ABSTRACT

Over the past decade, there has been significant interest in the additive manufacturing (AM) of thermosetting resin composites. However, there are issues associated with functionality of the composite, toughness, conductivity, and mechanical properties of the printed structure due to its standard processing techniques. Extrusion-based AM can be used to produce thermoset resin-filler composites with enhanced thermal properties and toughness at loading levels well above the percolation threshold.By optimizing the printing parameters via direct ink writing, lightweight composite materials can be engineered with enhanced properties, so they can be used in applications such as electromagnetic shielding materials, heat sinks, and thermal interface materials because they enhance the thermal coupling between two materials. Through this study, extrusion-based AM was used to produce thermoset resin-filler composites with enhanced thermal properties and toughness at loading levels well above the percolation threshold. The design rules for processing novel lightweight composite structures with tailored properties were established and the composite properties were characterized using macroscopic and microscopic techniques.

In this work, thermosetting epoxy resin, EPON 862, was mixed at varied weight concentrations (10% - 18%) of graphene nanoplatelet (GNP) fillers to investigate how the macroscopic properties of printed GNP composites are affected at the different weight concentrations and print speeds (10mm/s and 40mm/s). The rheology of each sample was tested to see the effect of filler concentration on the modulus, viscosity, and yield stress/strain of the samples. A thermal conductivity of 1.72 W/m$℃$ was achieved at 18wt% samples printed at 40mm/s, which is ~250% higher than that found in the literature. Results from performing dynamic mechanical analysis (DMA) showed an increase in glass transition temperature (Tg) at higher concentrations for the printed samples, due to the alignment of the filler particles reinforcing the strength of the material by restricting the polymer chains at higher temperatures. The printing and processing parameters were found to directly influence the thermal conductivity and mechanical properties of the GNP composites. These effects are due to the GNP particles aligning within the epoxy resin matrix from shear induced by 3D printing, which was confirmed through 2-dimensional x-ray diffraction (2D XRD) analysis.