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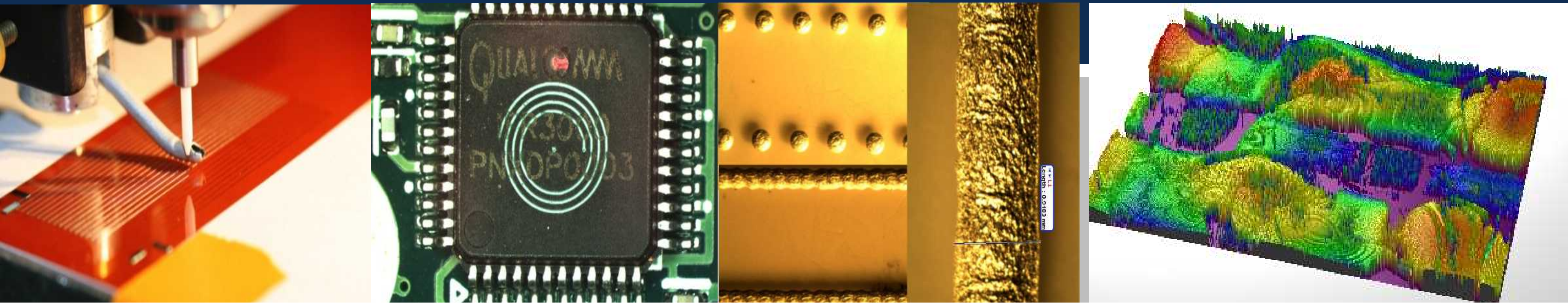

Variables Impacting Feature Definition of Polyimide Using a Syringe Based Printing

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U.S. DEPARTMENT OF ENERGY

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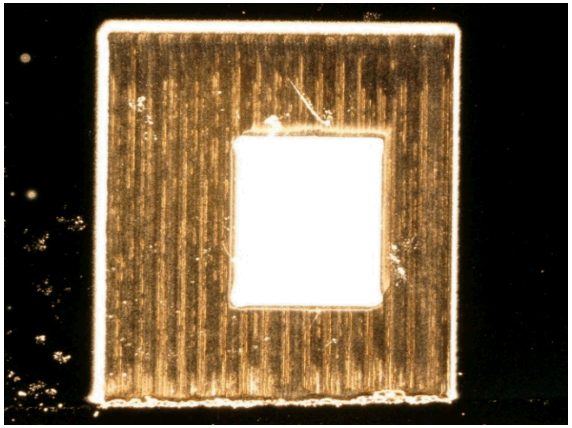
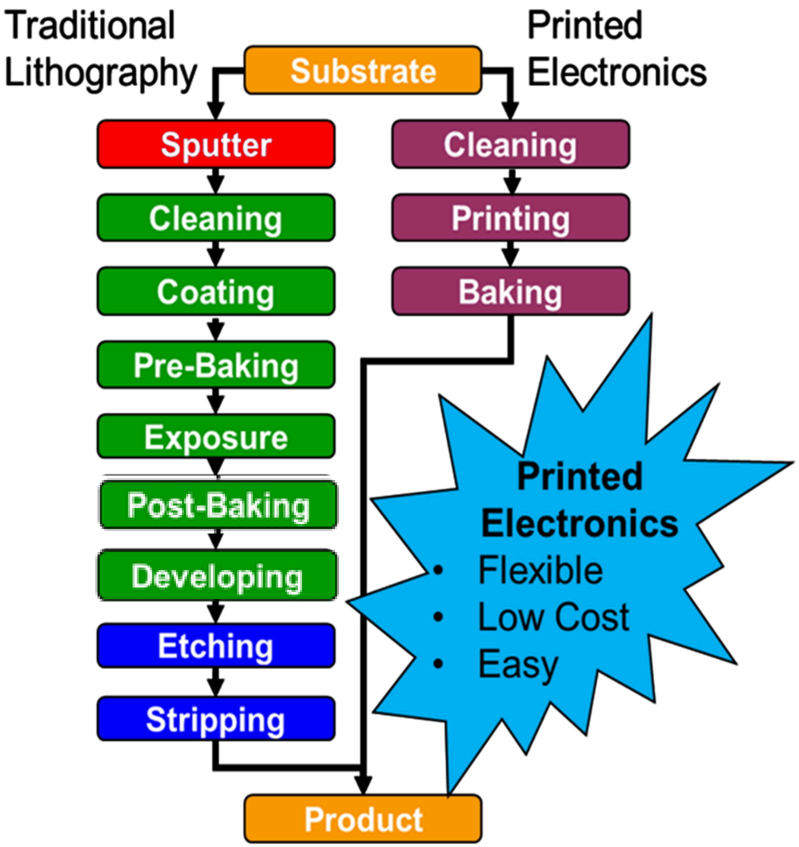
Overview

- Introduction
- Background
- Experimental
- Results
- Conclusions

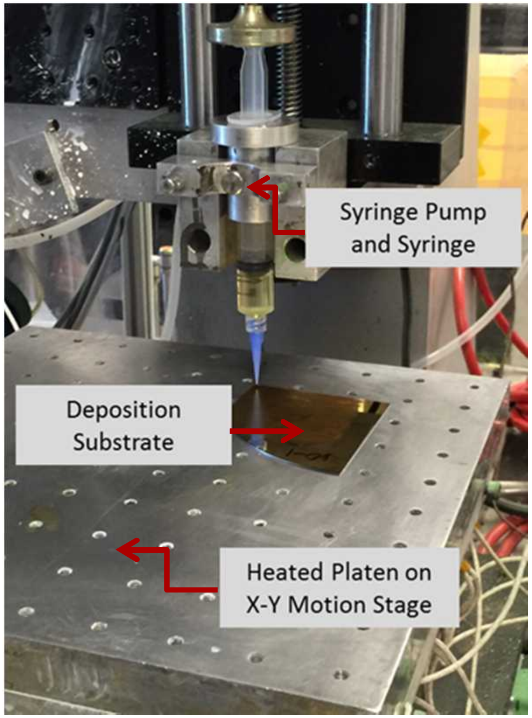
Why Printed Electronics?

- Eliminate many pieces of expensive equipment
- Tooling needs reduced
- Offers design flexibility
- Printers can be digitally reconfigured
- Offers more packaging options
- Minimization of processing supports high quality, high yield component fabrication

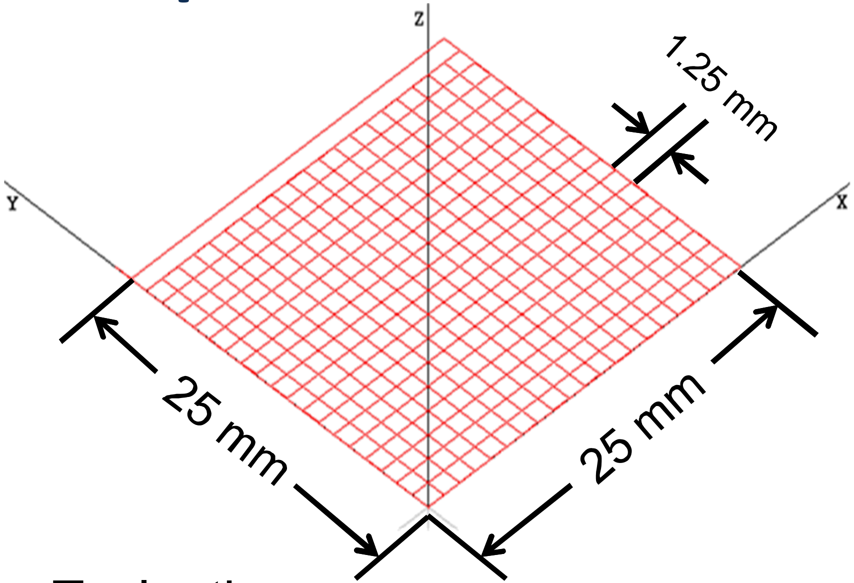




Experimental Setup



Tooling Setup



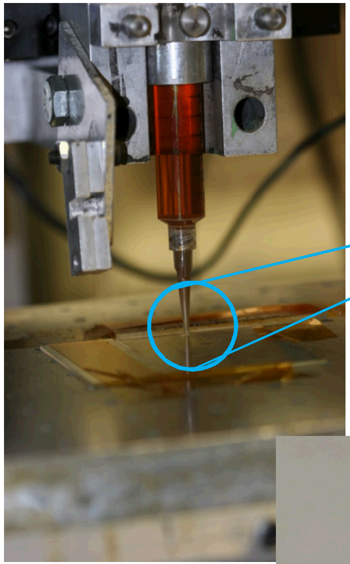
Toolpath:

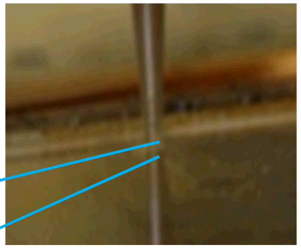
- Creates serpentine pattern for first layer in X-direction, and then an orthogonal pattern in the Y-direction for second layer.
- Table Speed 900 mm/min
- Extrusion Rate 0.045 ml/min

Print Variable Study

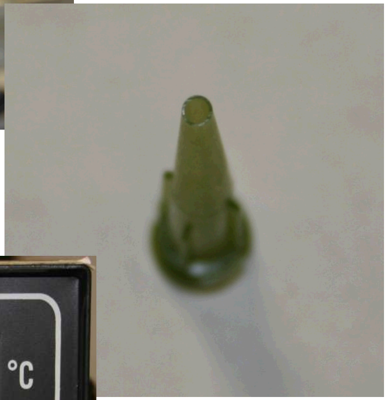
Variable	Values			
Temperature (°C)	60	80	100	120
Tip Diameter (mm)	0.25	0.41	0.84	1.19
Tip Height (mm)	0.125	0.188	0.25	0.313

- Material used: UT Dots PI1-AJ
- Substrate: Glass slides cleaned with acetone
- Material preparation: Degassed in vacuum oven for 15 minutes at 60 ℃
- Curing temperature: 150 ℃
- Cure time: 30 minutes
- Total number of samples: 64



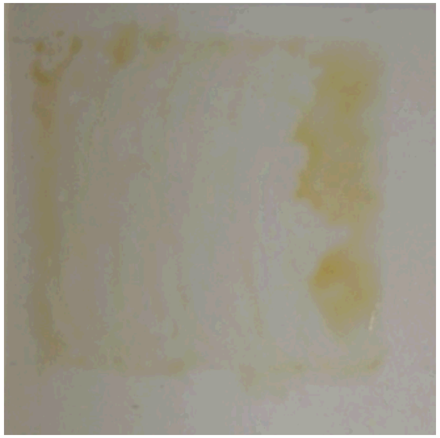


Nozzle offset

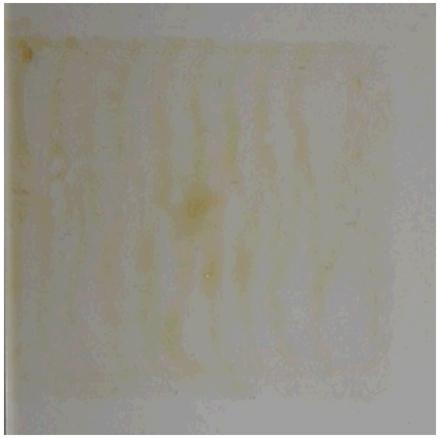


Tip Diameter

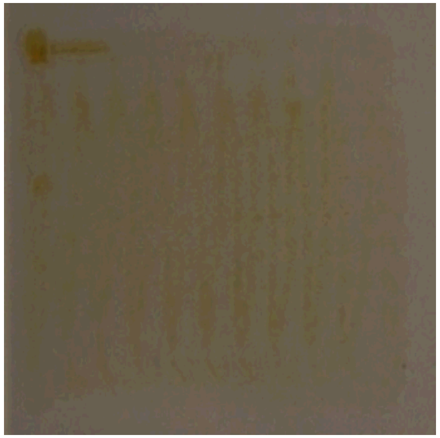
Platen Temperature



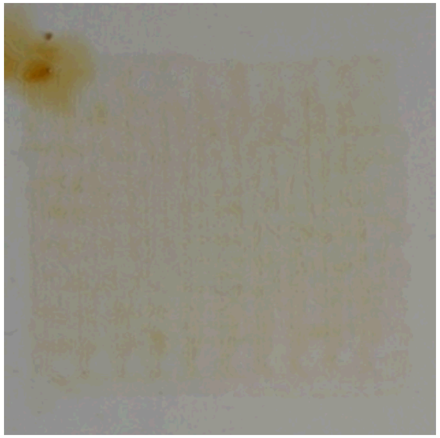
60℃



80℃

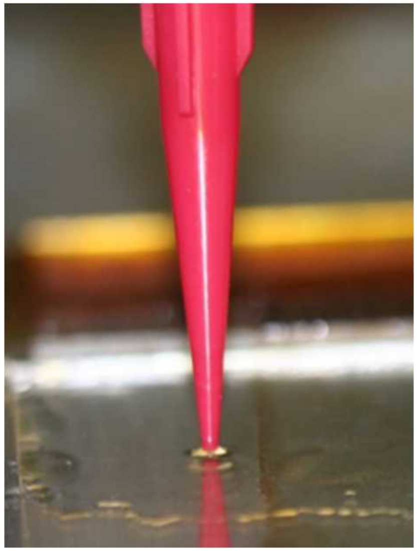


100℃

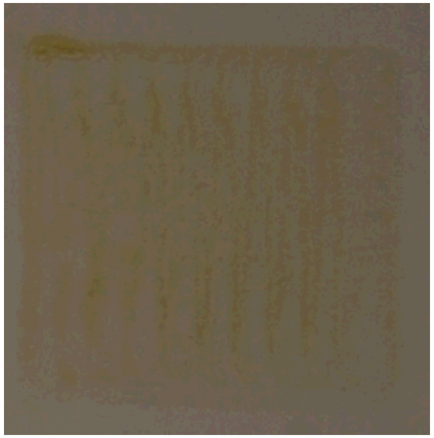


120℃

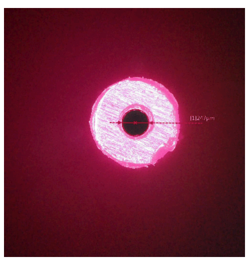
- At low temperature material runs on substrate
- Low temperature thickness about 15 μm
- At low temperature the material is pushed away from targeted deposition area by the meniscus that is formed between the tip and substrate
- At high temperature material stays in place
- High temperature thickness about 21 μm
- High temperature film is much more uniform



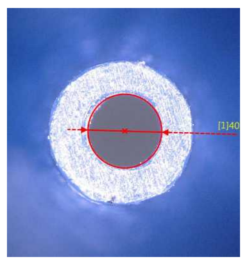
Tip Diameter



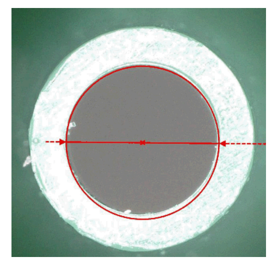
0.25 mm

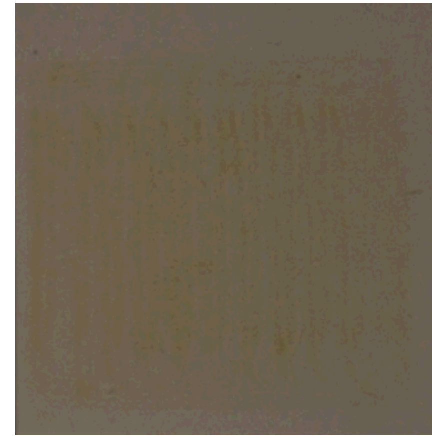


0.41 mm

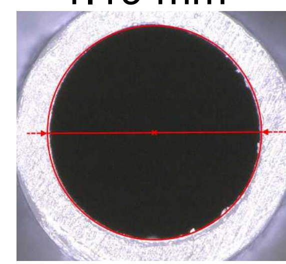


.84 mm



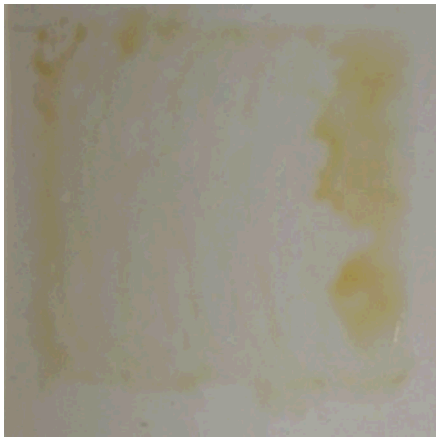


1.19 mm



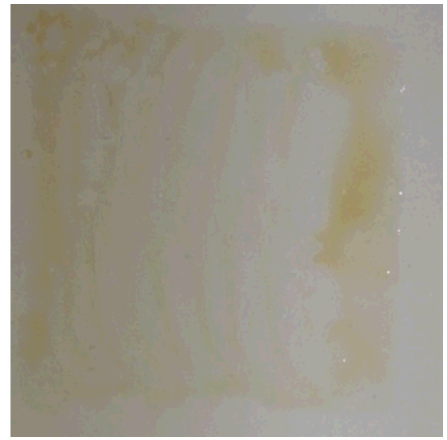
- Similar film thickness for all samples
- Data did not suggest any substantial change in film quality as tip diameter increased

Tip Height (low temperature 60 °C)

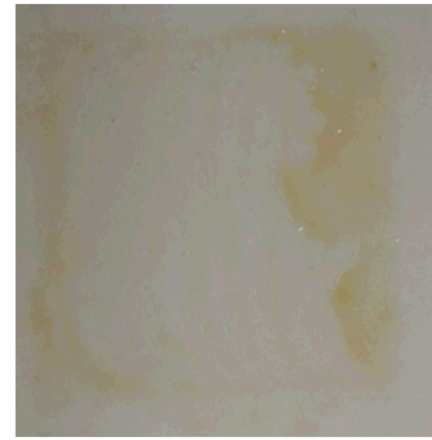


0.125 mm

0.188 mm

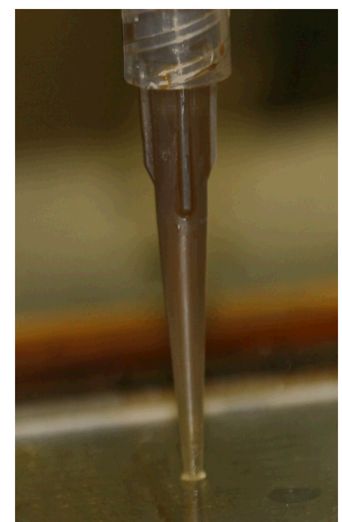


0.25 mm

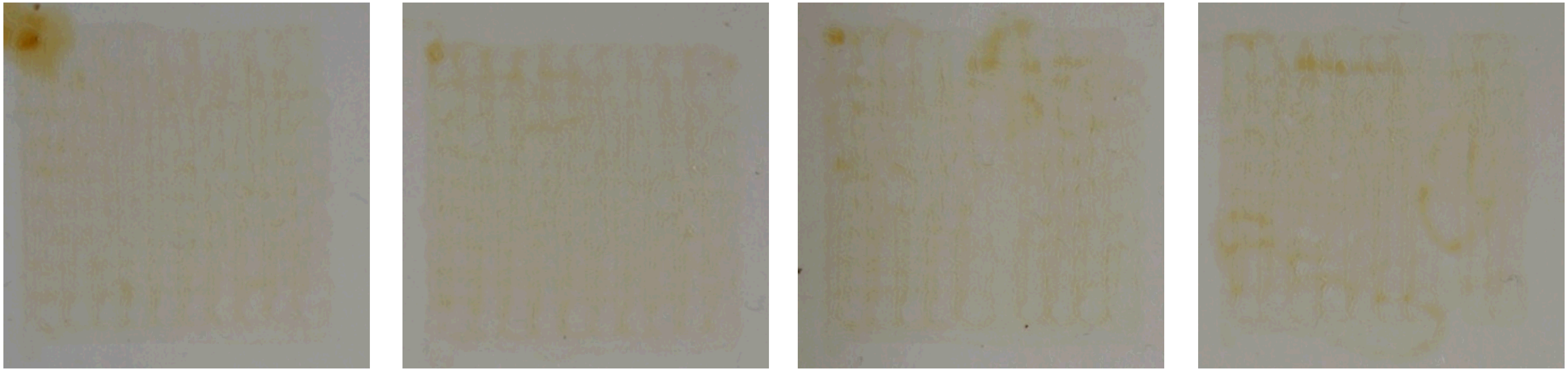


0.313 mm

- Tip height did not change the quality of the print at low temperature.
- At low temperature polyimide ink had excessive flow on substrate.
- Material was moved from target deposition area by meniscus between tip and substrate at all tip heights.

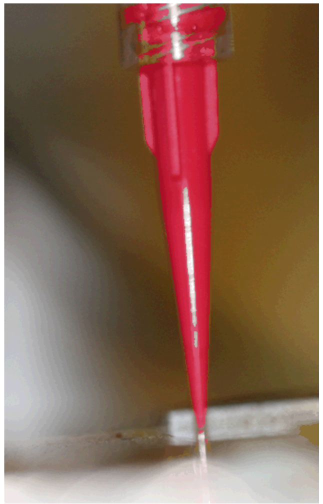


Tip Height (high temperature 120 °C)



.125mm .188mm .25mm .313mm

- At low tip height material adhered to substrate well
- At higher tip height the heat caused the meniscus between the tip and the substrate to disconnect causing inconsistent deposition
- The drops of material that landed on the substrate caused “coffee staining” in the film



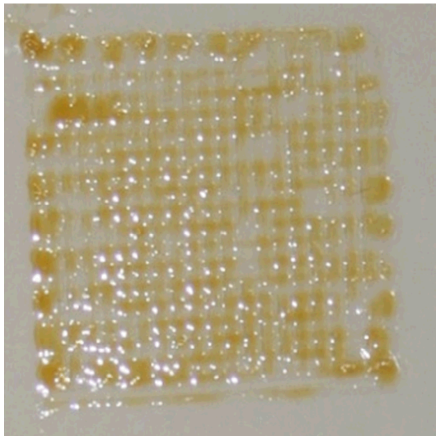
Material Study

Solvent	Dilution			
Water (Polyimide:Water)	1:1	1:2	1:3	1:4
Ethanol (Polyimide:Ethanol)	1:1	1:2	1:3	1:4

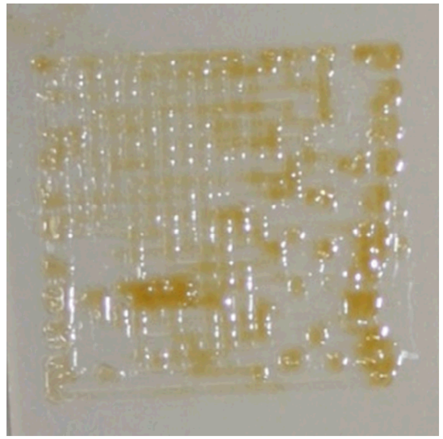
- Material used: UT Dots PI-SD2
- Substrate: Glass slides cleaned with acetone
- Material preparation: Degassed in vacuum oven for 15 minutes at 60℃
- Curing temperature: 150℃
- Cure time: 30 Minutes
- Total number of samples: 8

Range of concentrations used in the material study

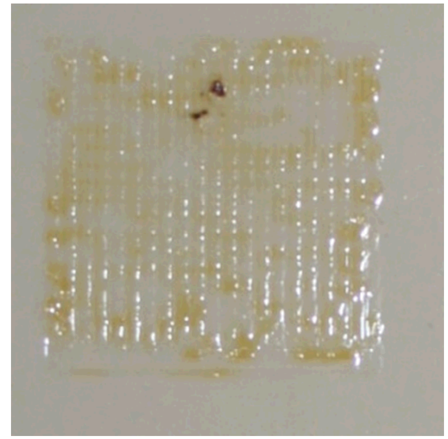
Water as Solvent



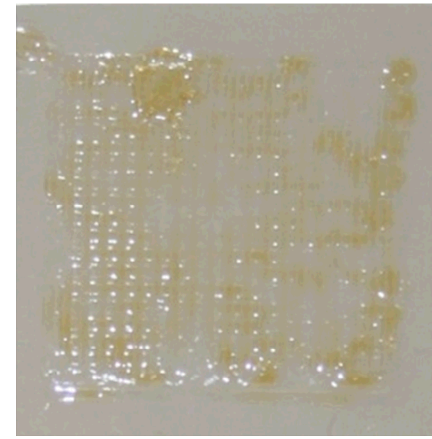
1:1



1:2

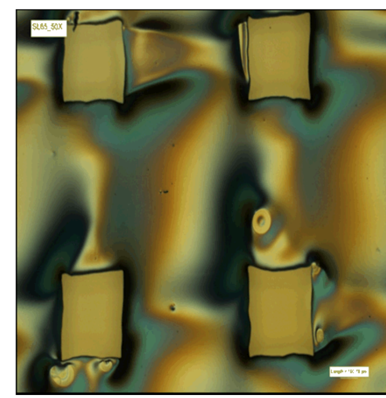


1:3



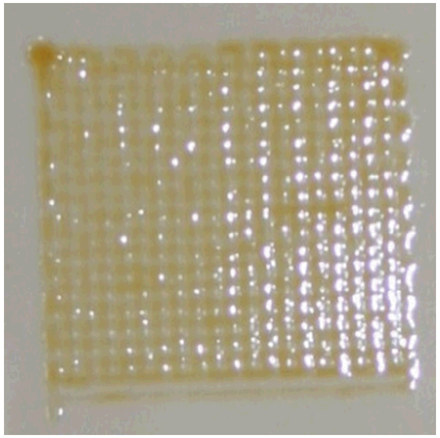
1:4

- 1:1 dilution had the least amount of material flow in-between rasters causing very distinct mounds of material
- Water did not wet to the glass slides causing rough and inconsistent films
- Overall the film becomes thinner and smoother as the polyimide is diluted more

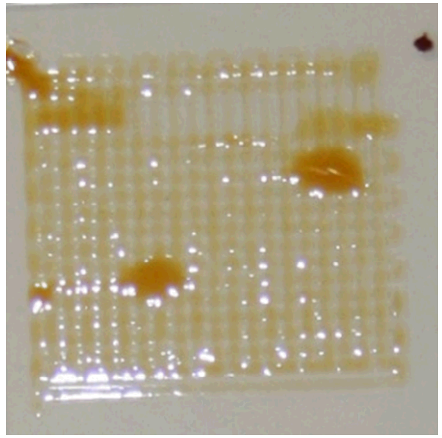


50x image of 1:1 dilution

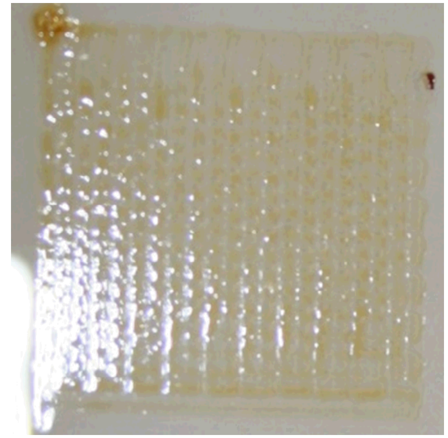
Ethanol as Solvent



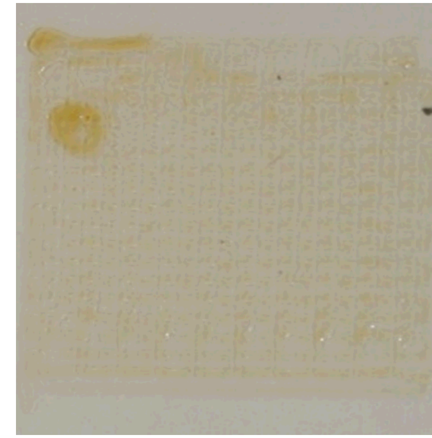
1:1



1:2

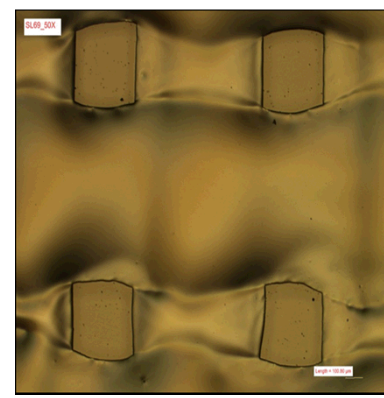


1:3



1:4

- 1:1 dilution had the least amount of material flow from one raster to the next causing very distinct mounds of material
- Ethanol allowed a the material to have a more complete wetting to the substrate causing smoother and more consistent films
- Overall the film becomes thinner and smoother as the polyimide is diluted more



50X image of 1:1 dilution

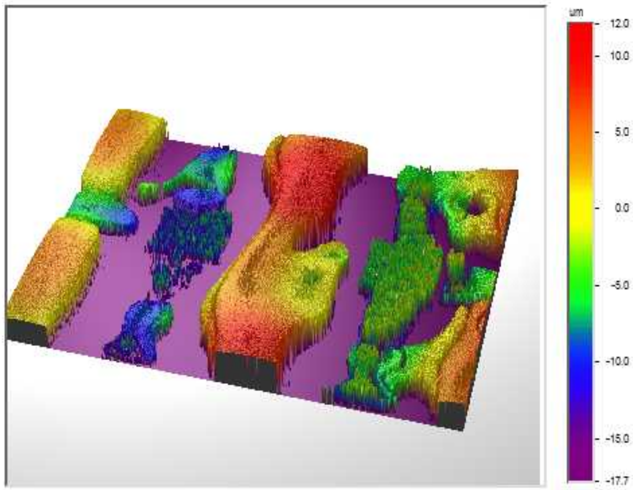
Ethanol vs. Water as Solvent

Surface Stats:

Ra: 5.46 um

Rq: 6.34 um

Rt: 29.77 um



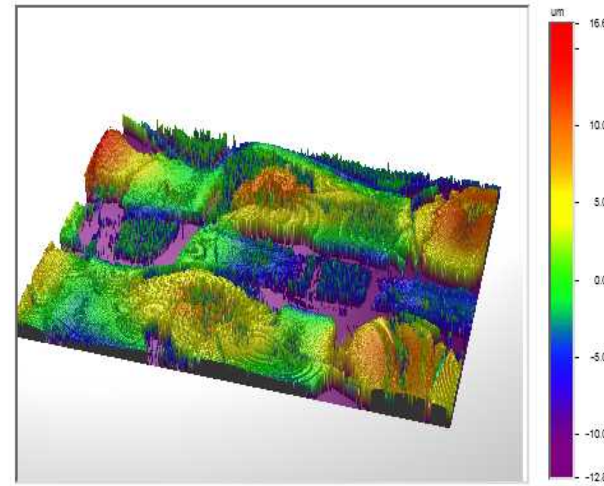
Water

Surface Stats:

Ra: 4.01 um

Rq: 4.89 um

Rt: 29.33 um



Ethanol

- 3D film thickness measurements with WYKO optical profilometer.
- Both images are of 1:1 dilution
- Ethanol left a smoother film even with 1:1 dilution
- Surface energy's play a big role in how smooth the polyimide film is

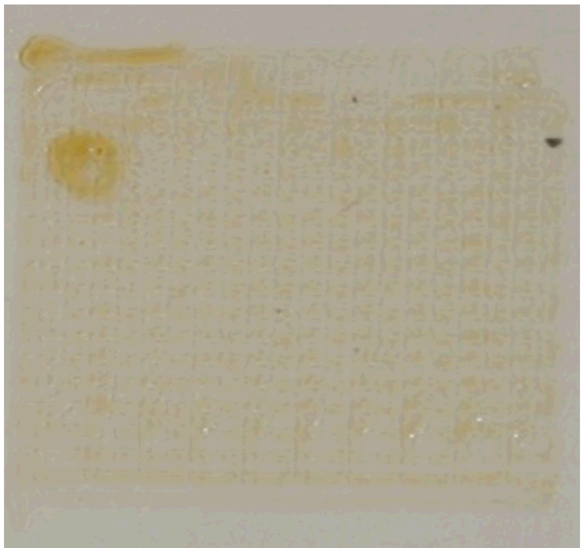
Conclusion

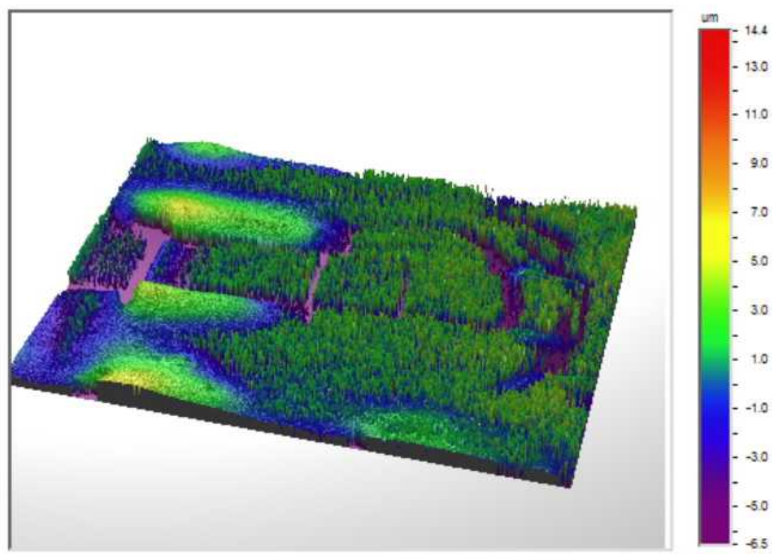
Best Print Variables

- 120℃ Platen temperature
- Any tip diameter
- 0.125mm tip height

Best Print Solvent/Dilution

- UT Dots PI-SD2 polyimide precursor
- Dilution 1:4, UT Dots:Water





Surface Stats:

Ra: 1.77 um

Rq: 2.13 um

Rt: 20.95 um

Best Parameters from each study

Future Work

- Multiple layer films
- Curing in between layers
- Other options for exploiting surface energy
- Toolpath parameters such as table speed, extrusion rate, and raster width