Functional Materials for 3D Manufacturing using Carbon's CLIP Technology

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1. Introduction

Additive manufacturing, or 3-D printing, is rapidly gaining traction in the medical [1], footwear [2], dental [3], automotive, consumer electronics [4], and aerospace [5] industries. 3-D printing enables exciting prospects in these industries that are neither possible nor practical through existing manufacturing techniques such as injection molding. Advantages of 3-D printing include mass customization; the fabrication of lightweight, but strong, lattice structures; economical low-volume and decentralized production; and rapid prototyping. 3-D printing is poised to play an increasingly important role in manufacturing.

However, in order for 3D printing to cross the chasm to manufacturing, a fundamental materials problem must be resolved. Light-based technologies, such as stereolithography (SLA) and ink-jetting provide impressive resolution and surface finish but the resulting mechanical properties of parts are poor when compared to thermoplastics. Heat-based technologies such as fused deposition modeling (FDM) and selective laser sintering (SLS) provide the mechanical properties of thermoplastics but lack resolution and acceptable surface finish. We propose that a combination of high resolution, good surface finish, and strong mechanical properties are needed. In order to achieve this, light-based printing technologies must cover a wide range of stress-strain curves to compete with thermoplastics used in injection molding (Fig. 1).

Here, we demonstrate a series of materials compatible on Carbon’s light-based CLIP technology that exhibit a range of useful properties for final manufactured parts in a variety of applications.

Fig. 1. Stress-strain curves of a variety of thermoplastics used in injection molding.

2. Experimental

All materials (PR-25, EPU-60, FPU-250, RPU-60, and CE-220) were used according to instructions for use as provided by Carbon. Test specimens were printed using Carbon’s M1 printer and measured according to ASTM protocols.

3. Results and discussion

RPU-60 (rigid polyurethane) (Fig. 2). RPU-60 is a rigid, tough, material useful for a variety of applications including automotive (interior), consumer electronics, orthotics, and other applications were rigidity and toughness are required. It has mechanical properties similar to ABS, only with a much higher elongation at break. It has a tensile strength of 50 MPa, an elongation at break of 120%, and a Young’s modulus of 1500 MPa.

FPU-250 (flexible polyurethane) (Fig. 3). FPU is a rigid, tough, material useful for a variety of applications including automotive (interior), living hinges, clips, fasteners, and other
applications where flexibility and toughness are required. It has mechanical properties similar to polypropylene. It has a tensile strength of 25 MPa, an elongation at break of 300%, and a Young’s modulus of 700 MPa. It also has a notched Izod impact strength of 40 J/m.

**Fig. 2.** Stress-strain curves of RPU-60 rigid polyurethane resin.

**Fig. 3.** Stress-strain curves of FPU-250 flexible polyurethane resin.

**EPU-60 (elastomeric polyurethane) (Fig. 4).** EPU is a high elongation, tough, elastomeric material useful for a variety of applications including automotive (interior), footwear, cushioning, gaskets, grommets, and other applications where durability, elasticity, and toughness are required. It has mechanical properties similar to injection molded TPU. It has a tensile strength of 6 MPa, an elongation at break of 300%, and a Young’s modulus of 7 MPa. It has a shore A durometer of 60.

**Fig. 4.** Stress-strain curves of EPU-60 elastomeric polyurethane resin.

**CE-220 (cyanate ester) (Fig. 5).** CE220 is a rigid, very strong resin with outstanding thermal properties. It is useful in a variety of applications requiring high temperature and high strength including automotive, medical, and aerospace. It has mechanical properties similar to glass-filled nylon. It has a tensile strength of 100 MPa, an elongation at break of 5%, a Young’s modulus of 4000 MPa, and a heat deflection temperature of 220 °C.

**Fig. 5.** Stress-strain curves of CE-220 cyanate ester resin.

When these engineering-grade resins are combined with the speed and resolution achieved by CLIP, a variety of final quality parts can be manufactured for a wide range of applications (Fig. 6).

**Fig. 6.** 3D printed parts made by CLIP. Left to Right: PR-25, RPU-60, FPU-250, EPU-60, CE220.

**References**