3D Printing for Optics and Microfluidics

EE 412 Fall 2015

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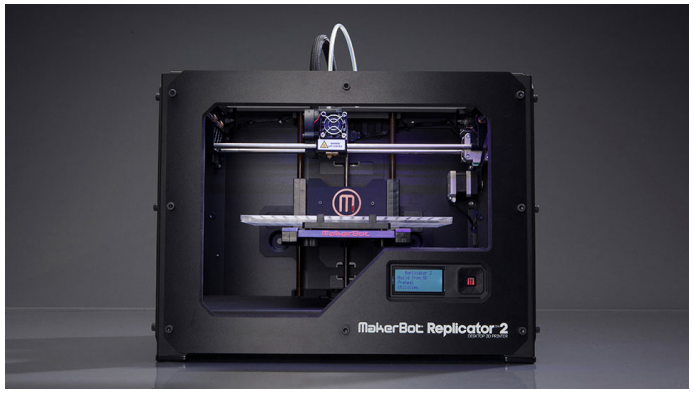
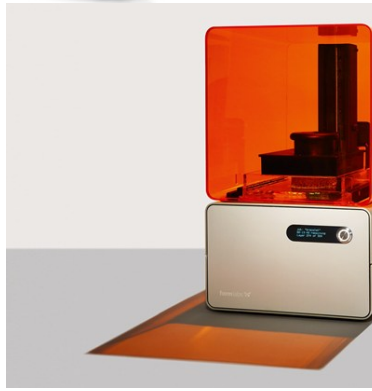
Instructor: Roger Howe

Contents

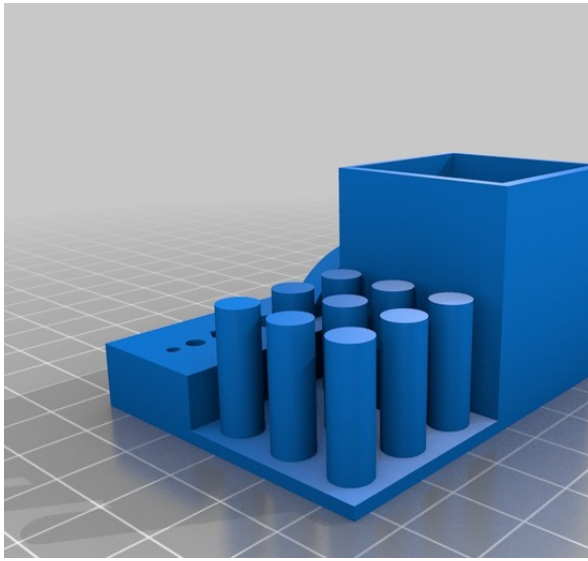
3D Printing



- known as Additive Manufacturing
- Machining (Auto CNC) = Subtractive Manufacturing
- ny different types of printers:
  - xtrusion (Fused Deposition Modeling FDM)
  - nk Jet (Multi Jet Modeling MJM)
  - ight polymerization (Stereolithography SLA, Two-photon)
  - Melting/sintering
- erials include plastics, metals, ceramics, food. . .
- re trait of building up layer by layer



Advantages and Disadvantages



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- Only skill required CAD software
- Usually inexpensive or cheaper than alternative
  - For one off productions
- Complex designs are possible that would be difficult otherwise

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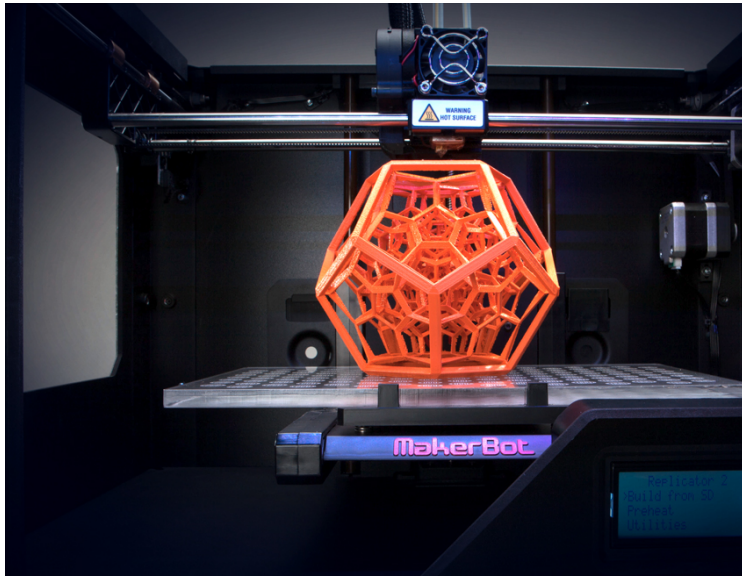
- Individual printers can have limited scope
  - Usually just one material choice
  - Time/resolution trade off
- Too slow for mass production
- Every printer has its own quirks



Uses for 3D Printing

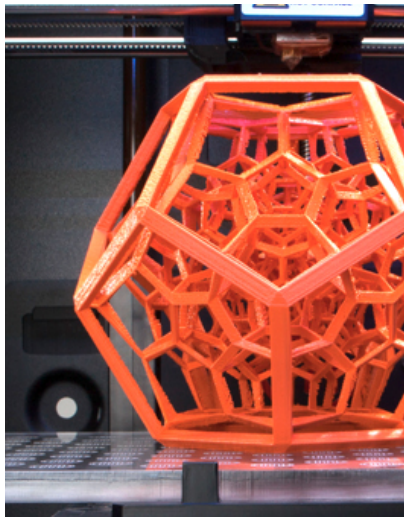
Applications and materials depends on the 3D printer

Consumer: knick knacks, toys, decorations

One-off prototypes

- Cheap plastic model
- Iterate over different parameters easily

Unique structures difficult to manufacture traditionally



Will not be replacing mass production or masterful craftsmanship for a while

Resources for 3D Printing

CAD Software:

- Solidworks free at Terman Library
- Autodesk free online

On Campus

- Room 36: several FDM, one projet (not for research)
- TRI-Lab
- SNF: Solidscape Studio

Off Campus

- Many services such as Protocafe

The Solidscape Studio

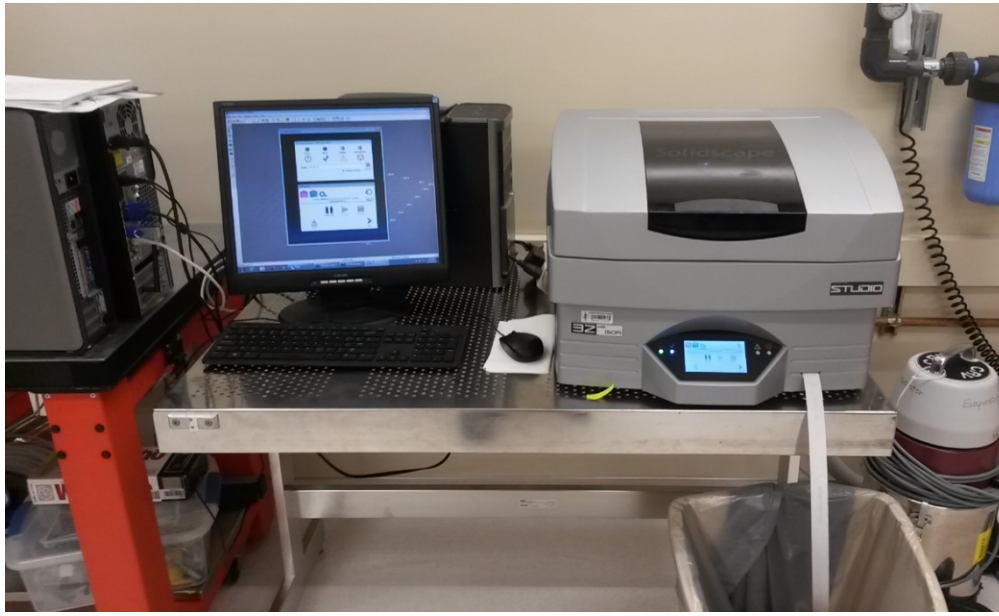
Marketed toward custom jewelers

Uses wax for model and support material

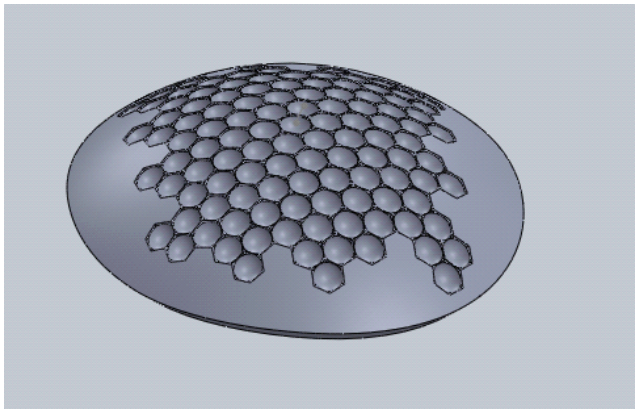
Proprietary software takes .STL parts

Specifications

- 6.4 um minimum layer size
- 5000x5000 DPI X-Y resolution
- Up to ~800 nm RMS surface finish
- 6”x6”x2” build area



Application 1: Optics



Goal: Use unique abilities of 3D printing to make PDMS optical devices

Initial problem: Printer is too rough

Further Problems: PDMS does not cure on wax, layer resolution

Solution: Use smoothing process then coat in Parylene

Process Steps

Print Mold with 6um surface finish

Use Smoothing Process

- Room temperature 10% IPA-H20 bath for 15 minutes

Coat with Parylene

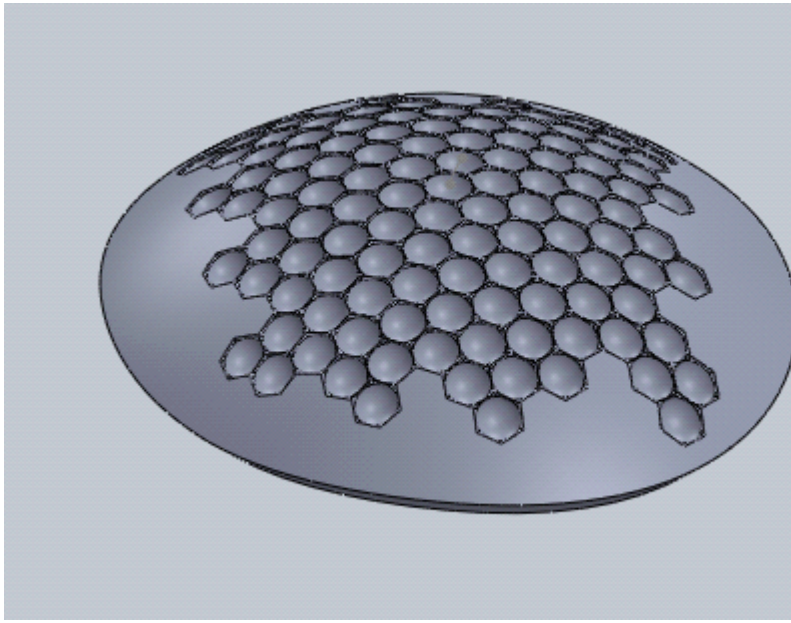
- 10 g with a Silane Treatment

Fill with PDMS and cure at 60^{o}C for 2 hours.

Extract Piece, salvage or toss master

Printing Device

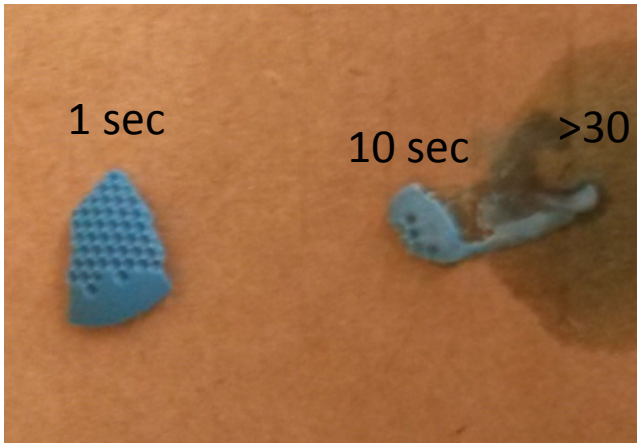
- Open .STL file in 3ZWorks, append additional files, select parameters
- Create .3zs file, transfer to printer
- Start Job and Wait
- Use hot plate to release devices
- Dewax support material using 140^{o}F mineral oil
- Let dry



Smoothing Processes

Untested: Vapor bath, chemical-mechanical planarization, sandpaper,

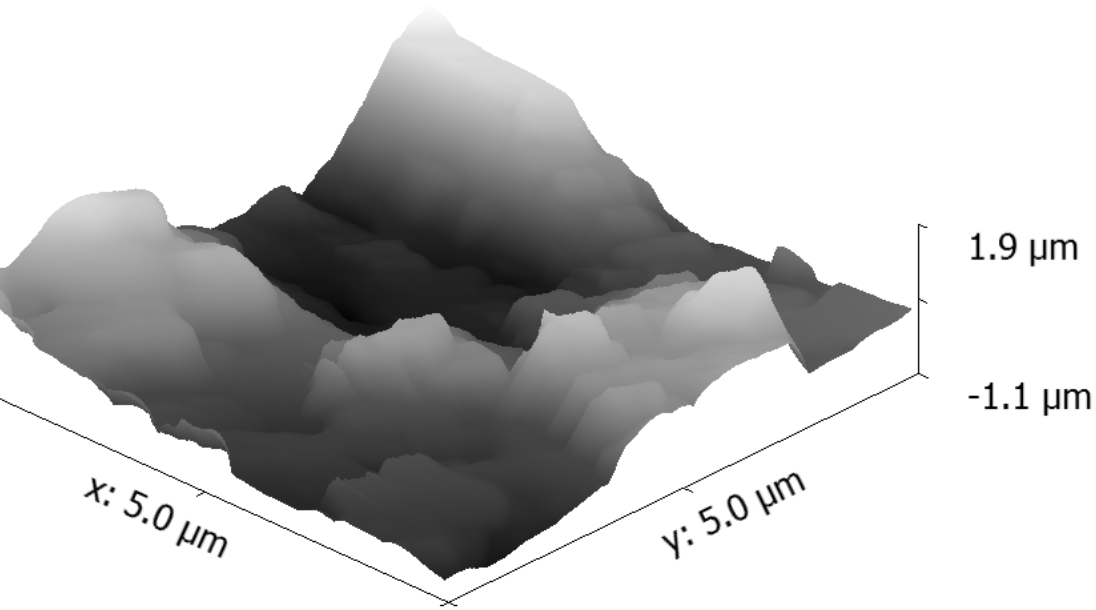
electroplating



Flame and heat lamp treatments proved difficult to control

Model material dissolves in IPA, use low concentration IPA bath

Control



Statistical Quantities

Minimum: -1.0859 µm

Maximum: 1.8622 µm

Median: -0.1283 µm

Ra: 0.4837 µm

Rms: 0.5777 µm

Rms (grain-wise): 0.5777 µm

Skew: 0.6091

Kurtosis: -0.4652

Surface area: 46.26672 µm^2

Projected area: 25.00000 µm^2

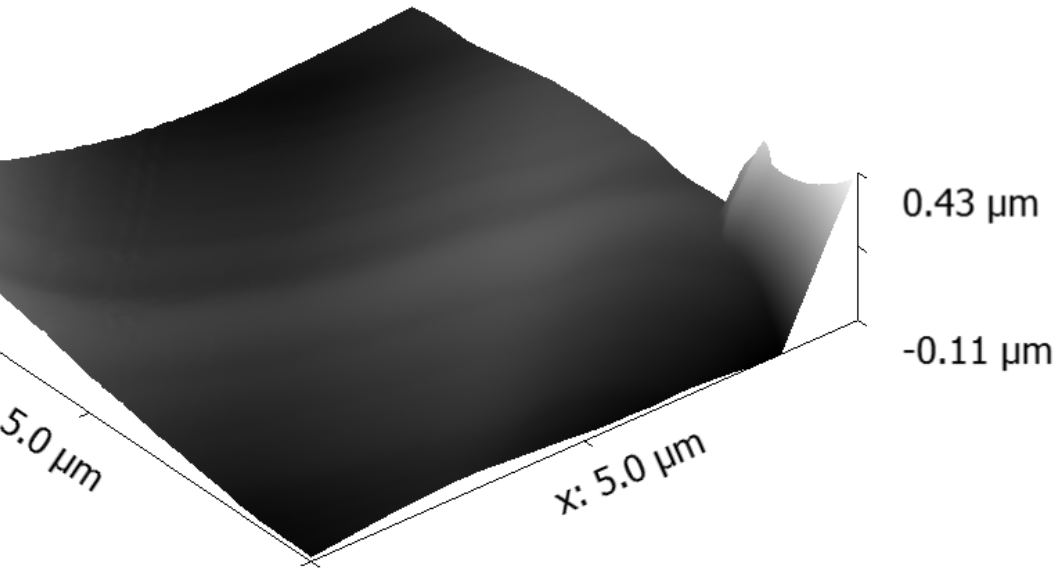
Variation: 34.253 µm^2

Entropy: -13.114

Inclination θ: 12.06 deg

Inclination ϕ: -47.89 deg

15 min
10% IPA Bath



Statistical Quantities

Minimum: 60.95 nm

Maximum: 64.20 nm

Median: 62.42 nm

Ra: 0.90 nm

Rms: 1.02 nm

Rms (grain-wise): 1.02 nm

Skew: 0.4438

Kurtosis: -0.7808

Surface area: 0.00344 µm^2

Projected area: 0.00343 µm^2

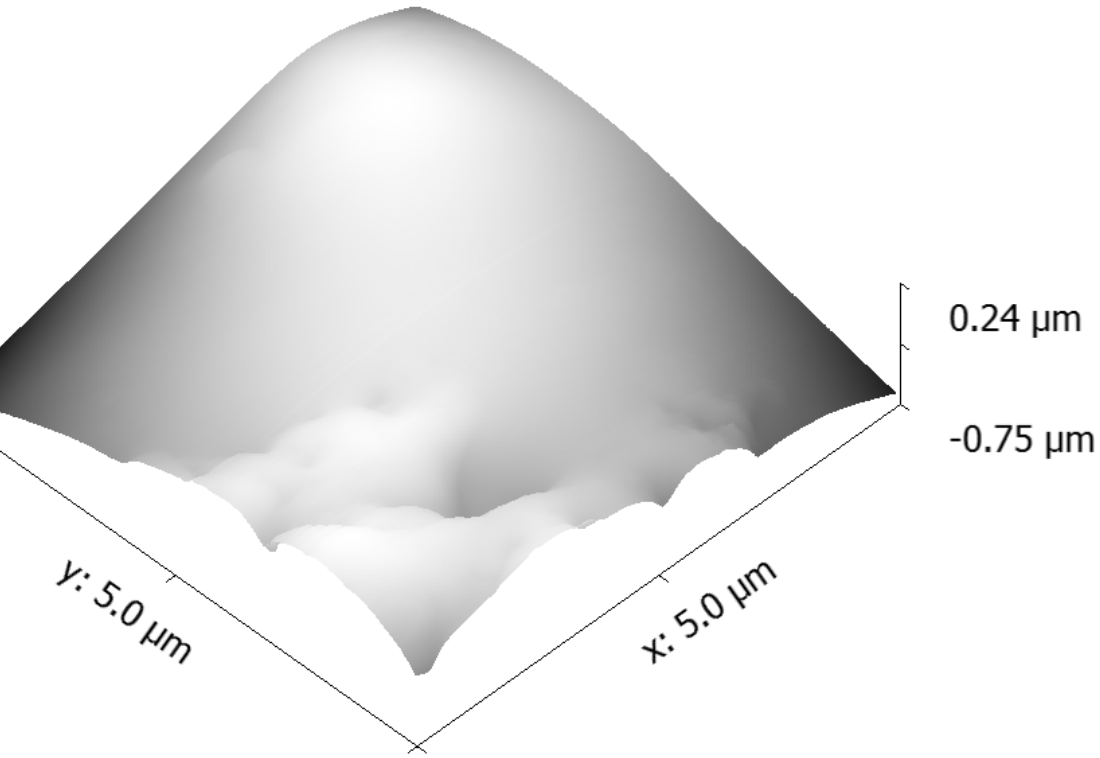
Variation: 200.61 nm^2

Entropy: -19.548

Inclination θ: 3.20 deg

Inclination ϕ: 114.23 deg

30 min
10% IPA Bath

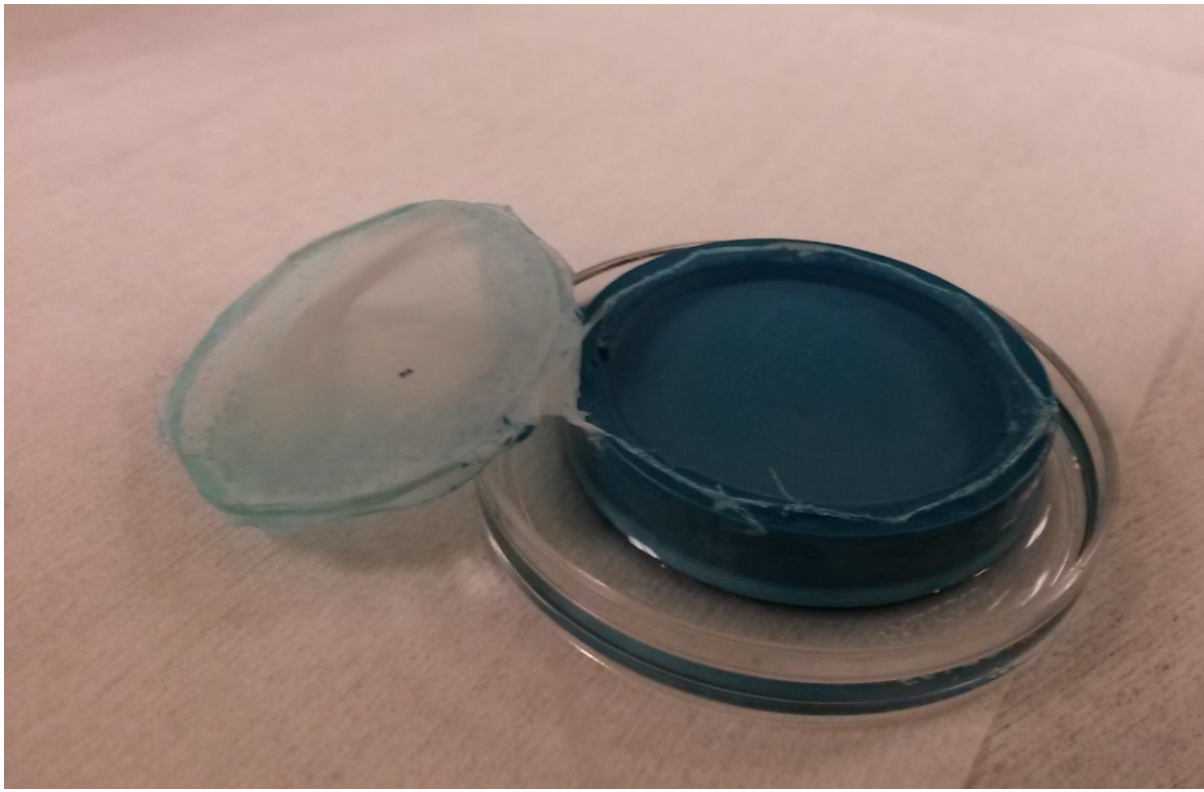


Statistical Quantities

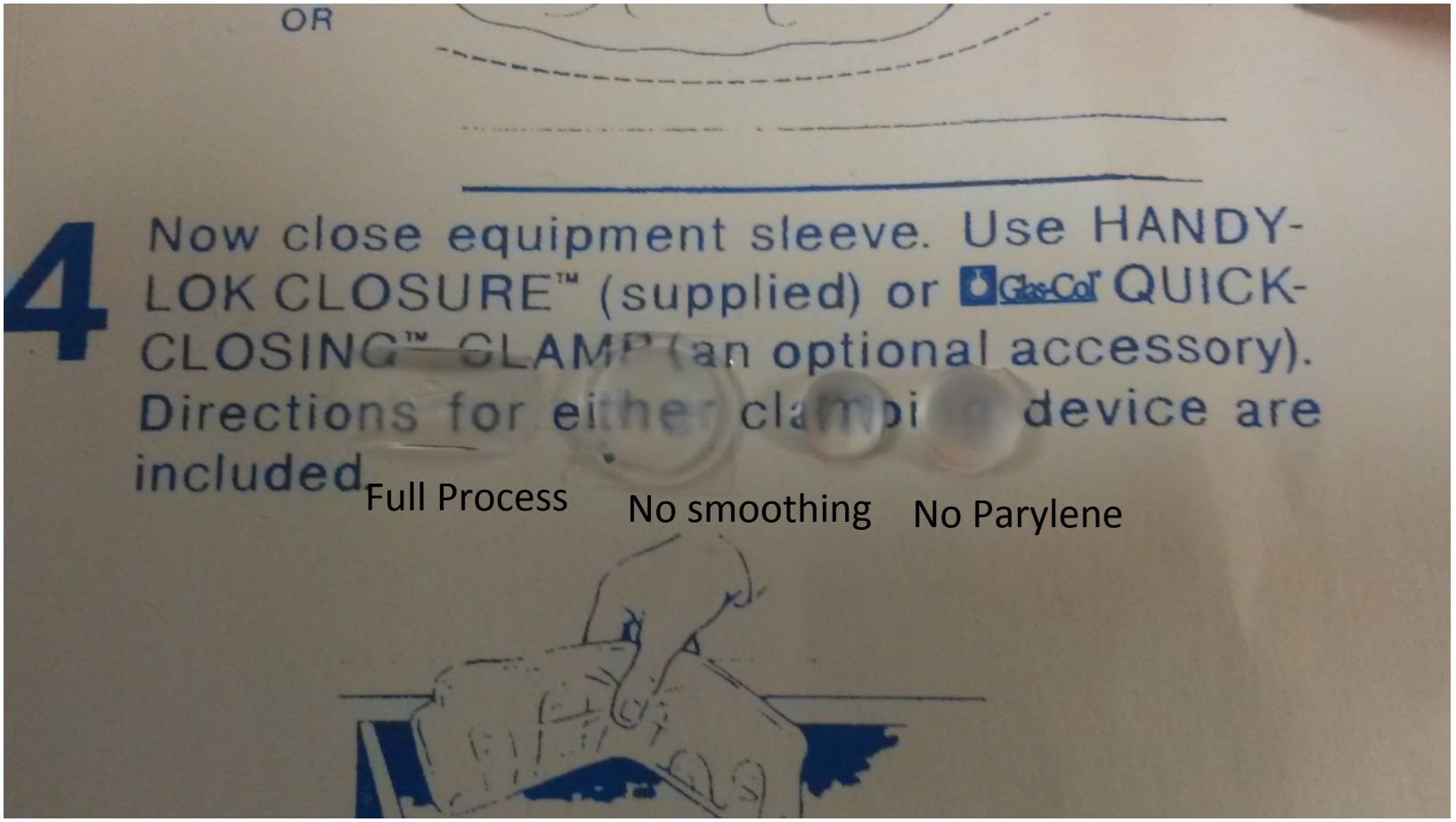
Minimum:	-752.10 nm
Maximum:	241.67 nm
Median:	48.32 nm
Ra:	145.98 nm
Rms:	**186.35 nm**
Rms (grain-wise):	186.35 nm
Skew:	-1.202
Kurtosis:	0.9853
Surface area:	26.41582 µm^2
Projected area:	25.00000 µm^2
Variation:	7.2406 µm^2
Entropy:	-14.332
Inclination θ:	2.25 deg
Inclination ϕ:	43.52 deg

Parylene Coating

- Good barrier between PDMS and wax
- Thickness needs to be tested
- Silene Treatment: Four drops of A-174 Silane before pump down



Finished Devices



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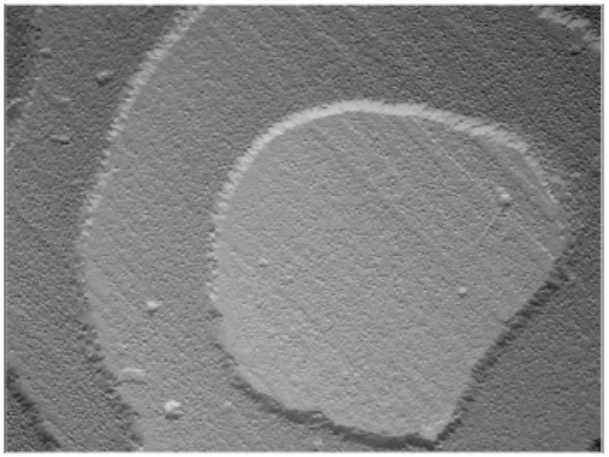

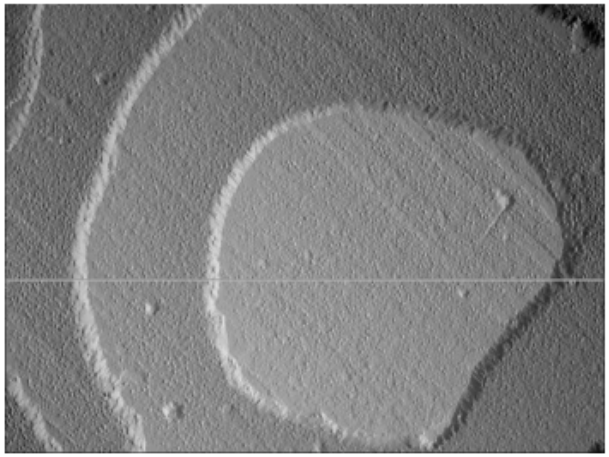

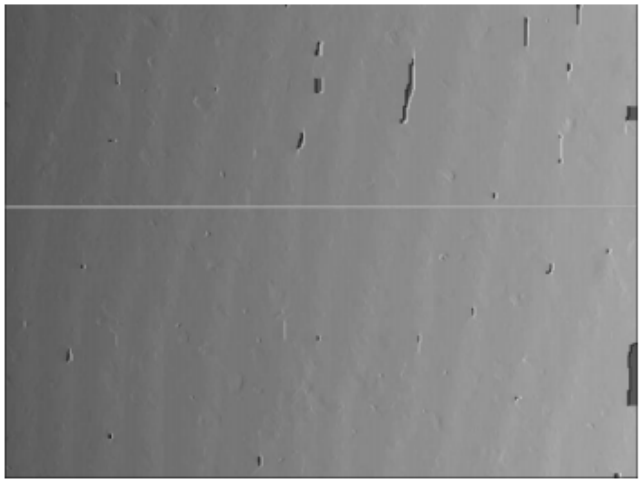

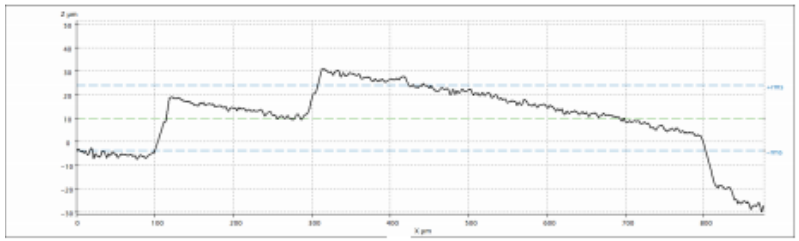

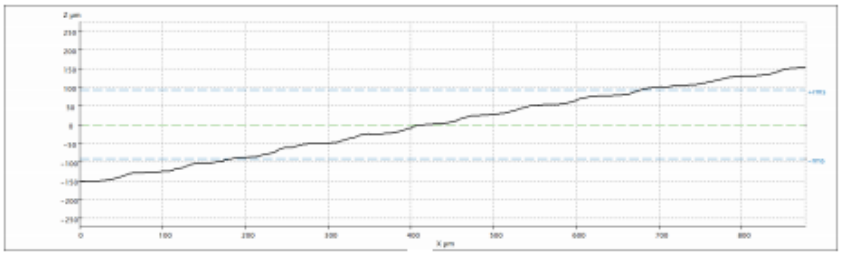

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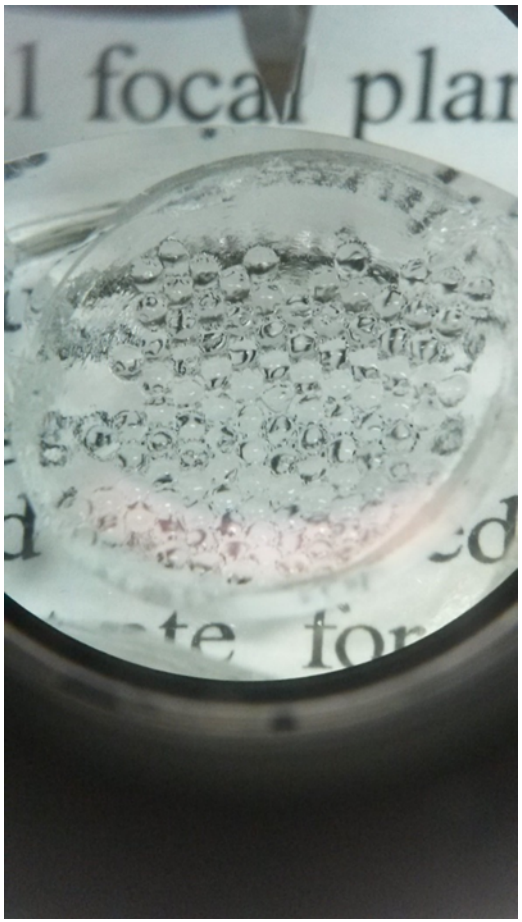

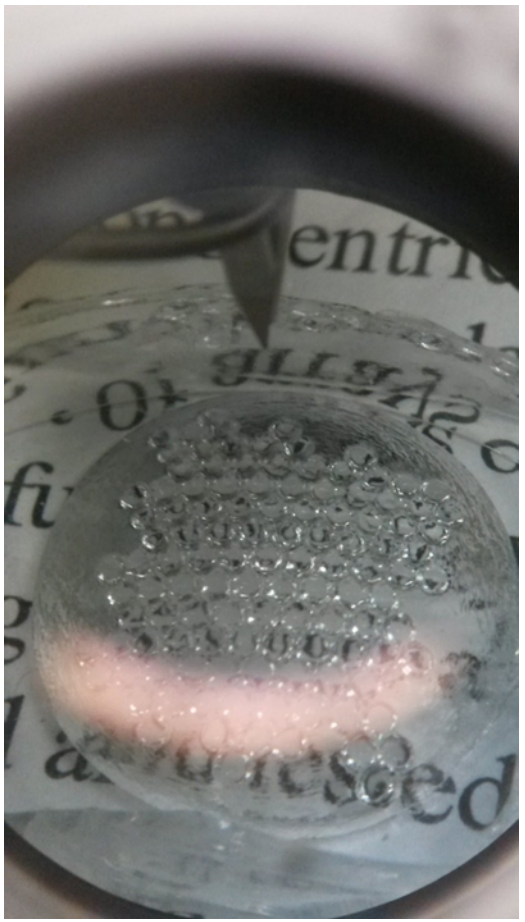

Conclusion

Future work

- Optics: refine smoothing process
- Microfluidics: 3D designs and pushing printer capabilities

Further applications

- Reflective optics
- Inductors
- ???