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MICROSTRUCTURAL AND MECHANICAL CHARACTERIZATION OF CARBON NANOFIBER REINFORCED COMPOSITES

Aashish Rohatgi
Science Applications International Corporation,
1220 12th St. SE, Suite 140,
Washington, DC 20003
aashish.rohatgi@saic.com

William R. Pogue, III
Multifunctional Materials Branch, Code 6350,
Naval Research Lab, 4555 Overlook Ave. SW,
Washington, DC 20375
pogue@anvil.nrl.navy.mil

Jared N. Baucom
Multifunctional Materials Branch, Code 6350,
Naval Research Lab, 4555 Overlook Ave. SW,
Washington, DC 20375
baucom@anvil.nrl.navy.mil

James P. Thomas
Multifunctional Materials Branch, Code 6350,
Naval Research Lab, 4555 Overlook Ave. SW,
Washington, DC 20375
jthomas5@anvil.nrl.navy.mil

ABSTRACT

Carbon nanofibers, such as single walled carbon nanotubes (SWNT), multiwalled carbon nanotubes (MWNT) and vapor-grown carbon nanofibers (VGCF or VGCNF) are routinely compounded with polymers to create thermally and electrically conductive polymer nanocomposites. Our group is interested in combining the conduction with structural functionality by reinforcing a high-performance thermotropic liquid crystal polymer (LCP) matrix with vapor-grown carbon nanofibers and single walled carbon nanotubes. High strength and stiffness can be achieved in LCPs through the alignment of molecular domains during high-shear mixing and extrusion. Further strength and stiffness enhancements are potentially possible if the carbon nanofibers could also be aligned, perhaps, with the assistance of the aligned domains of the LCP matrix. However, the geometrical structure of VGCF is quite different and the diameter is one to two orders of magnitude larger than that of SWNT. Therefore, the processing conditions and the interactions between the LCP domains and the nanofibers are expected to lead to different dispersion and alignment characteristics of VGCF and SWNT within the LCP matrix.

In this work, twin-screw and Maxwell-type mixer-extruders were used to produce neat LCP filaments and LCP-nanofiber composite filaments with various concentrations of VGCF and SWNT. The dispersion and orientation of the VGCF and SWNT reinforcements were determined by X-ray diffraction and electron microscopy. The filaments were loaded in quasi-static uniaxial tension until fracture to determine the tensile modulus, strength and strain-to-failure. The mechanical properties showed a strong dependence on the filament diameter, nanofiber concentration and processing parameters. A significant increase in mechanical performance was observed with decreasing filament diameter irrespective of the carbon nanofiber concentration. Fracture surfaces examined under electron microscopy revealed hierarchical features at multiple length scales. At the macroscopic scale, a skin-core configuration was observed in the filament cross-section with the skin possessing a greater degree of LCP molecular alignment and nanofiber alignment than the core. The mechanical and electrical properties of the LCP, LCP-VGCF and LCP-SWNT nanocomposite filaments will be described and related to processing parameters, the type of carbon nanofibers (VGCF or SWNT) and the resulting composite microstructure.