

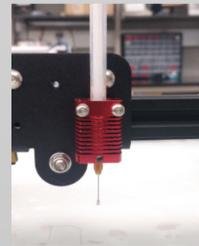
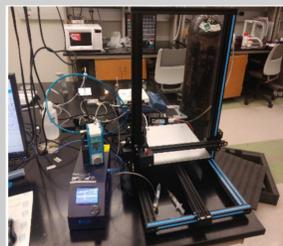
3D Printing of Thermally Insulated Thermosets

Kristen F. Arias, Biran Wang, Dr. Shiren Wang
Department of Industrial & Systems Engineering
Texas A&M University, College Station, TX 77843-3122

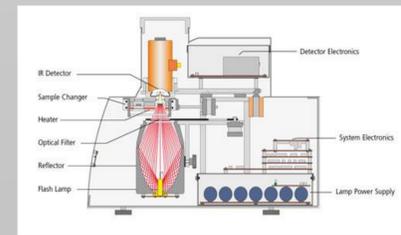
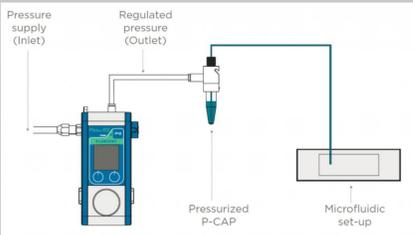
Introduction

Thermoset materials have become increasingly important by replacing various metals and alloys in a multitude of industries. In the aerospace industry, the ability to 3D print thermally insulated thermoset parts is especially vital for NASA space craft, both in keeping astronauts safe and allowing them to print needed parts in space. The Additive Manufacturing of thermosets has the potential to become more **cost effective, material efficient, time conserving** and **productive** in comparison to traditional means. In our research, we have utilized a newly developed ink that solidifies near instantaneously through **frontal polymerization**. We 3D printed thermoset samples with differing conditions, such as temperature, pressure and more. Finally, the thermal properties of the samples are being recorded for further study.

Equipment



SainSmart x Creality CR-10 Semi-Assembled Aluminum 3D Printer modified to be a **Direct Ink Writing (DIW) 3D Printer**



Flow EZ: Flow (Pressure) Controller

Flow EZ is capable of reaching 7000 mbar if provided enough initial pressure.

Laser Flash Apparatus (LFA) 447

We tested the thermal properties of the samples using liquid nitrogen and the LFA.

Thermal Conductivity = Thermal Diffusivity * Specific Heat * Density
Thermal Diffusivity = Sample Height / Half-Time Rise of Heat

Ink Preparation



0.6ul of TEP inhibitor

400 ul of GC2 catalyst

5g of DCPD (95%)+ENT(5%)

Mounted in the Printing system

- Dicyclopentadiene (DCPD)
- Triethyl Phosphite (TEP)
- Phenylcyclohexane (PC)
- 5-ethylidene-2-norbornene (ENB)
- Second-Generation Grubbs' Catalyst (GC2)

Printed Samples and Morphology

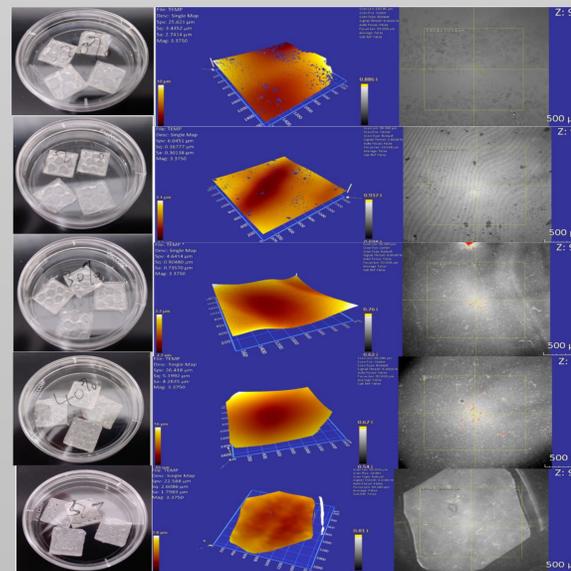
20% infill

25% infill

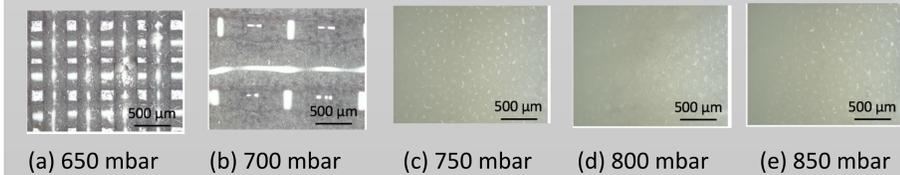
30% infill

40% infill

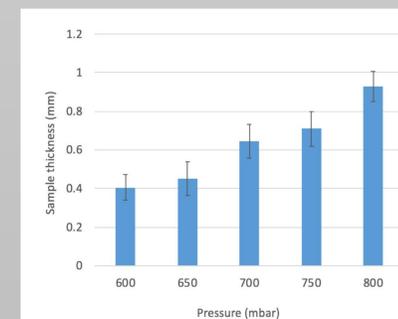
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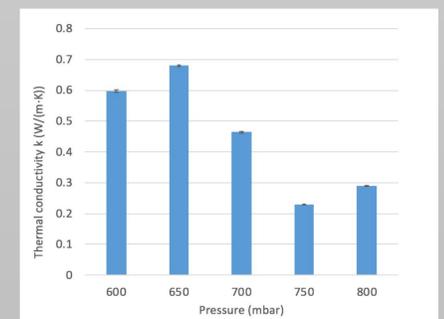
Results – Pressure



Sample Thickness - Pressure



Thermal Conductivity - Pressure



Future Outlook

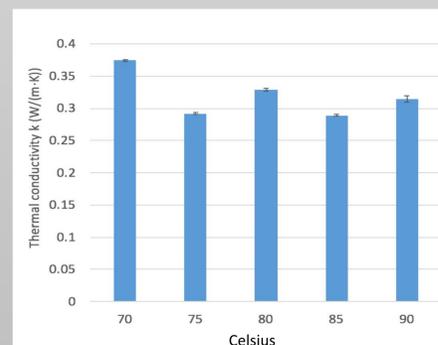
With the aim of improving thermal characteristics, we plan to test the effects of the following factors on the thermoset samples.

- 3D Printer printing speed
- Different sized needles
- 3D printing patterns

The combination of these factors is also important. For example, the pressure and temperature should be higher when the 3D printing speed is increased. Otherwise, the ink patterns will be discontinuous and the layers will not cure fast enough.

Results - Temperature

A higher temperature of the 3D printer bed leads to a faster curing for the thermoset object being printed. The temperature's effects on thermal characteristics is still largely inconclusive at this point in our research.



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