Hybrid Extrusion 3D Printing of Self-Deployable Smart Solar Panel Hinges

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OVERVIEW

Shape memory polymers (SMPs) have diverse applications in the aerospace, biomedical, and automotive fields since they can recover to their original shapes upon exposure to external stimuli after they are programmed to a deformed shape. Stereolithography (SLA) is the most common 3D printing method used to fabricate SMPs, but the build material must have a low viscosity and ultraviolet (UV) crosslinkability, severely constraining the selection of SMPs. In this work, we developed a hybrid direct ink writing (DIW)/embedded 3D printing (e-3DP) method to freeform fabricate SMPs with complex geometries. Fig. 1 outlines the mechanism of this method:

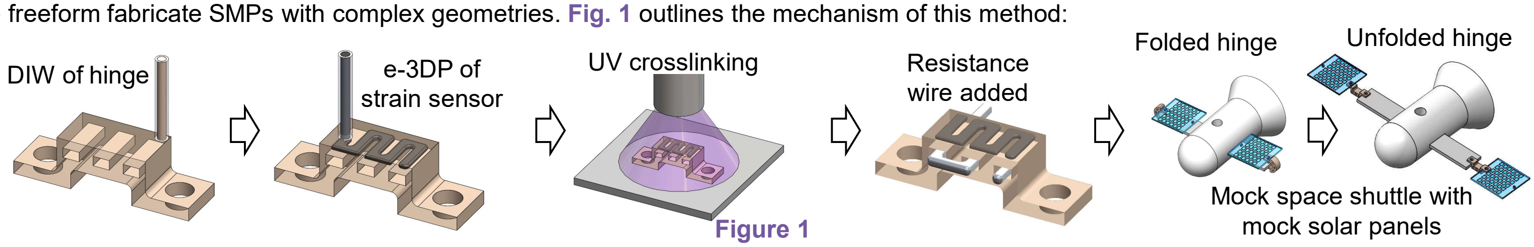

Figure 1

INTRODUCTION

SLA is reported to be the main fabrication method for SMPs, but fabricating additional monitoring devices may need extra and complicated post treatments. In this work, a SMP ink material proved to be both self-supporting and act as support bath for the embedded strain sensor made of carbon conductive grease. This new method proposed to make smart solar panel hinges from SMP material meets the mission of NASA Innovative Advanced Concepts, a Space Technology Mission Directorate program.

METHODS

- Material design (Table 1)
- Rheological measurements:
  - Steady shear rate sweeps
  - Thixotropic sweeps
- Hinge printing and testing
  - Hinge printing experiments
  - Functionality testing

Table 1

tBA/AUD \ FS	6%	8%	10%
50%/50%	✓	✓	✓
60%/40%	✓	✓	✓
70%/30%	✓	✓	✓

RESULTS

Rheological measurements

Rheological tests were preformed at 24˚C on the Anton Paar Modular Compact Rheometer MCR 92 (Fig. 2).

Figure 2

The yield stresses (Fig. 3) of the concentrations were determined from steady shear rate sweeps:

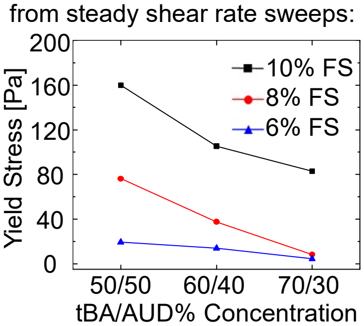

Figure 3

Thixotropic sweeps (Fig. 4) determined the response time of the concentrations:

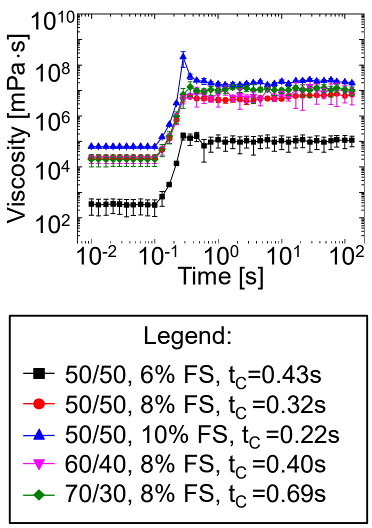

Figure 4

Hinge printing and testing

Both hinge printing experiments were preformed using a EnvisionTEC bioplotter (Fig. 5). The UV light system used is the OmniCure S2000 (Fig. 6). The SMP smart hinge was printed via DIW, and carbon conductive grease was printed via e-3DP (Fig. 7a). Then, the DIW/e-3DP SMP smart hinge was UV crosslinked (Fig. 7b).

Figure 5

Figure 6

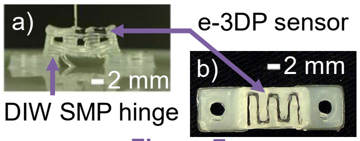

Figure 7

The hinges were attached to a mock space shuttle and mock solar panels for the functionality testing. The hinges unfolded when the resistance was heated to 90˚C via joule heating: banana clips were attached to the ends of the resistance wires heated using a power supply (Fig. 8):

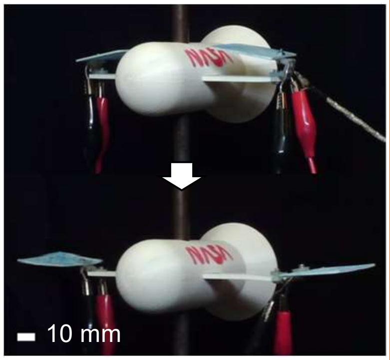

Figure 8

CONCLUSION

- The addition of fumed silica did significantly adjust the rheological properties of the SMP ink.
- This SMP, self-supporting ink allowed a hinge with complicated geometry to be printed via DIW, which remained viscous enough though to allow a stain sensor of carbon conductive grease to be printed via e-3DP
- The smart hinge printed via DIW/e-3DP was able to show its SMP characteristic due to an increase in temperature of the resistance wires woven through slots in the hinge. This was displayed by using the hinge to attach mock solar panels to a mock space shuttle.

REFERENCES

[1] Zhang, B., et al., Mechanically Robust and UV-Curable Shape-Memory Polymers for Digital Light Processing Based 4D Printing. Advanced Materials. 2021, 33, 2101298. https://doi.org/10.1002/adma.202101298

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