Multiphase polymer/nanoparticle 3D printing with shape memory property for untethered actuation

Darius Hampton-Ross, Aerospace Engineering
Mentor: Dr. Kenan Song, Associate Professor
School for Engineering of Matter, Transport, and Energy

SONG LAB

INTRODUCTION

Material Extrusion is one of six main 3D printing categories used in the development of advanced materials, and more specifically in polymers and composites. It works by utilizing the continuous filament of thermoplastic or composite material to construct 3D parts. . The material extrusion category is broken into two methods: Fused Deposition Modeling and Direct Ink Writing. Both methods work by nozzle extrusion and patterned layering onto a building platform, but Fused Deposition Modeling works by melting solid filaments before extrusion and Direct Ink Writing works directly with inks such as polymer solutions.

ADDITIVE MANUFACTURING

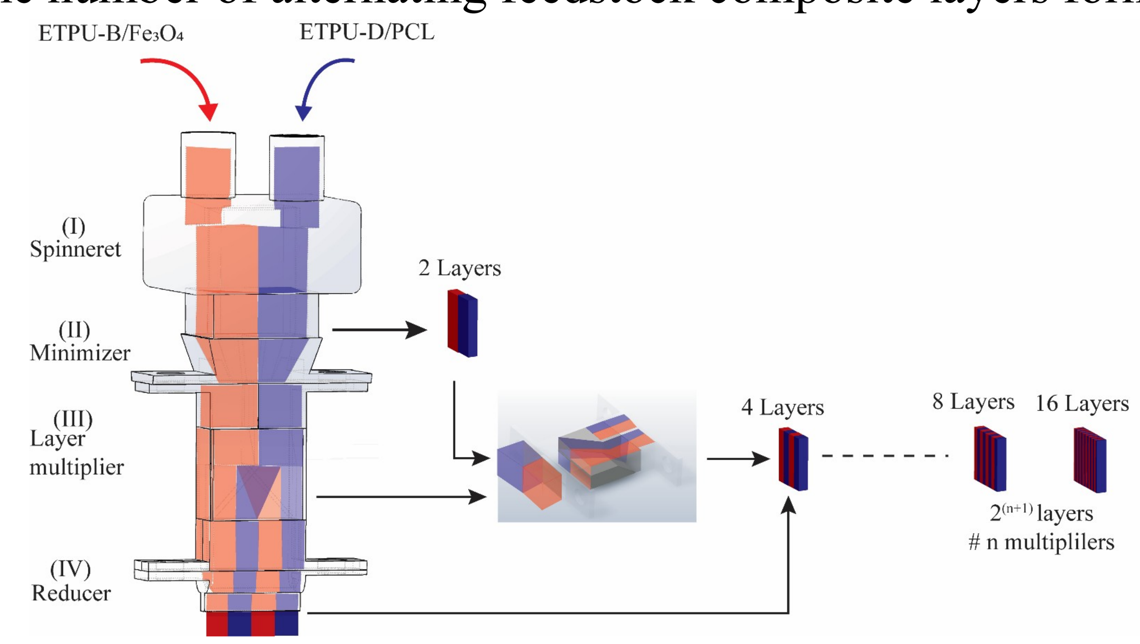
- Vat Poly
  - Steriolithography (SLA)
  - Digital light processing (DLP)
  - Continuous liquid interphase production (CLIP)
  - Multiphoton polimerization (MPP)
- Mat Ext
  - Fused deposition modeling (FDM)
  - Direct ink writing (DIW)
- Mat Jet
  - Materiel jetting
  - Binder jetting
- PBF
  - Selective laser sintering (SLS)
  - Selective laser melting (SLM)
- DED
  - Powder-based
  - Wire-based
- SLM
  - Laminated object manufacturing (LOM)
  - Ultrasonic additive manufacturing (UAM)

Method

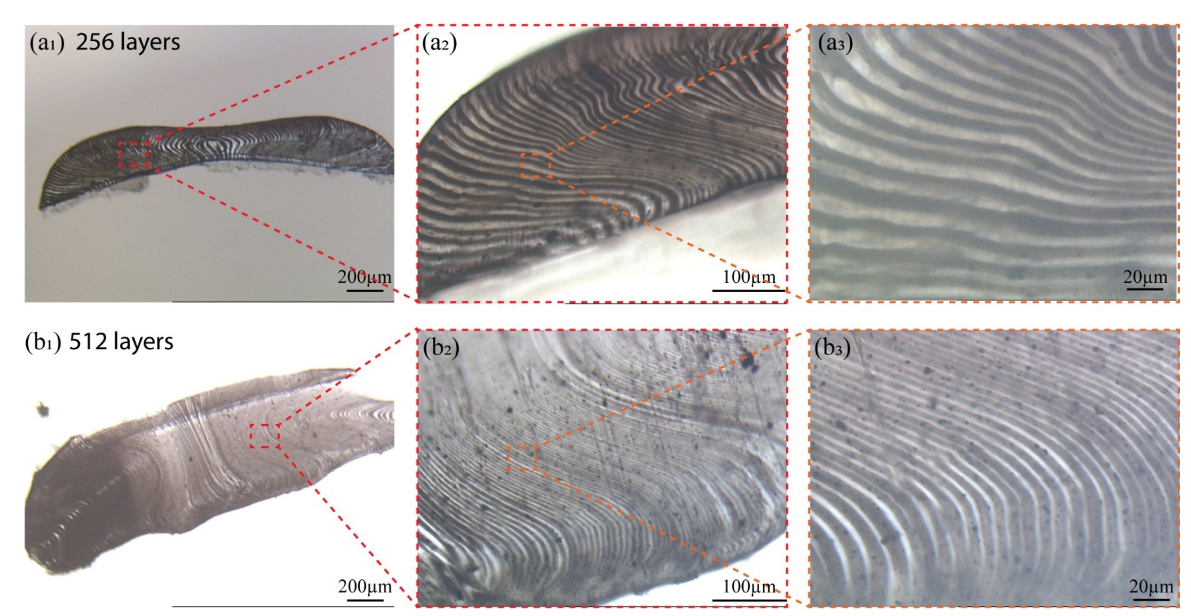
The multiphase direct ink writing is a newly developed 3D printing mechanism following the traditional material extrusion 3D printing process. It is designed to take in two feedstocks as inlets while rearranging them to form layers within each printed line.

Mechanism

Two feedstock composites are fed into nozzle inlet ports. The feedstock flow through a series of compartments varying in dimension and shear rate. In the layer multiplier, the inflow feedstock is divided horizontally and rearranged vertically to form alternating layers of the inlets. The multiplier in the nozzle determines the number of alternating feedstock composite layers formed.



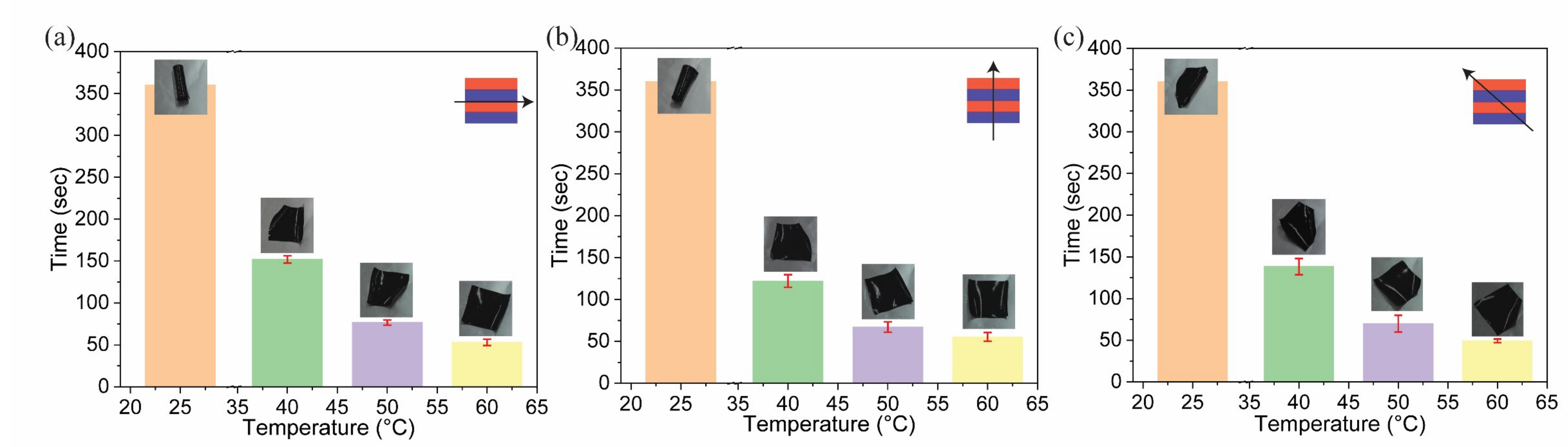
The two feedstock composites are A. TPU 1254D13U / PCL which primarily features high-temperature sensitivity and B. TPU B60A 10 WHTSG000 / Fe_3O_4 which primarily features high strength and magnetic stability. The resulting composite is intended to exhibit a compromise of both feedstock characteristics and produce both thermal and magnetically controlled actuation.



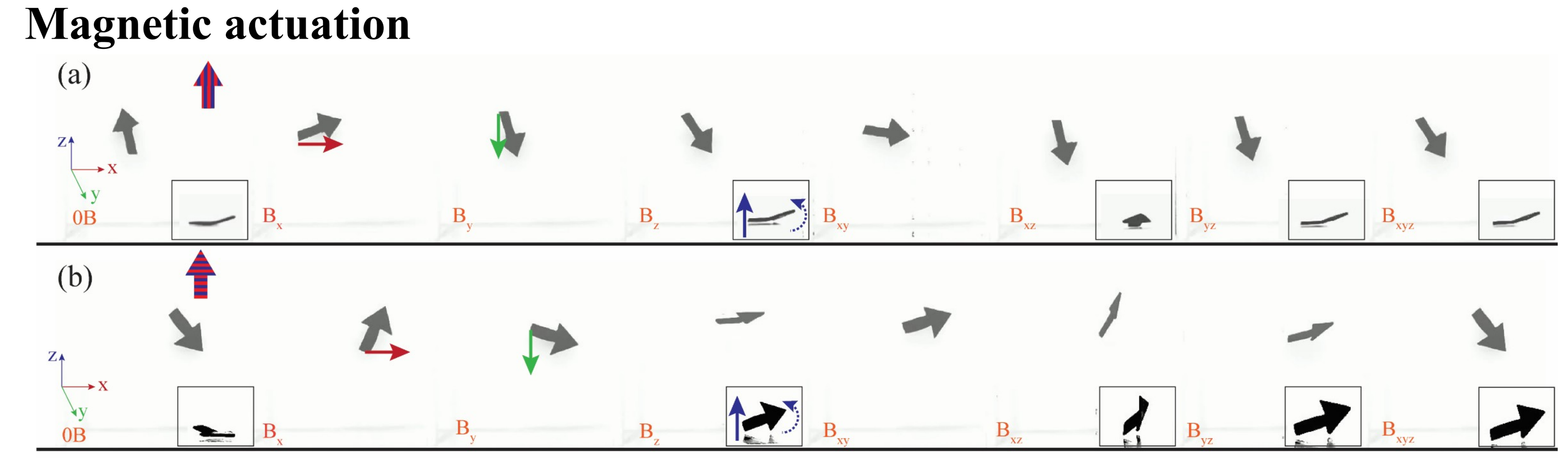
This methodology allows for efficient, high-quality prints capable of altering composites, which is useful when aiming for the optimization of nanoparticle distribution and their reinforcement effects. The MDIW 3D printing was developed with sustainable and optimum use of feedstock materials for large area printing without compromising on the print speed.

RESULTS

Thermal actuation



Magnetic actuation



CONCLUSION

- Successfully fabricated multiphase composites using two grades of TPU with shape memory property.
- The addition of PCL and Fe_3O_4 produced the necessary thermal and magnetic responsiveness with environmental control.
- Studied the actuation dependence on the layer direction and folding direction for both thermal actuation.
- Studied the dependence on layers direction for magnetic actuation using an electromagnetic system.

ACKNOWLEDGEMENTS

I would like to thank Dr. Kenan Song and Dharneedar Ravichandran for their support and guidance during my project in Song Lab. I also like to thank FURI for its support and recognition.

FURI

Ira A. Fulton Schools of Engineering
Arizona State University