3D PRINTING AND IN-SITU THERMAL CURING OF CONTINUOUS FIBER-REINFORCED THERMOSET COMPOSITES

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Outline

- Challenges in composite manufacturing
- Additive manufacturing of composite materials
- Composite printing using thermoresponsive thermoset resin
  - Discontinuous fiber composites
  - Continuous fiber composites
- Conclusions

Challenges in Composite Manufacturing

Boeing autoclave

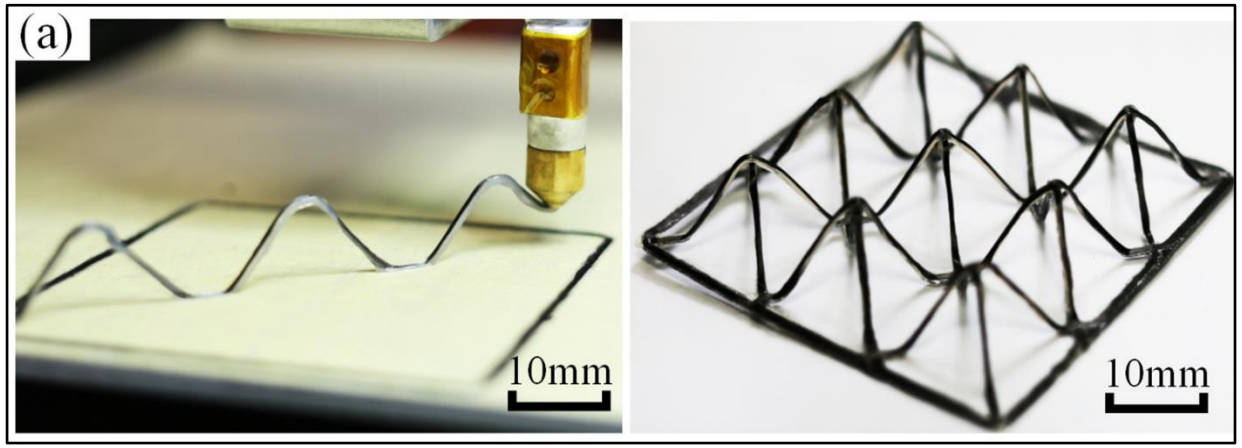
Heated mold for manufacturing a wind blade

Challenges in Composite Manufacturing

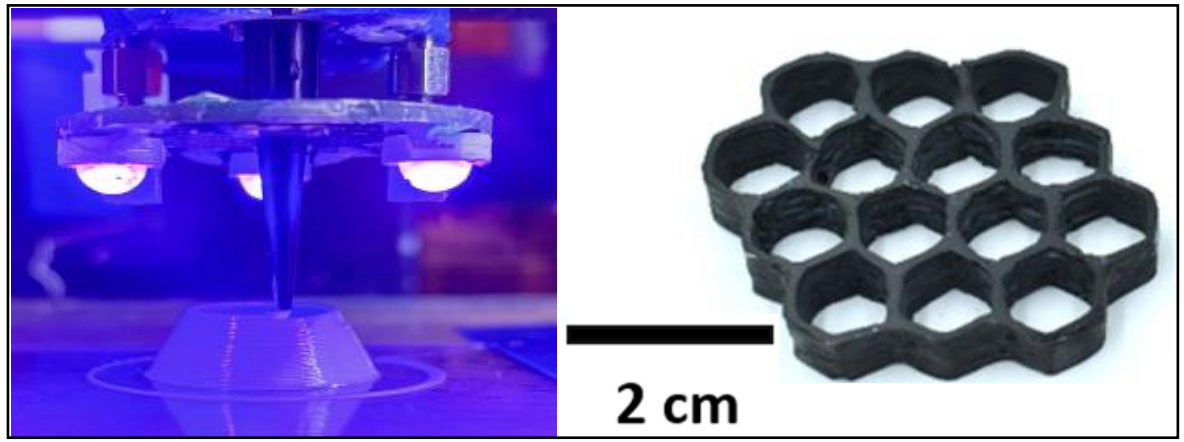
Subtractive Tooling Manufacturing

Additively Manufactured Tooling

Additive Manufacturing of Composites



Liu et al., *Materials and Design,* 2018



Clarkson et al., *Journal of Ceramic Materials,* 2022

Thermoplastic matrix:

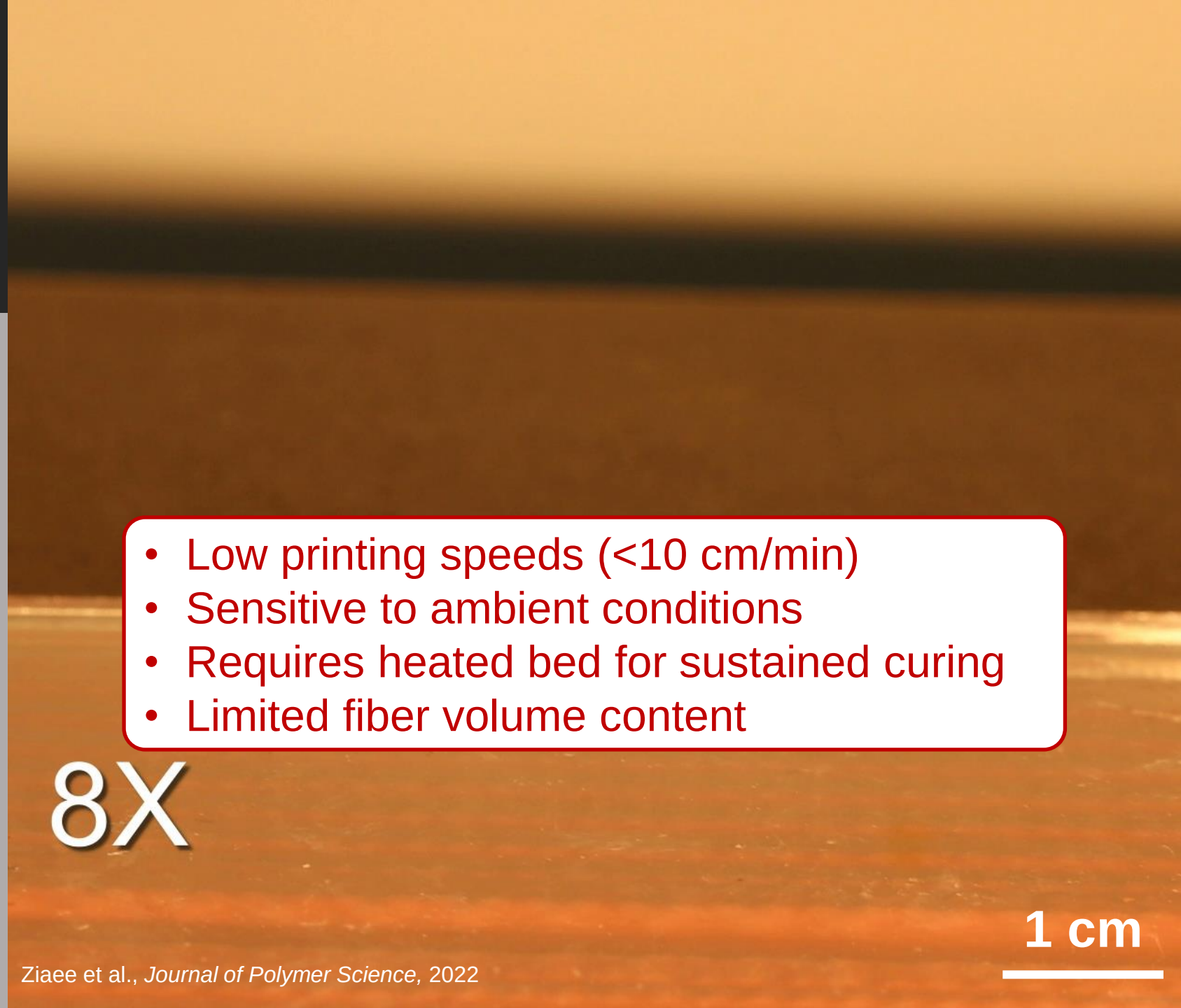
- Poor thermomechanical properties
- Limited fiber content
- Large void content

Photocuring:

- Poor mechanical properties
- Limited fiber content
- Require post-curing steps, especially for carbon fiber composites

Printing via Frontal Polymerization

- Self-propagating cure mechanism driven by heat of polymerization
- Enables printing in air without additional stimulus

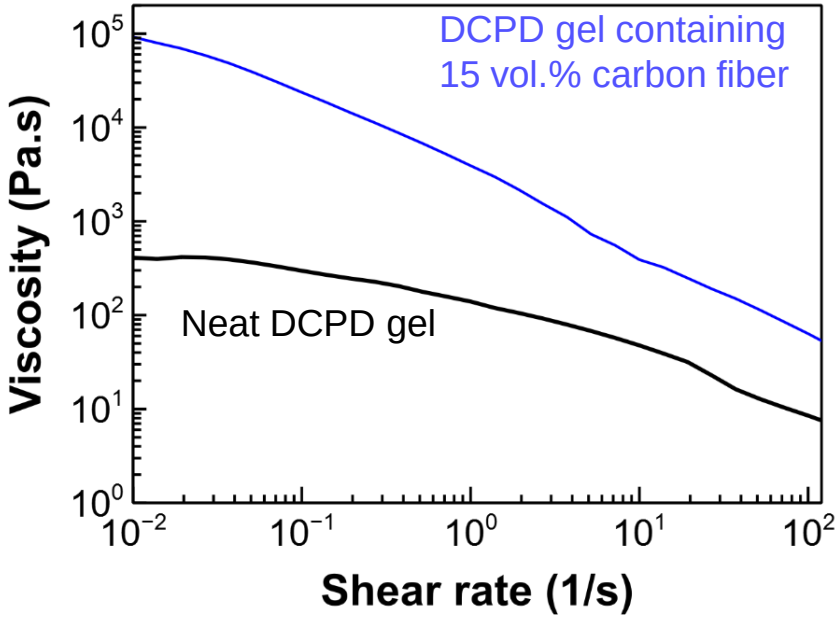


Ziaee et al., *Journal of Polymer Science*, 2022

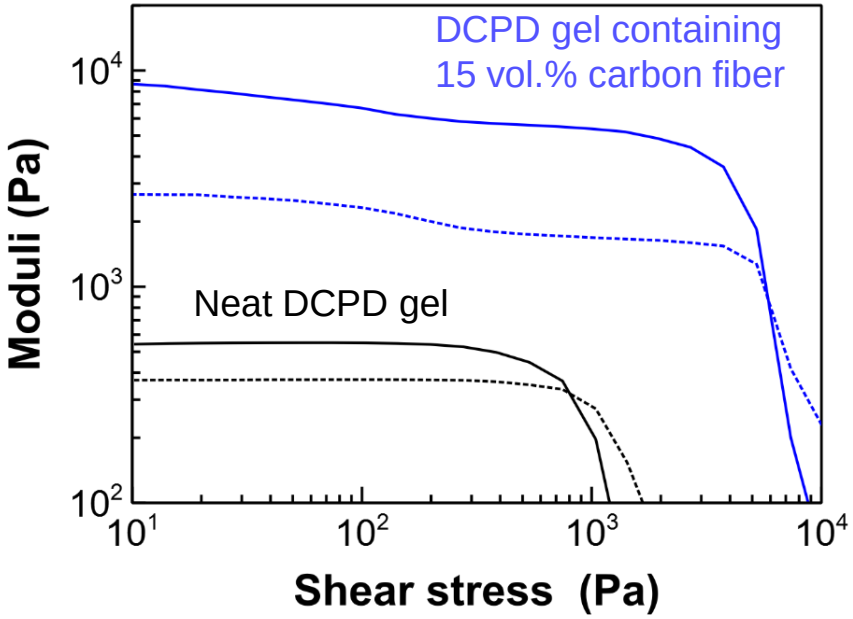
Ink Rheology

- Printing composites via direct ink writing (DIW) technique

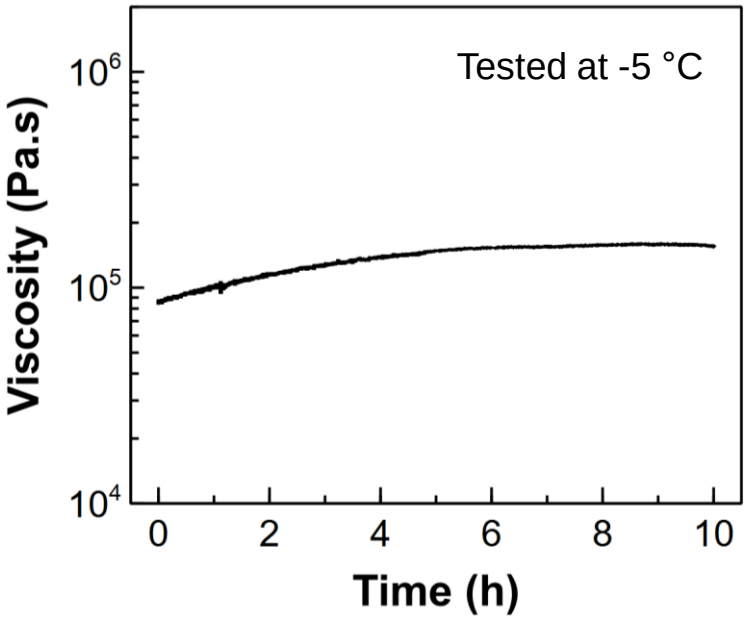
Shear-Thinning Material



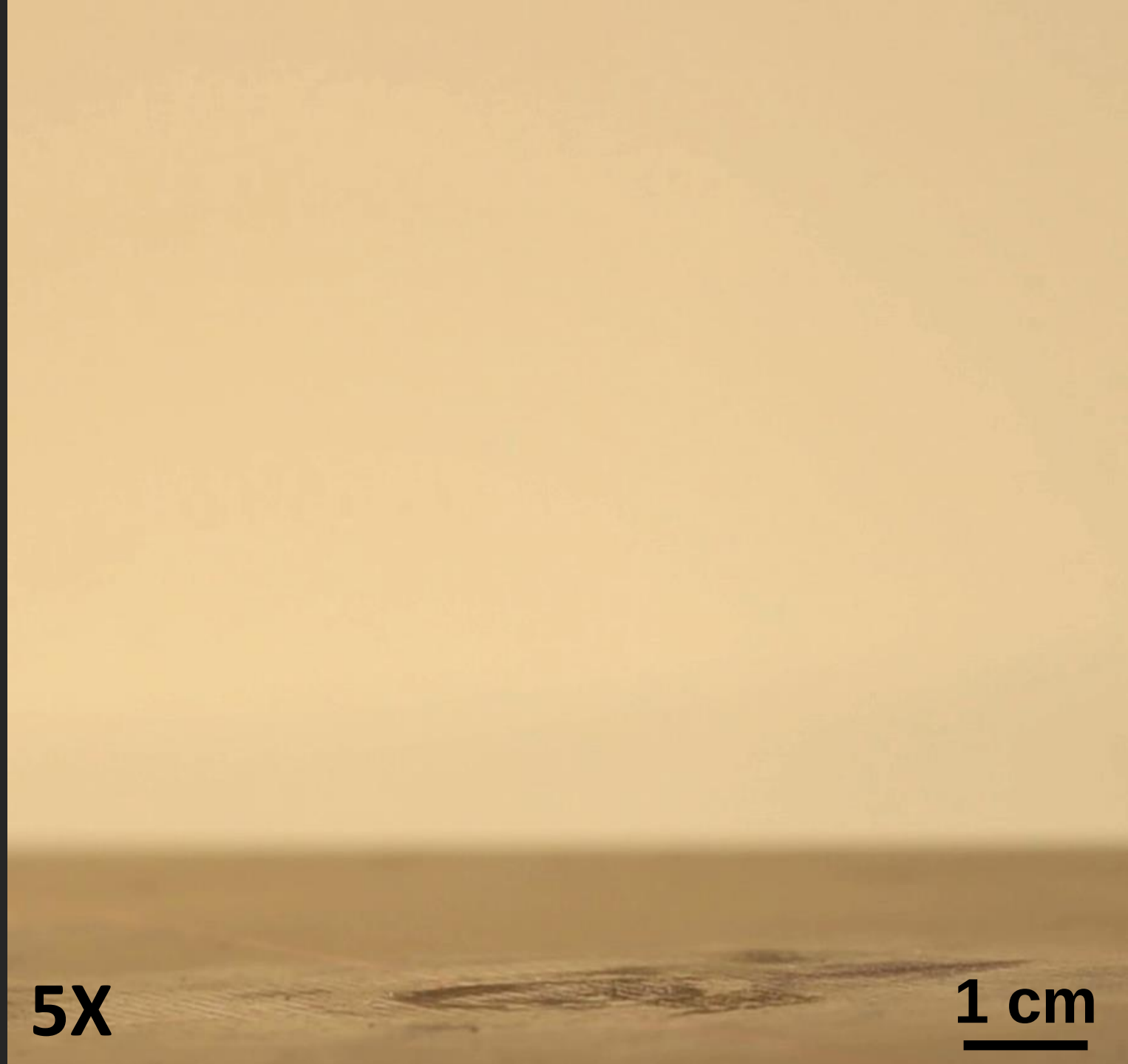
High Moduli for Shape Retention



Minimal Change in Viscosity



Discontinuous Fiber Composite Printing



Discontinuous Fiber Composites

4X

1 cm

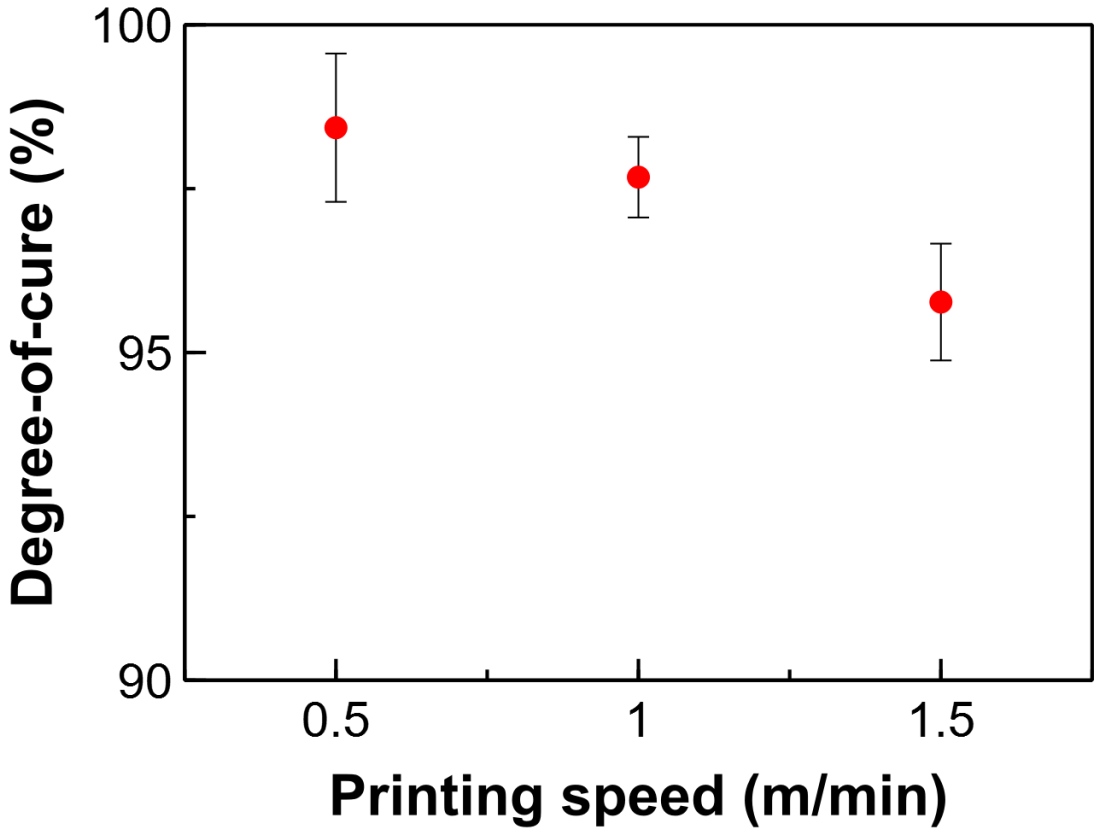
Rapid Printing of Continuous Fiber Composites

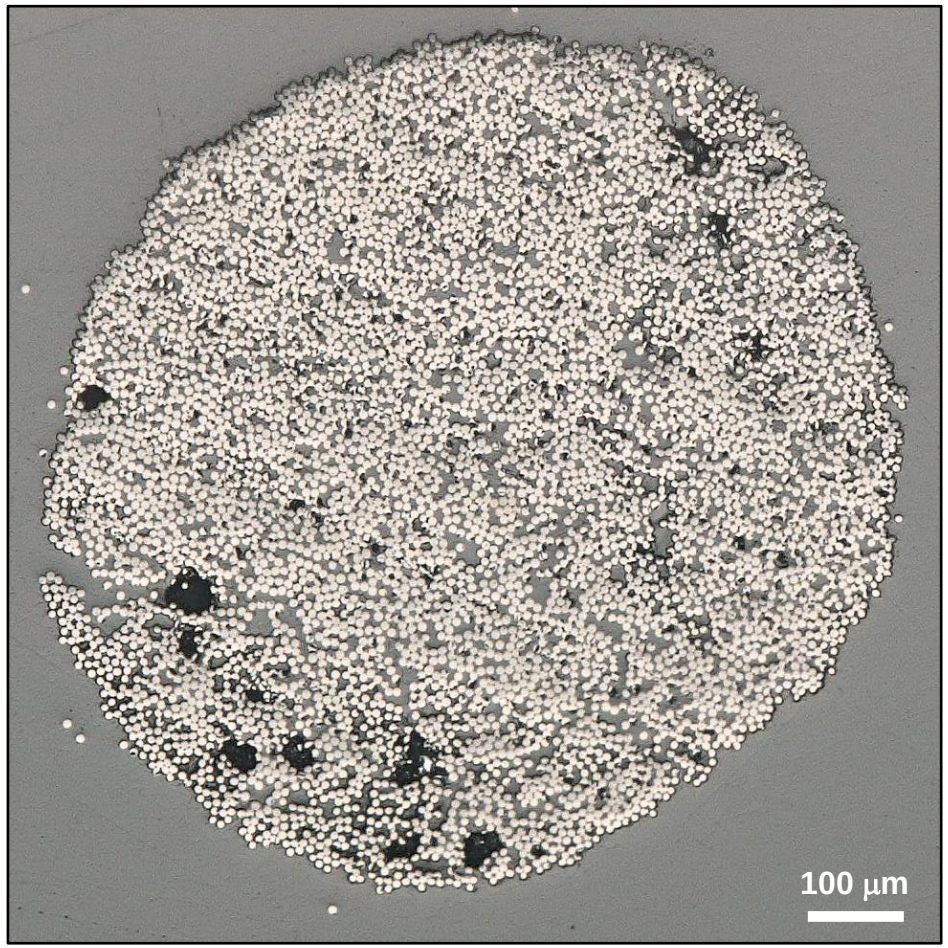
Layer-by-Layer Printing of Continuous Fiber Composites

8X

Characterization

- Degree of cure exceeds 95% at speeds up to 1.5 m/min
- Fiber volume fraction > 50% and void content < 1.5%





Conclusions

- We developed a novel technique for printing thermoset polymer composites
- *In-situ* rapid curing allows for in-air printing without using support materials
- Ability to print discontinuous and continuous fiber composites at speeds up to 1.5 m/min
- High quality composites with a high volume-fraction of carbon fibers (> 50%) and a low void content (<1.5 %)
- No post cure required