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Nadim S. Hmeidat, James W. Kemp, Brett G. Compton

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High-strength epoxy nanocomposites for 3D printing

*Nadim S. Hmeidat, James W. Kemp, and Brett G. Compton**

Mechanical, Aerospace, and Biomedical Engineering Department
University of Tennessee, Knoxville
Knoxville, TN 37996
USA

ABSTRACT

Clay-based nanoscale filler materials are commonly used to impart unique and desirable properties to polymer resins. Small volume fractions of nanoclay have disproportionately large effects on stiffness, toughness, strength, and gas barrier properties of polymer matrices due to their high surface-to-volume ratio and platelet morphology. Recent work has suggested that highly loaded epoxy/clay/fiber mixtures possess desirable rheological properties for use as feedstock materials for direct-write 3D printing, but little is known about the effects of the deposition process on the resulting properties of the printed composites. In this work we characterize the effects of a functionalized nanoclay on the rheological properties and printing behavior of an epoxy resin in the absence of fiber reinforcements, and investigate the effects of clay content and the deposition process on the thermo-mechanical properties of the resulting 3D-printed epoxy/clay nanocomposites. The rheological properties of ink formulations containing up to 12.5wt% nanoclay are measured using parallel plate rheometry, and the thermo-mechanical properties of the printed composites are measured using 3-pt flexural testing, dynamic mechanical analysis, and thermo-gravimetric analysis. Flexural strength values range from 80 MPa to 100 MPa for cast samples and printed samples tested transverse to the printing direction, and up to 143 MPa for printed samples tested parallel to the print direction. Although the observed anisotropic strength values indicate that the deposition process does impart orientation to the nanoclay, the strength in each direction is significantly greater than values reported for 3D printed thermoplastic composites, suggesting that the epoxy/clay system has high potential for further development as a 3D printing feedstock material.

Keywords: 3D printing; epoxy; composites; nanoclay; thermoset.
*Corresponding author: bcompto1@utk.edu

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