Team 19

CNT Reinforced Ceramics 3D Printer

Midterm I Presentation

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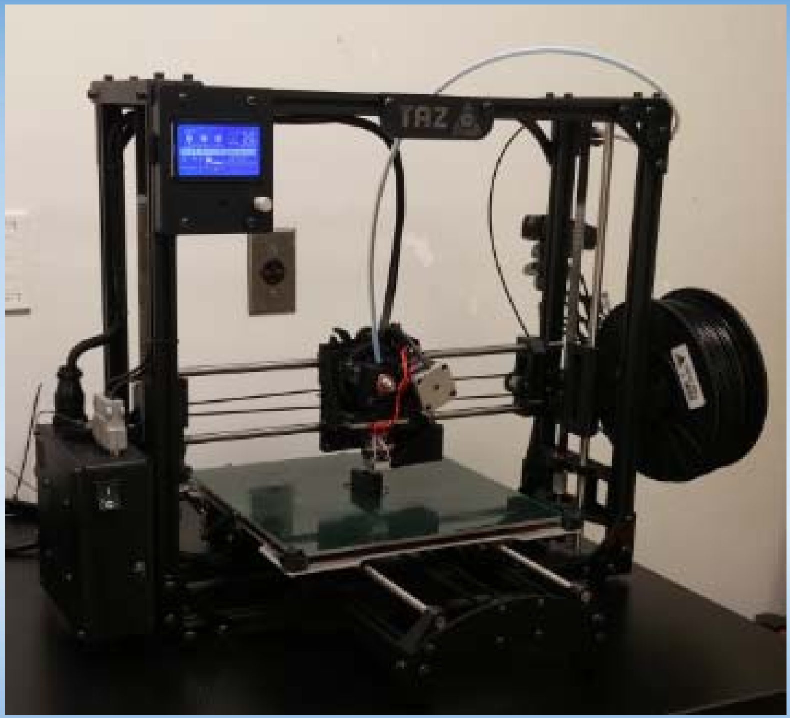
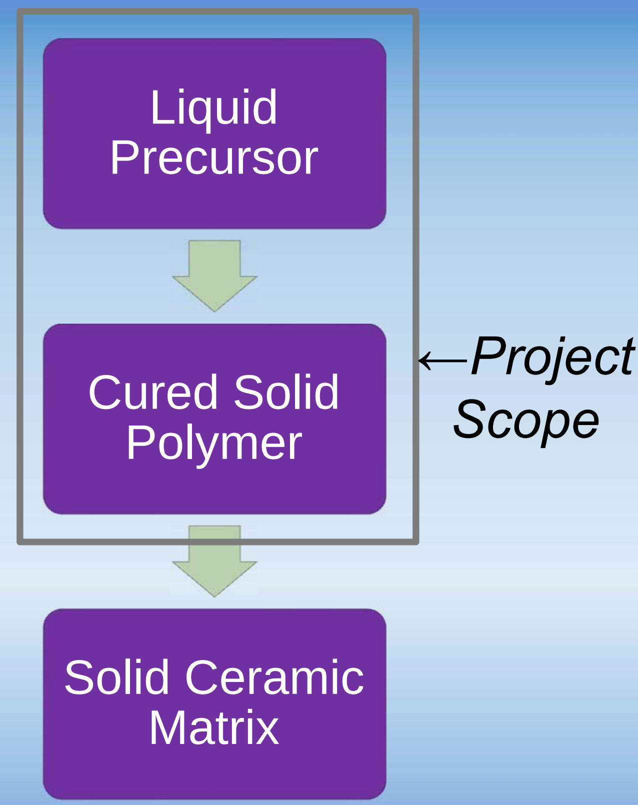


Figure 1. The TAZ 3D printer to be retrofitted.

Introduction and Background

- **Goal**: print solid parts using liquid polymer precursor
  - Additive manufacturing allows creation of arbitrary part geometry with no wasted material
- **Scope**: Retrofitting a 3D printer to extrude the liquid polymer precursor and curing the precursor layers during the print job



Polymer Matrix

- Low viscosity liquid polymer matrix
- Curing reagent added for solidification
  - Heat or UV light options available
  - Reagents to control curing time
- Precursor for ceramic material
- Nanopowders
  - Carbon Nanotubes (CNTs) or Silicon Carbide
  - Enhance material properties of ceramic
  - Increases viscosity

Project Scope →

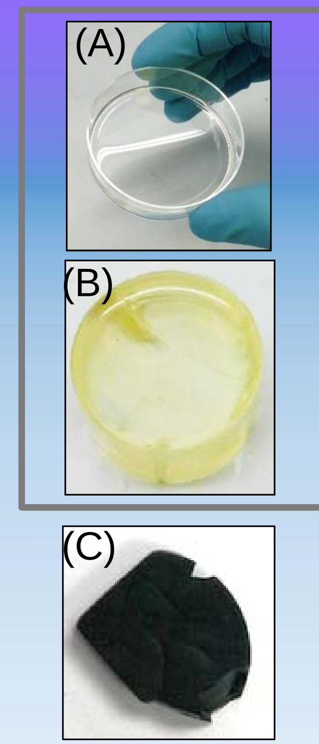
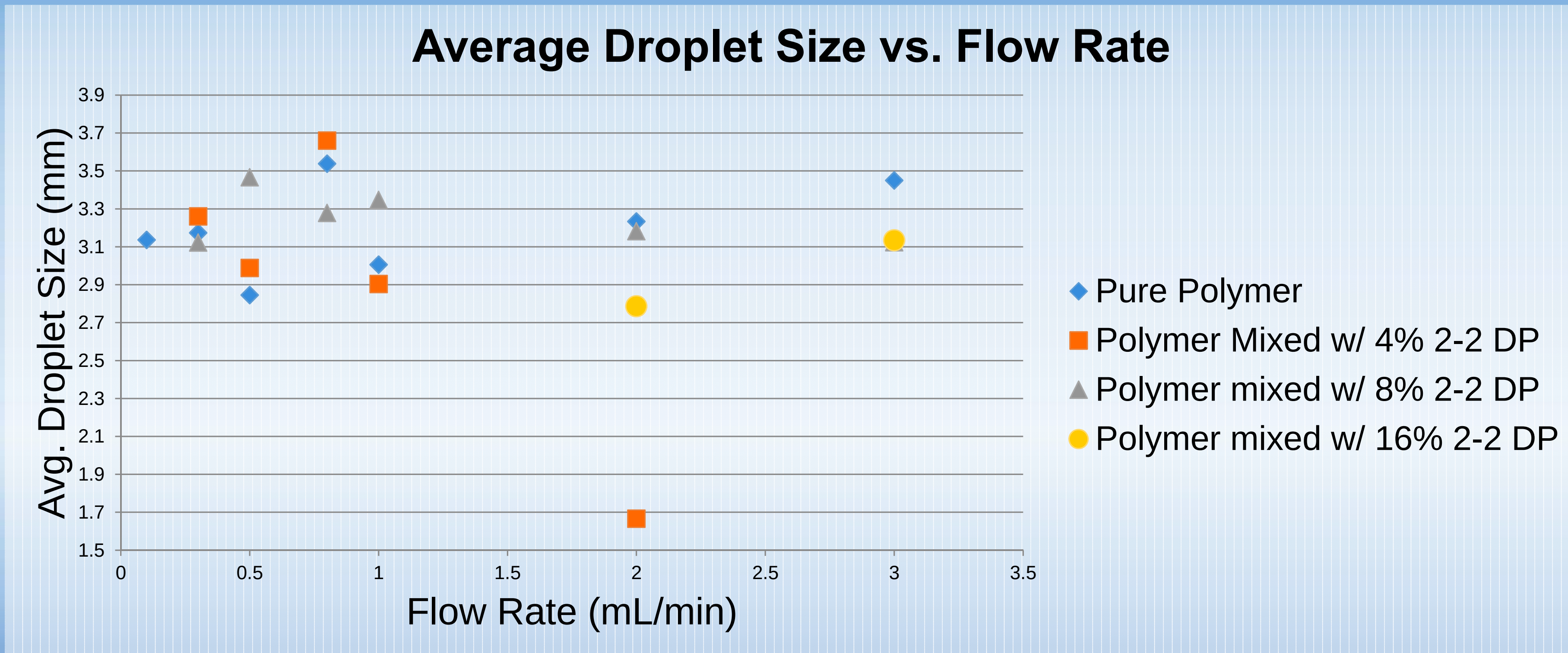


Figure 2.
(A) Liquid pure polymer
(B) Cured solid polymer matrix
(C) Solid ceramic matrix

Testing / Experiments



Testing / Experiments

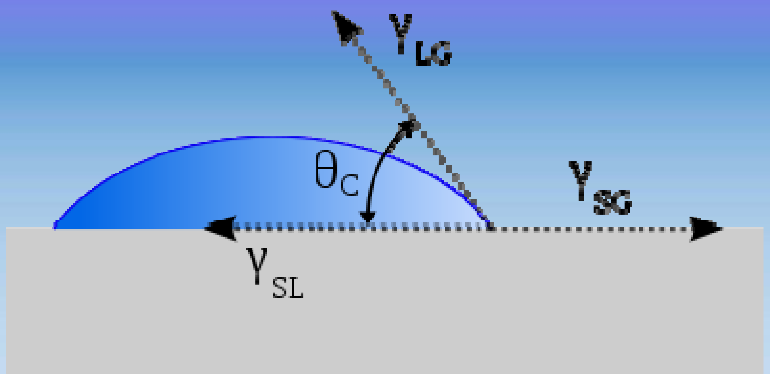


Figure 3. A liquid droplet on a substrate with interface angle labeled.

Polymer Extrusion

- Minimizing droplet size
- Surface Tension
  - $\theta_c = cos^{-1}\left(\frac{\gamma_{SG}-\gamma_{SL}}{\gamma_{LG}}\right)$
  - Droplet geometry controlled by substrate, ambient, and material interface interactions
  - Only controllable variable is substrate

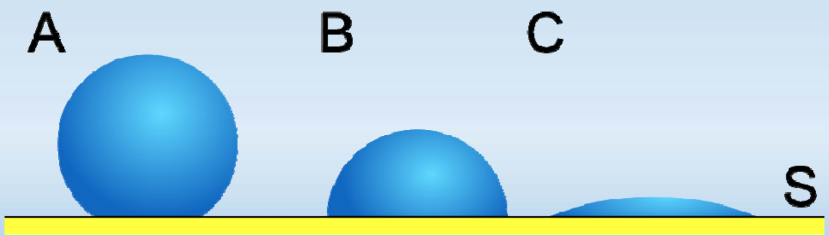


Figure 4. An example of varying droplet geometries and their contact angles with surface S; (A) large contact angle; (B) medium contact angle; (C) small contact angle

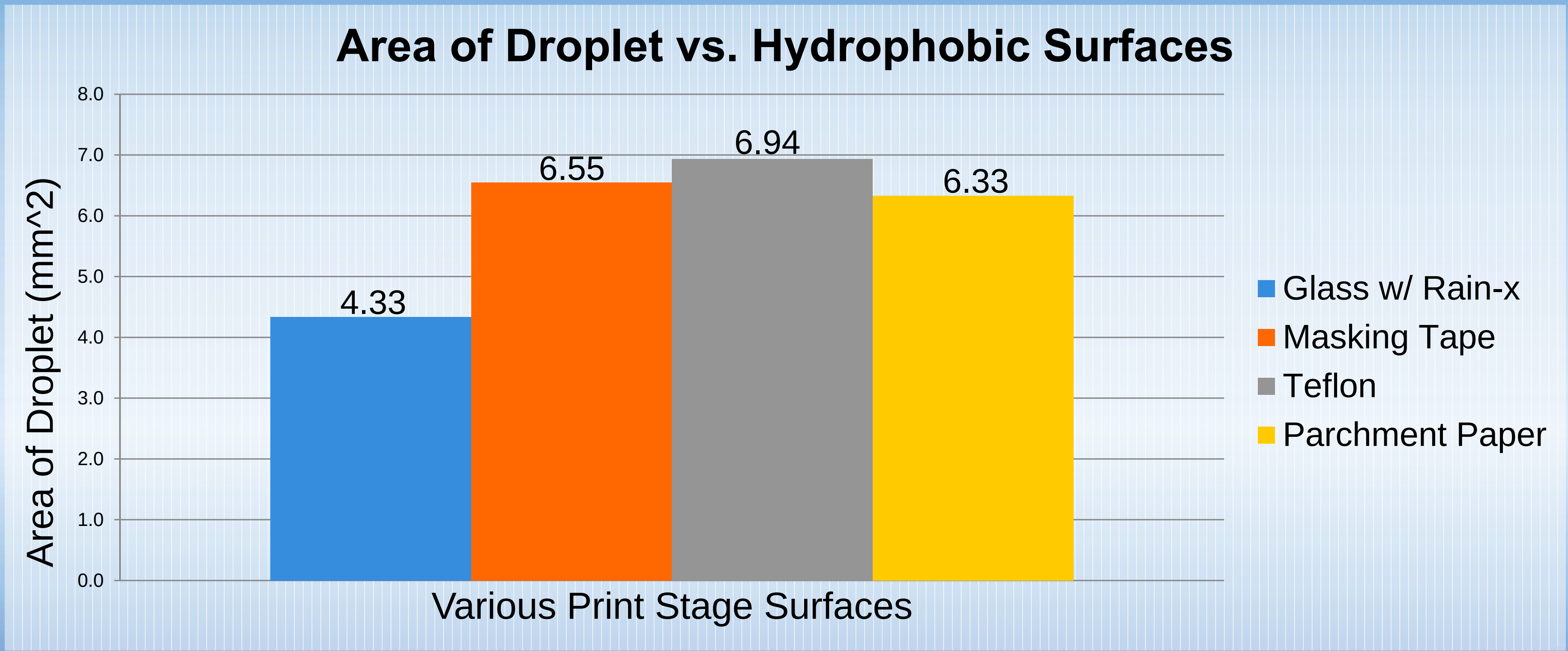
Testing / Experiments

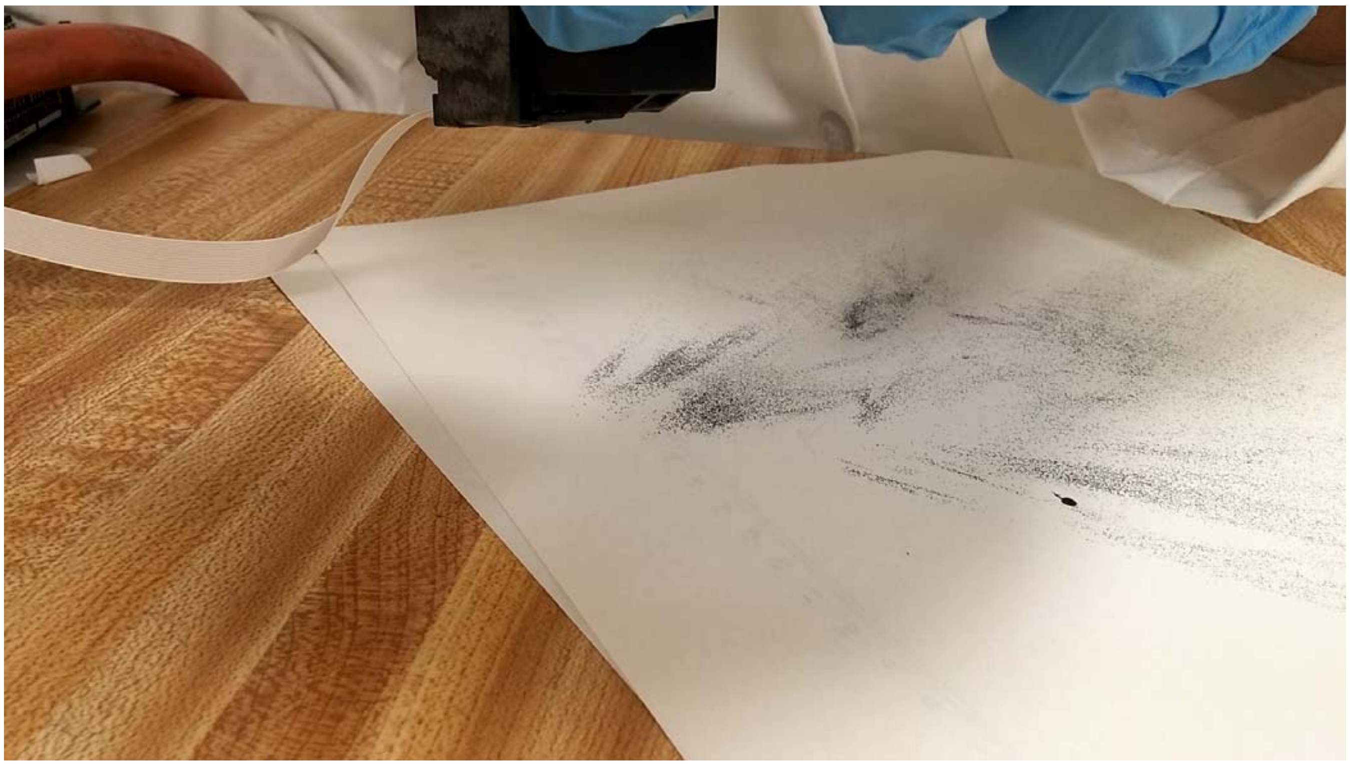
Polymer Extrusion

- Substrate Interface
  - 25 mL syringes controlled by a half step motor
  - Extrude polymer matrix onto varying print bases with different tips
    - Masking Tape
    - Teflon
    - Glass with RainX
    - Parchment Paper

Figure 5. Numerous tests on different surfaces

Testing / Experiments





Testing / Experiments

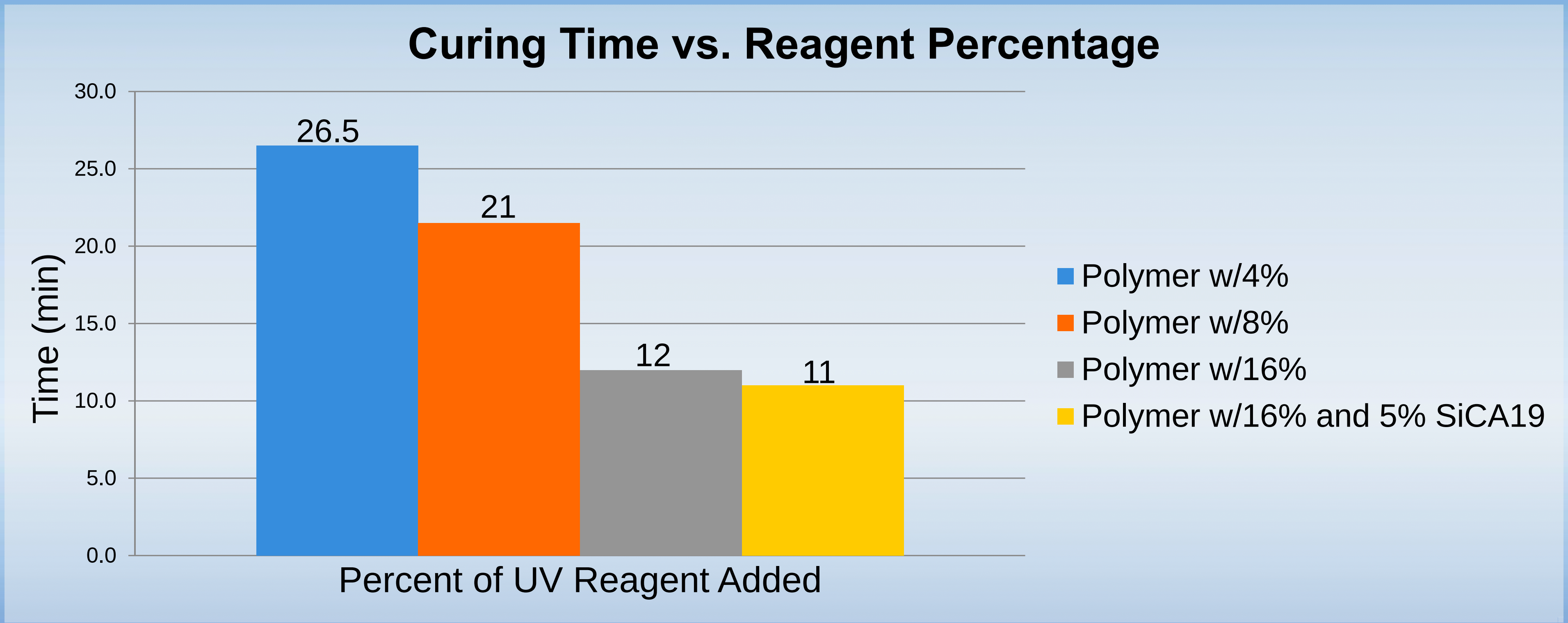
Polymer Curing

- LED Array (240 mW)
  - Power output insufficient to quickly cure material
  - Considering experimental parameters
    - **Size of the array**
    - **Placement**
    - **Focus**
    - **Timing**
- Higher power array ordered, defective
- Experiment: How does curing reagent effect curing time?

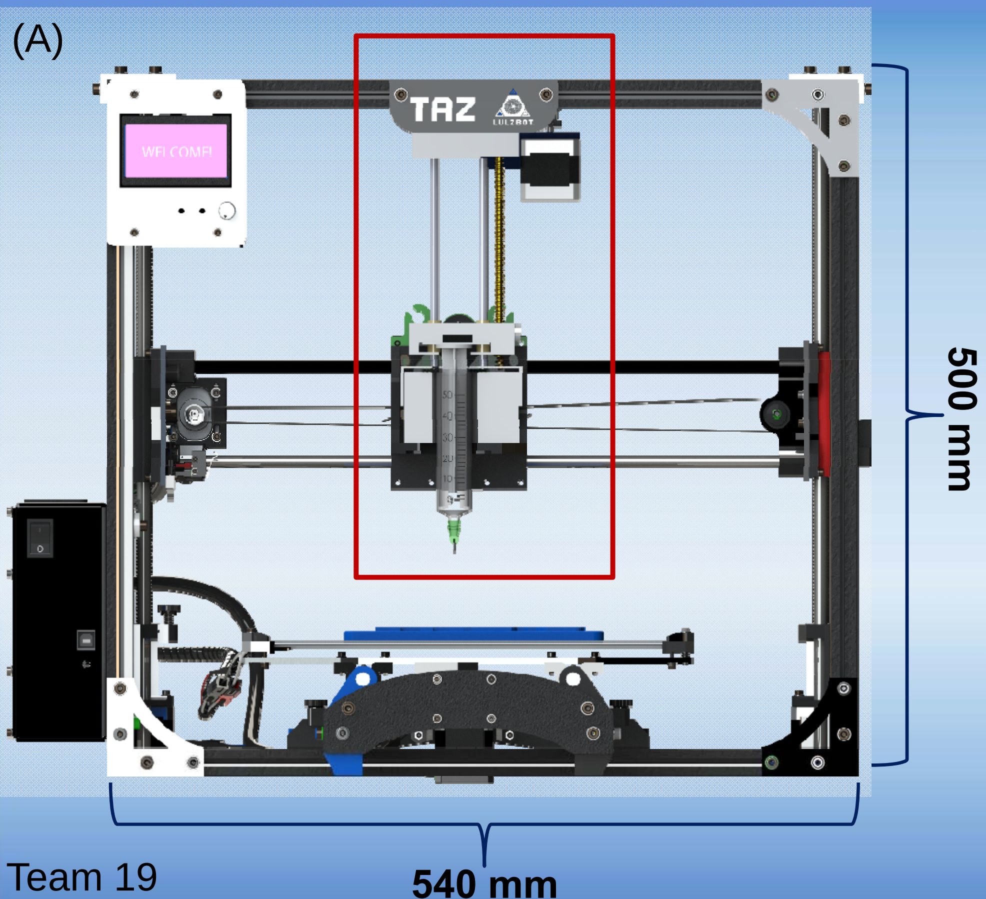
Figure 8. Testing the polymer curing time with UV LED bulbs.

Figure 9. The LED Array with 20 W power output.

Testing / Experiments



Renderings



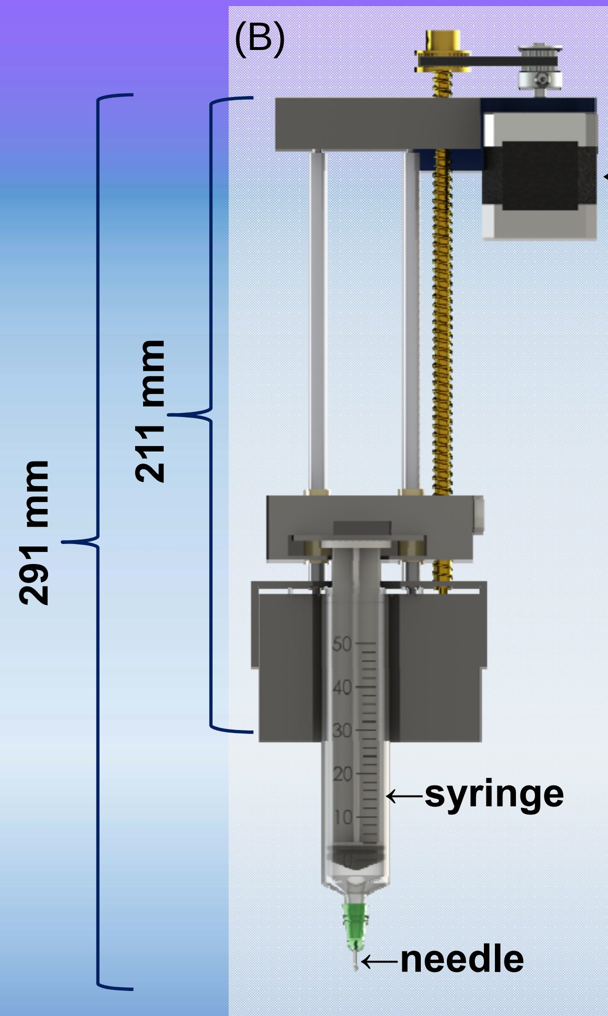


Figure 10. (A) The full 3D printer system after retrofitting the syringe pump. (B) A blow up of the syringe assembly with major parts labeled.

Current Actions

- AME open house
- Printing parts for custom design
- Viscosity variation testing
  - Find optimal solution by varying viscosity
- Dedicated operating PC
- UV Curing System
  - LED Array
  - Lamp / Bulb
- OPM and Design Manufacturing Reports

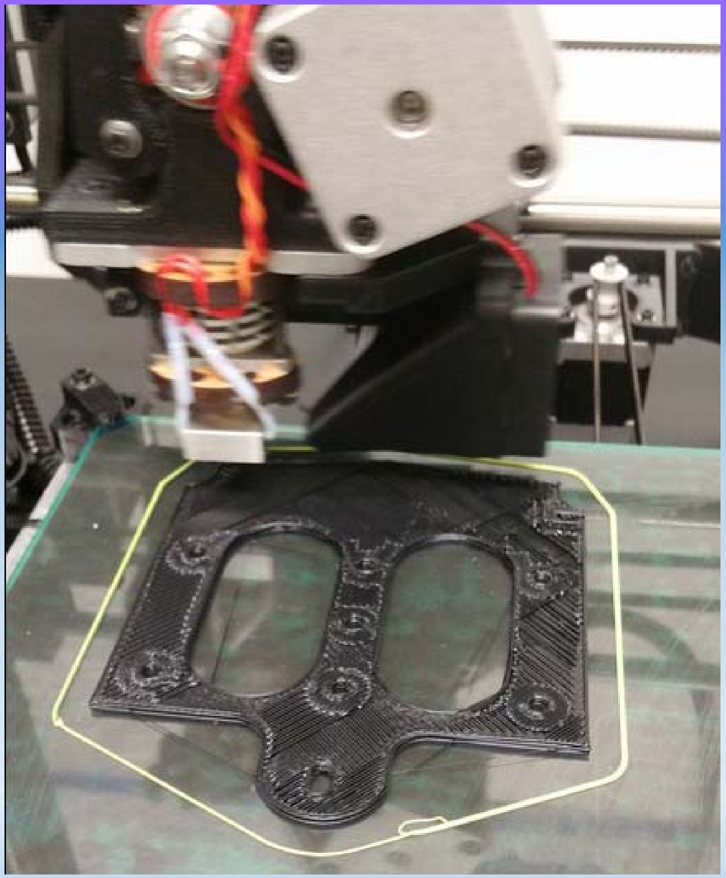


Figure 11. Printing part of the mount for the syringe to be retrofitted onto the existing printer.

Budget

Date	Supplier	Item	Total Cost
11/3/2014	Mouser Electronics	Arduino Mega	$45.95
11/3/2014	Nicholas C. Lewis	Inkshield	$66.00
11/3/2014	Digi-Key Corp.	UV Lights	$58.06
12/1/2014	Lulzbot	3D Printer	$1,995.00
12/11/2014	SIGMA-ALDRICH	Needles	$83.30
12/11/2014	Amazon	Thermometer	$29.99
12/11/2014	Amazon	Webcam	$69.65
12/1/2014	Amazon	Tripod	$22.75
1/14/2015	Lulzbot	ABS Filament	$171.80
1/29/2015	Amazon	UV Lamp	$89.00
1/29/2015	Amazon	UV Safety Glasses	$64.80
1/29/2015	Amazon	Blunt Tips	$9.90
1/29/2015	4inkjets	Cartridges	$19.98
1/29/2015	Amazon	Syringes	$9.50
		TOTAL	**$2,735.68**

Challenges Faced, and Lessons Learned

- **CNT Alignment**
  - Simply not possible in given time period
- **Curing Method**
  - Began with two potential methods
  - How to incorporate within the frame
  - Focusing the light
- **Layer Adhesion**
- **Expect the Unexpected**
  - Entire scope altered

Conclusion

- ~65% Complete
- Future Actions
    - Final Report
    - Webcam and PC Interface
    - Physically Retrofitting 3D Printer
    - Finalize material mixture
    - Graduate student training

(A)

(B)

Figure 12. (A) Webcam with gooseneck clamp. (B) Control interface on printer with a print in progress.

Questions?

References

- *http://commons.wikimedia.org/wiki/File:Surface_tension.svg (Figure 4)*
- *http://nicholasclewis.com/projects/inkshield/ (Figure 6)*