Nanoscale Resin Flow and Permeability of Preformed Single-Walled Nanotube (SWNT) Networks

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ABSTRACT

The single-walled carbon nanotube (SWNT) has received considerable notice because of its unique and exceptional material properties. SWNTs are considered the most promising reinforcement for the next generation high performance composites. Unlike conventional fibrous reinforcements, SWNTs have intense interactions with resin matrix due to their nanoscale dimension (0.4~18 nm in diameter and up to 1 or several mm in length), extra-large surface area (as high as 1500m2/g) and strong van der Waals forces causing by sp2 electronic structure. For example, by adding only 1 or 2% by weight of SWNTs in composite processing, the viscosity of the resin/SWNT mixture could dramatically increase to a very high level. Sometimes the mixture could become as thick as paste and lose its flow ability. This also will lead to poor tube dispersion in the nanocomposites.

The authors developed a new approach for preparing SWNTs reinforced nanocomposites to avoid direct mixing of tubes/resin matrix during composite processing. Unlike current techniques, SWNT nanocomposites are fabricated in a three-step process: 1) SWNT networks are preformed, sometime in a high magnetic field, 2) resin solution is infiltrated through the preformed SWNT networks to achieve tube/resin impregnation, and 3) a hot press is used to produce the final nanocomposite. Using this method, uniform nanostructures, tube alignment and high nanotube loading can be achieved in the nanocomposites. Good tube alignment can be obtained if we preform the SWNTs under a high magnetic field. In the preformed SWNT networks, individual tubes will form ropes or bundles of a diameter around 20~40 nm, with the open distance of the pore structures between tube ropes about 50~200 nm. Since resin flow and infusion occur at nanoscale, we investigated the influence of molecular interactions on resin flow within preformed SWNT networks by using molecular dynamics simulation. The through thickness permeability (Kzz) of both random and aligned SWNT preforms were measured. The comparison between the measured permeability and theoretical estimation were obtained based on Darcy's Law and the Kozeny-Carman (K-C) Model. The relationship between nanoscale porous parameters, molecular interactions and permeability were explored. This paper reports the results of these efforts, which revealed the influence of intensive molecular interaction on the nanoscale resin flow behaviors for fabricating SWNT-reinforced composites.

Keywords: Nanocomposites, SWNT, Resin flow, Permeability