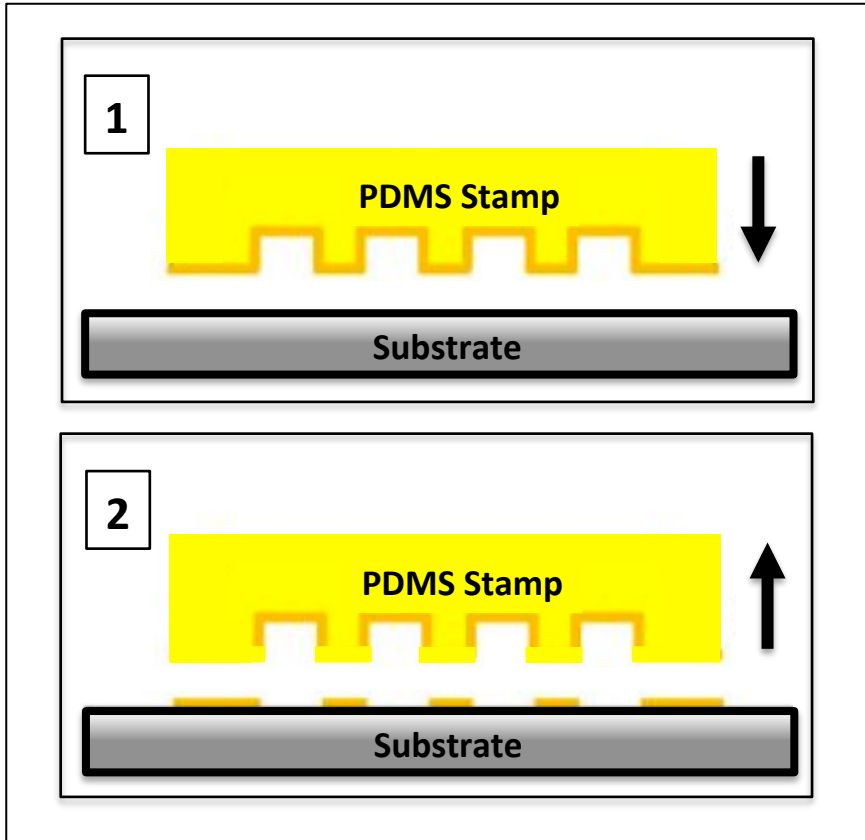
²King Fahd University of Petroleum and Minerals

Outline

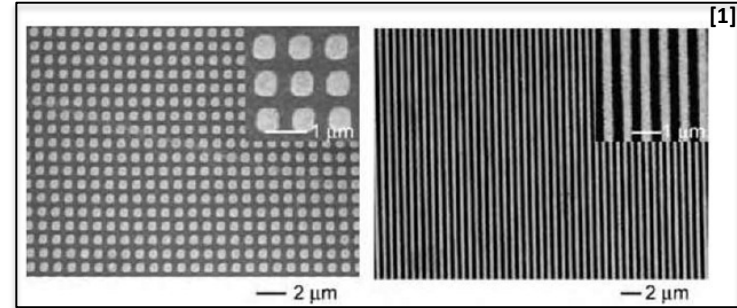
- Introduction
- Research Motivation and Objectives
- Simulations
 - . Simulation methodology
 - . Simulation results
- Conclusions and Future Work

Microcontact Printing

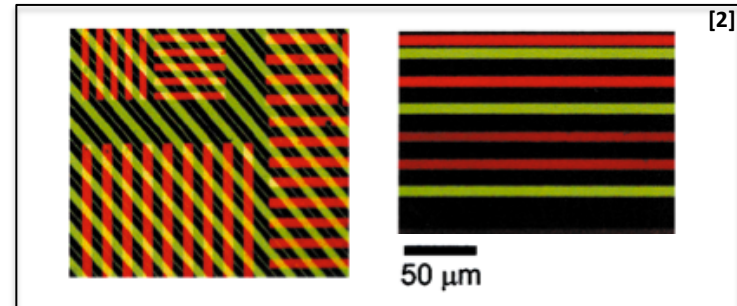
Microcontact printing



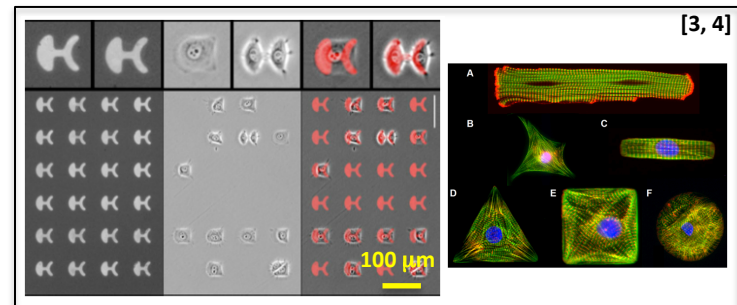
Etch resists for micromachining



Protein patterns for biosensors



Cell patterns for tissue engineering research



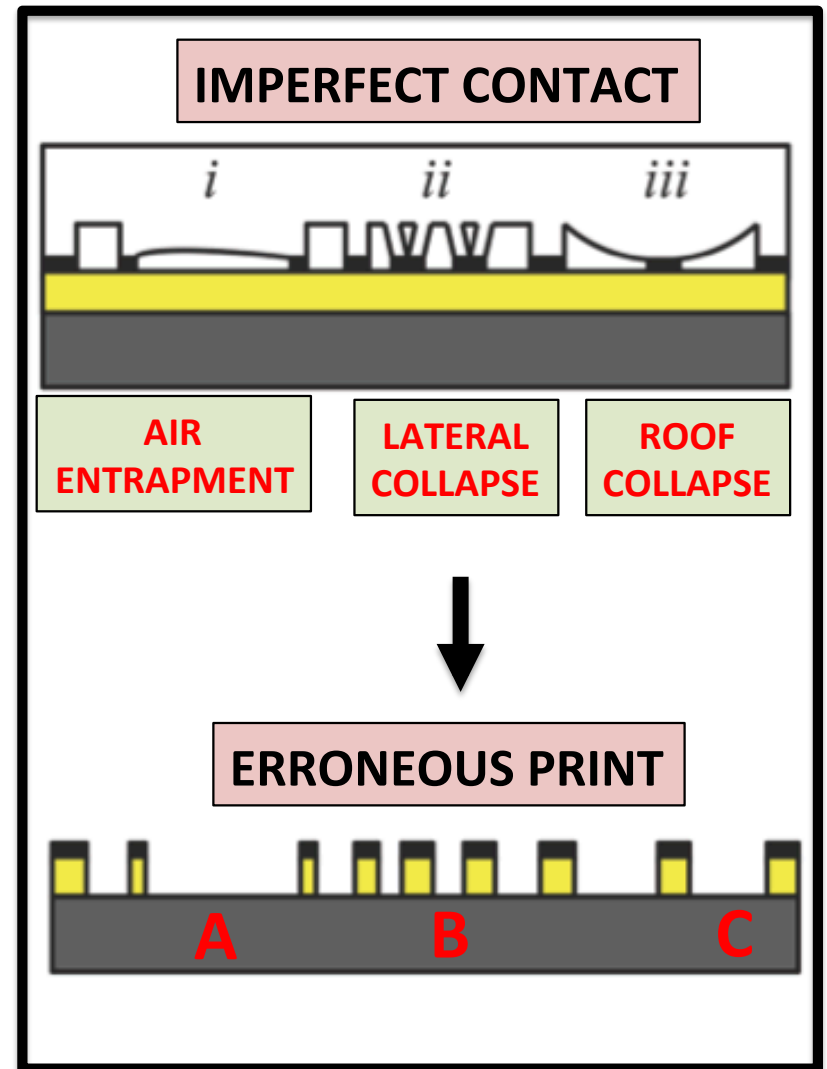
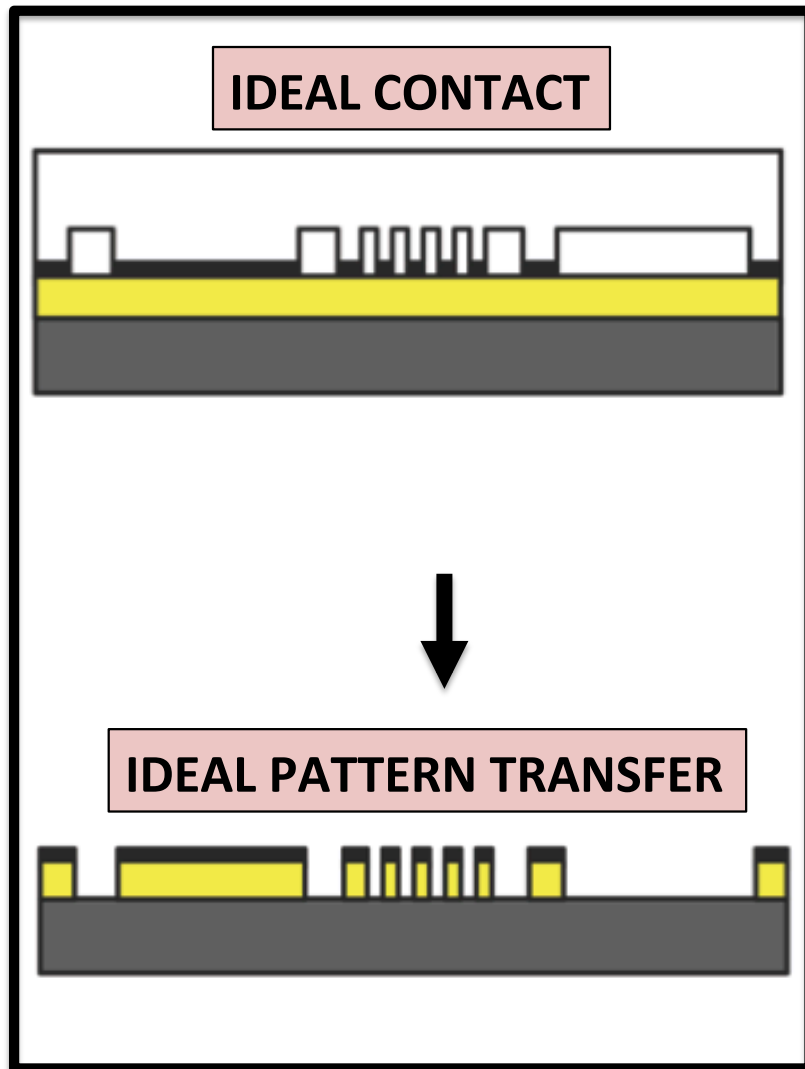
[1] what-when-how.com

[2] A. Bernard *et al.*, *Advanced Materials*, 2000.

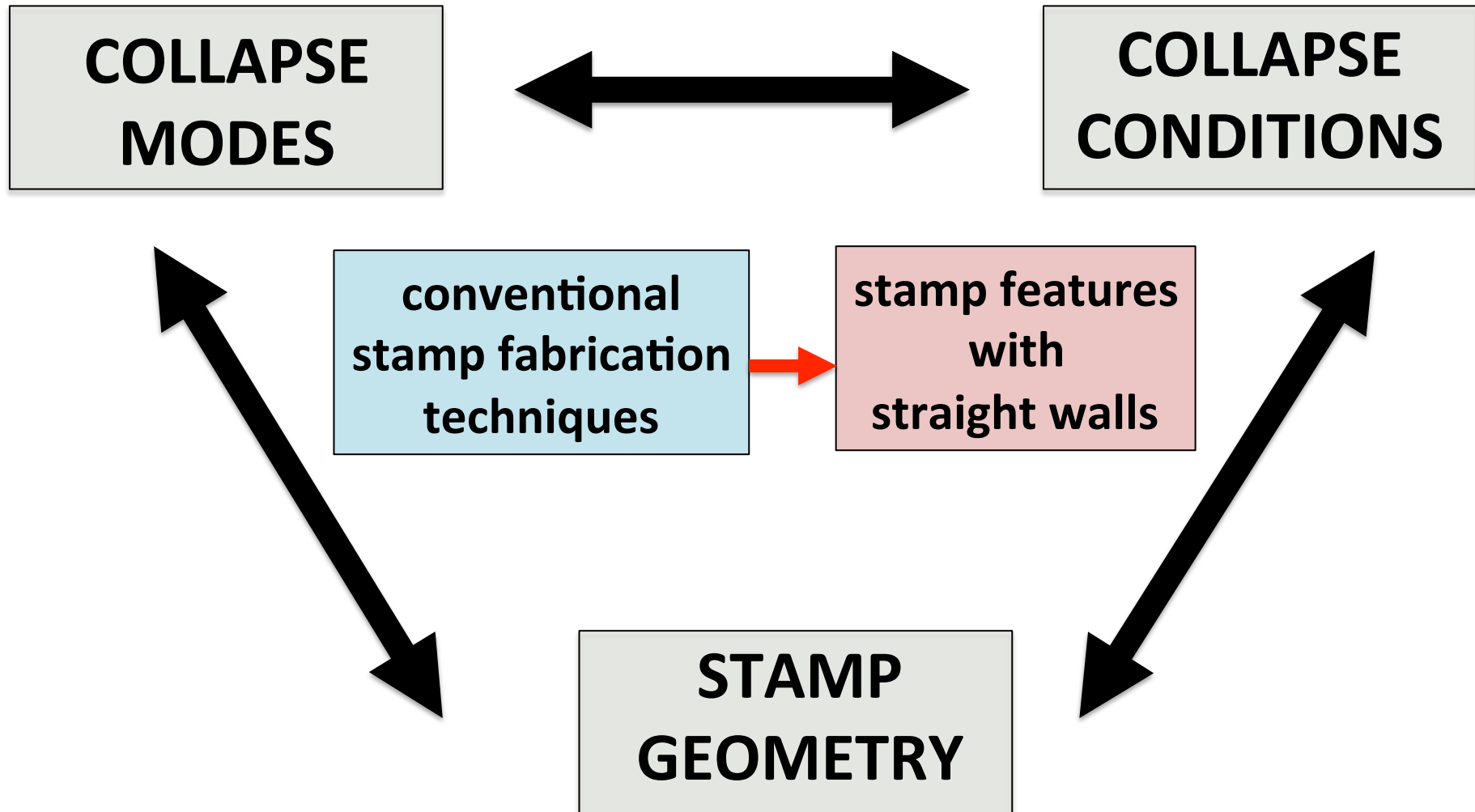
[3] M. They and M. Pitel, *Cold Spring Harb Protoc*, 2014

[4] diseasebiophysics.seas.harvard.edu

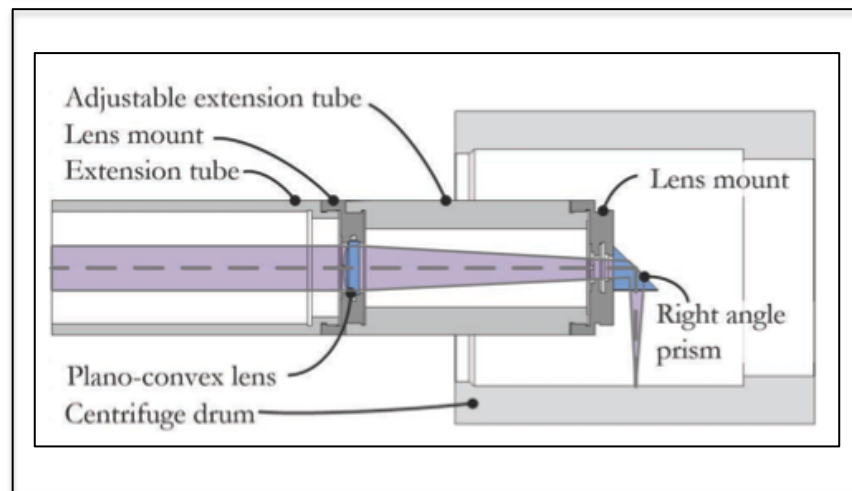
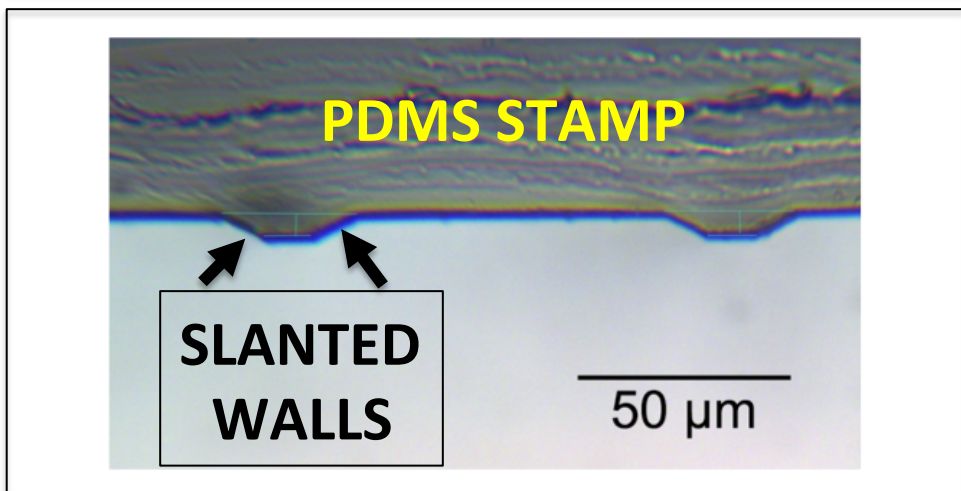
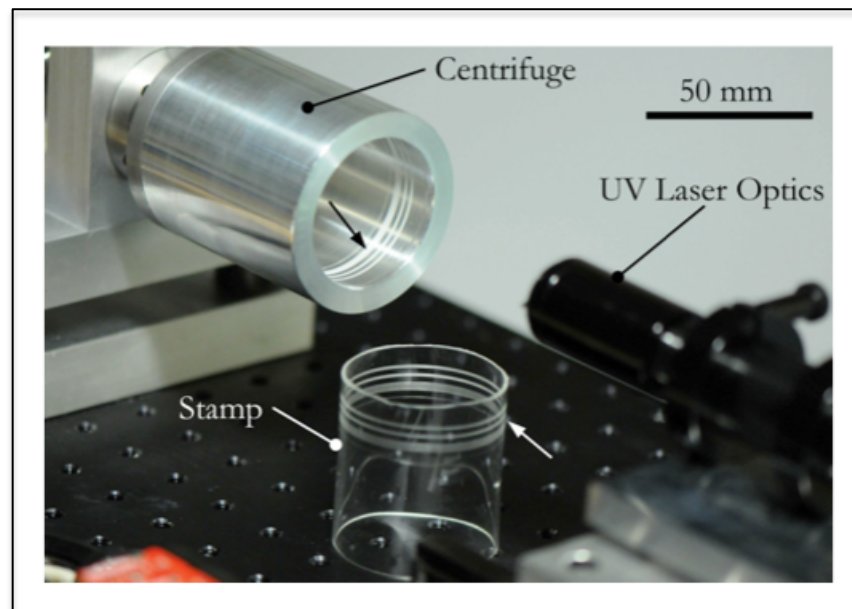
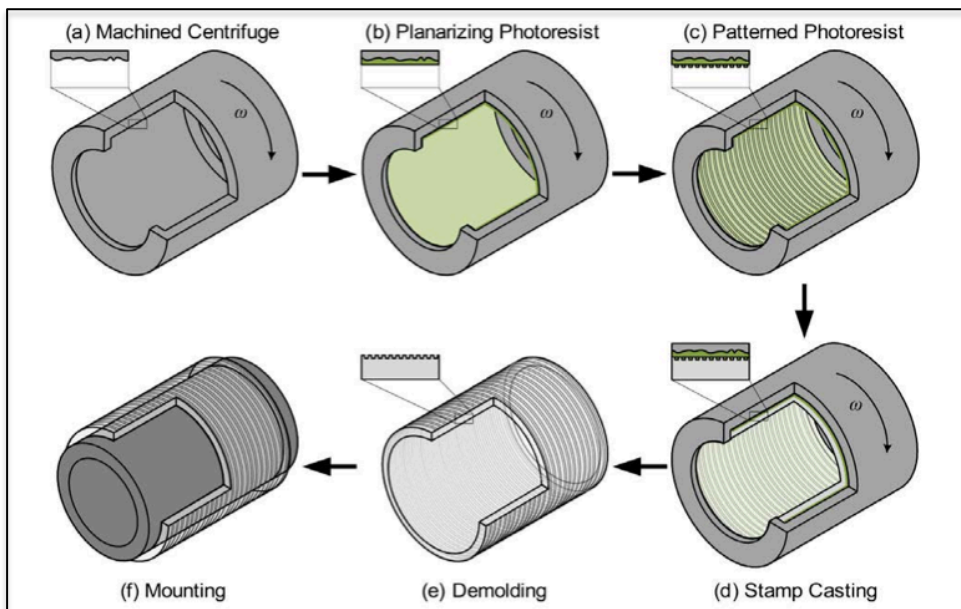
Defect Modes



Existing Studies: focus on Straight Walls

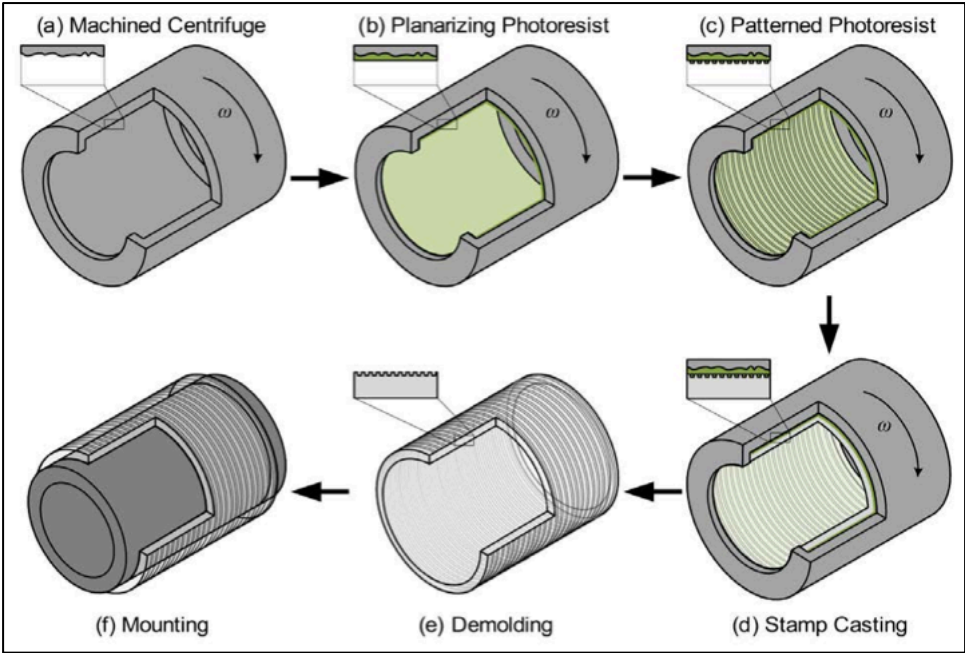


Motivation: Features with Slanted Sidewalls



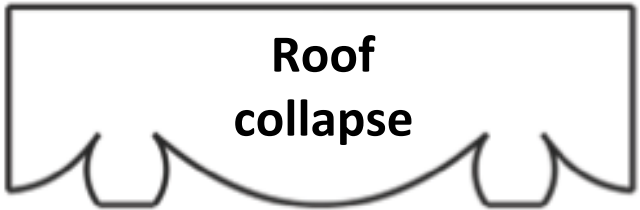
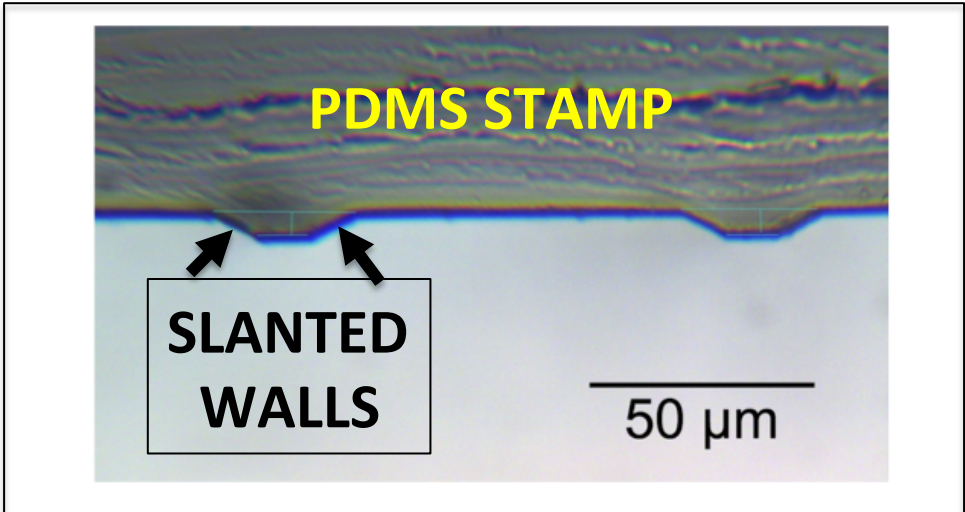
J. E. Petrzela and D. E. Hardt, Proceedings of SPIE, 2013.
J. E. Petrzela, PhD Thesis, Massachusetts Institute of Technology, 2012.
L. Nietner, MS Thesis, 2014.

Objectives

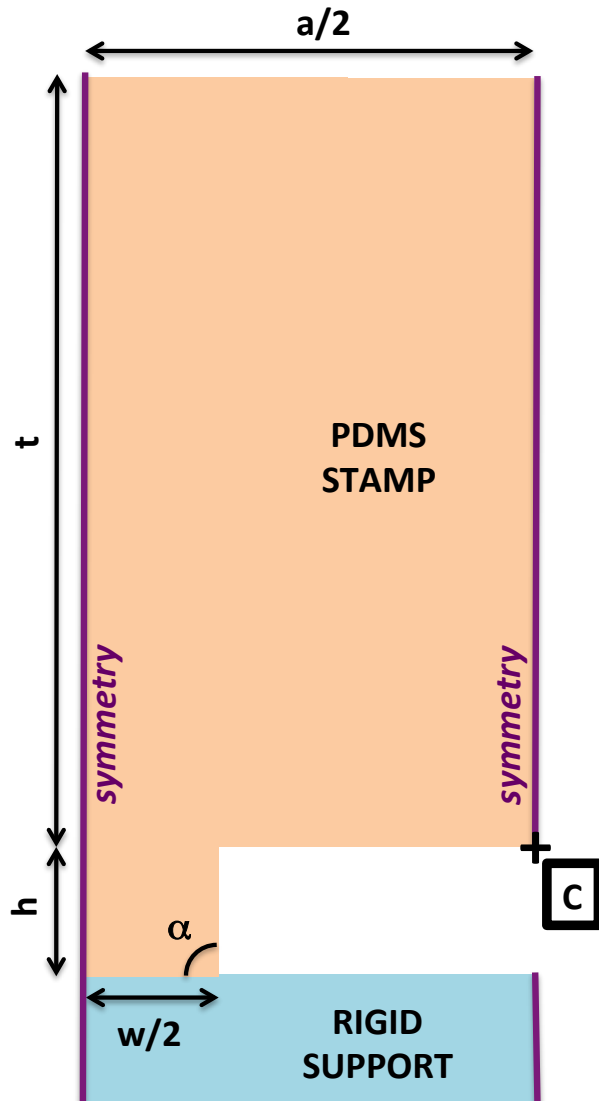


How do slanted walls behave?

- Roof collapse pressure?
- Effect of slant angle?
- Effect of feature spacing ?



Simulation Setting



- Simulations in experimentally achievable dimension range
- Free triangular mesh enables better convergence compared to other structured mesh types
- Rigid support is fixed constraint
- PDMS stamp is hyperelastic material

Dimensions

$h=10 \mu\text{m}$

$w=20 \mu\text{m}$

$t=2 \text{ mm}$

$100 \mu\text{m} < a < 400 \mu\text{m}$

$90^\circ < \alpha < 150^\circ$

PDMS properties

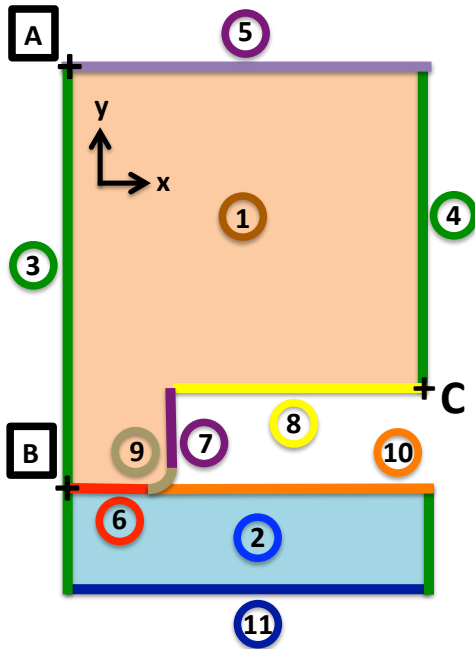
Density = 970 kg/m^3

Lame parameter $\lambda = 6.93 \text{ GPa}$

Lame parameter $\mu = 0.77 \text{ GPa}$

Poisson's ratio = 0.43

Simulation Setting



Domain, Boundary, Point	Condition
1	- Hyperelastic material
2	- Fixed constraint
(10); (6, 9, 7, 8)	- Contact couple 1 (zero friction coefficient)
(8); (9, 7)	- Contact couple 2 (zero friction coefficient)
3, 4	- Symmetry
5	- Prescribed displacement
6, 7, 8, 9, 10, 11	- Free
B	- Fixed constraint
A	- Prescribed displacement ($d_x=0$, $d_y=unspecified$)

Upper stamp boundary

- Displace with 1 micron increments until roof collapse occurs

Traction at the top boundary

- Convert displacement to load

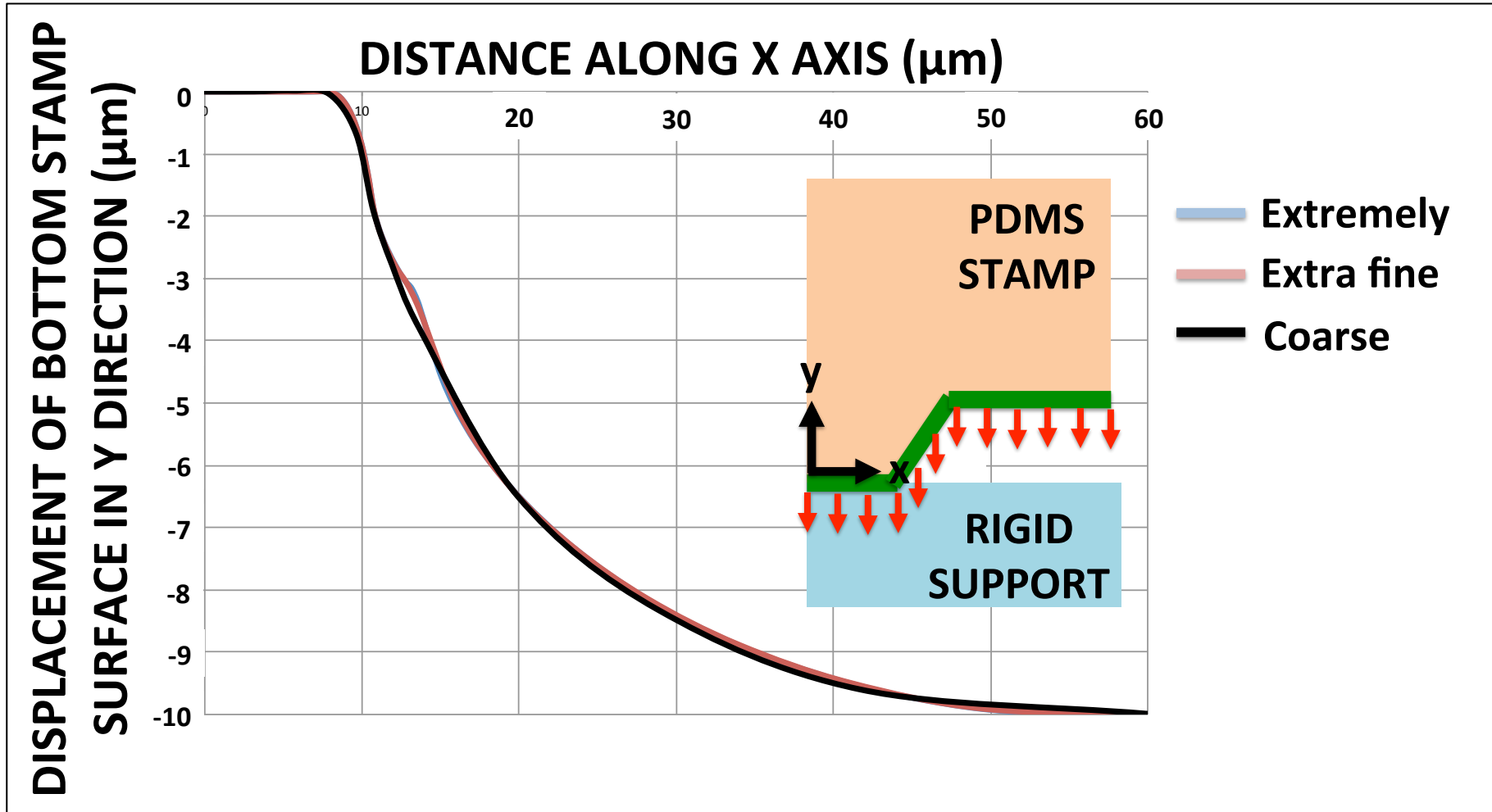
Two contact couples

- Support and stamp contact
- Contacting stamp edges

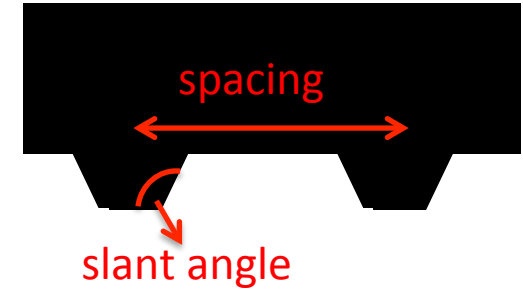
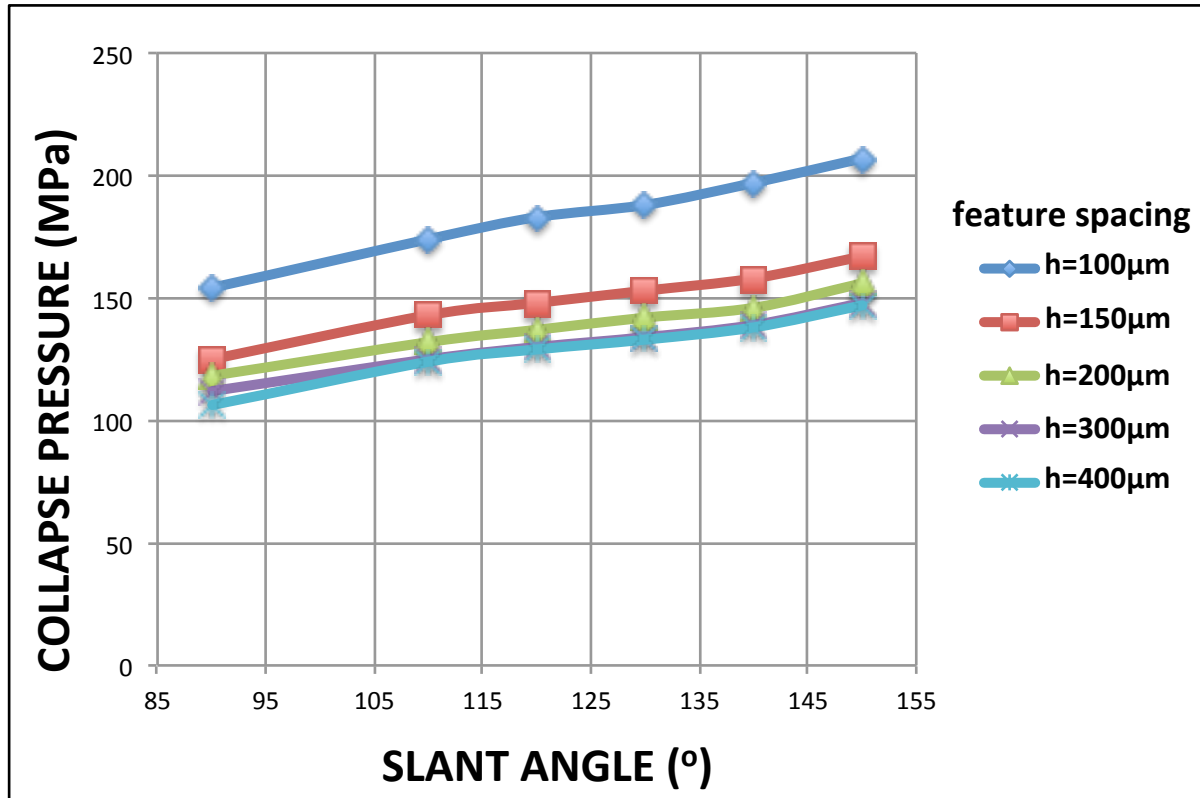
3-micron fillet at stamp corner

- Eliminate convergence issues

Mesh Refinement

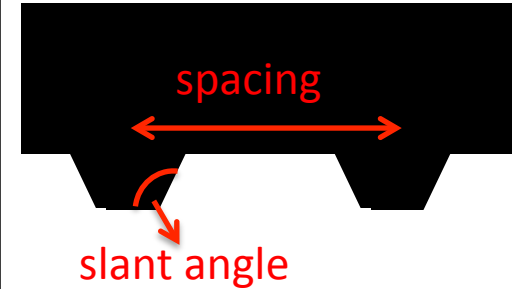
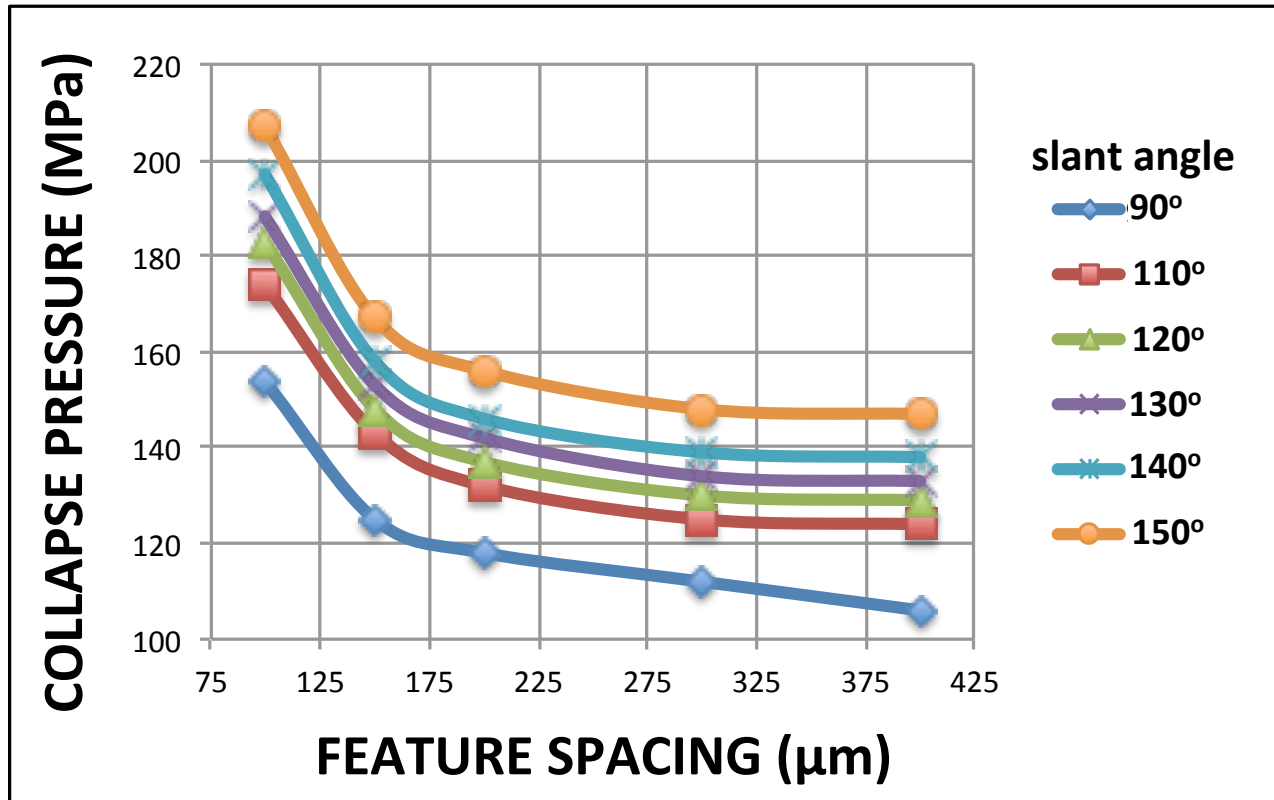


Simulation Results



- Collapse pressure increases by 50% with slant angle
- Slanted walls are beneficial for printing

Simulation Results



- Collapse pressure decreases with feature spacing for all slant angles
- Collapse pressure not affected by spacing for $h > 300 \mu\text{m}$

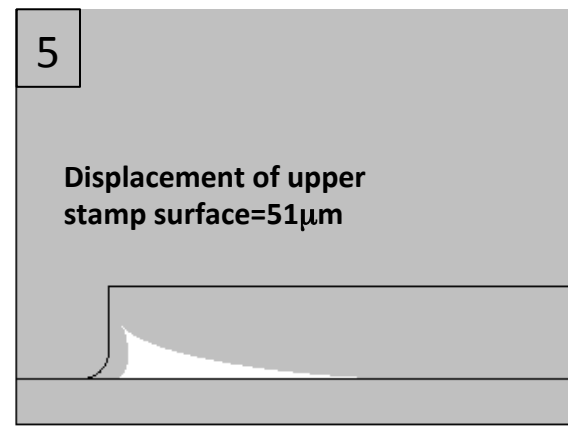
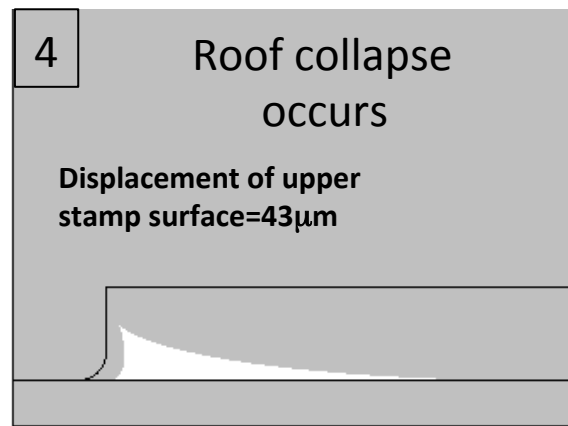
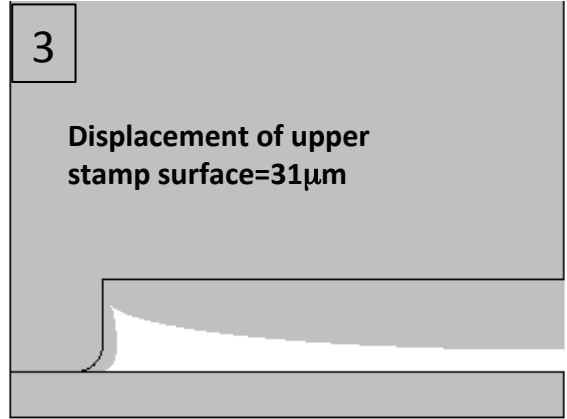
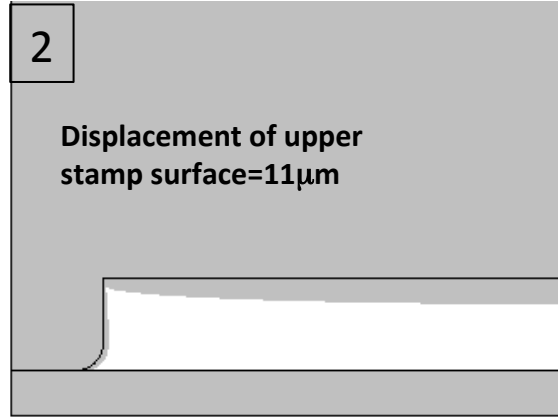
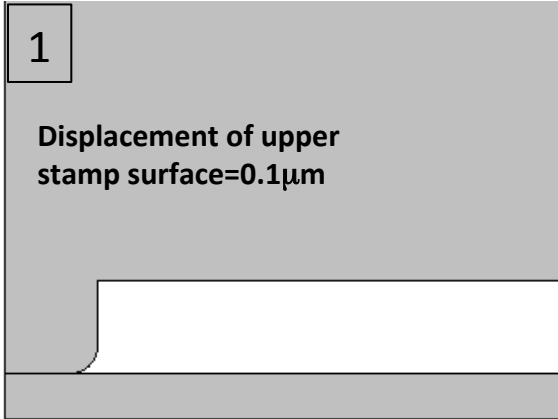
Conclusions and Future Work

- Design guidelines are established to prevent roof collapse of stamps using slanted-walled features
- Simulations show that slanted walls help improve stamp stability
- Future work is to examine other collapse modes and include liquid ink in the simulations

Thank you

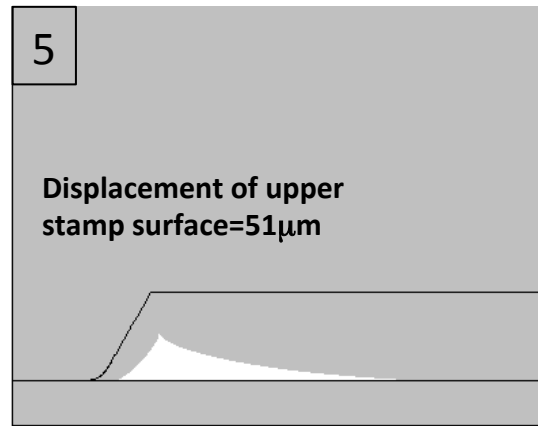
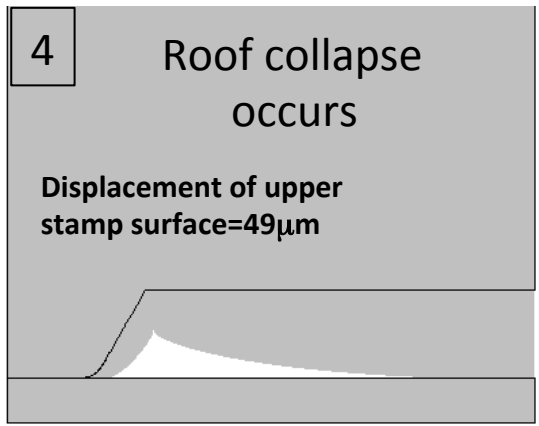
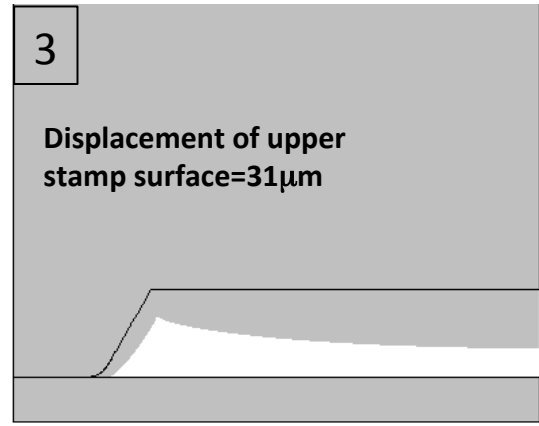
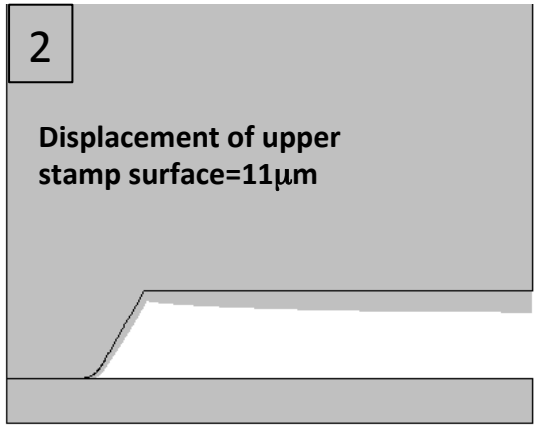
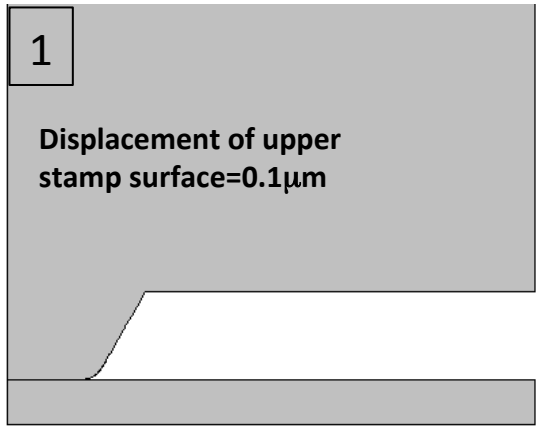
Q&A

Straight Walls



feature height=10 μ m
feature width=20 μ m
thickness of layer above stamp feature=2 mm
feature spacing=100 μ m

Slanted Walls



feature height=10 μ m
feature width=20 μ m
thickness of layer above stamp feature=2 mm
feature spacing=100 μ m
wall slant angle=30 $^{\circ}$