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Effect of Nanofiller Shape on Effective Thermal Conductivity of Fluoropolymer Composites

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Abstract

Filler particle shape and size influence interconnectivity within a polymer matrix and both play a significant role in controlling the effective thermal conductivity of a composite. This study examines the effect of nanofiller particle shape in a polytetrafluorethylene (PTFE) matrix on thermal energy transport. Experimental measurements using a laser flash analysis method are performed on PTFE with three different shaped carbon fillers: nano-diamond spheres, carbon nanotubes (CNT) and graphene flakes. Filler concentration ranged from 0 to 30 %. The experimental results are coupled with a particle connectivity model to understand the relationship between energy transport and filler connectivity. Results show filler particles with more micron scale dimensions form better interconnected networks at lower volume concentrations than fillers with fewer micron scale dimensions. Filler connectivity influences effective conductivity: specifically, nano-diamond spheres showed negligible interconnectivity and result in negligible change in thermal conductivity. The CNT, with one-micron scale dimension (i.e., length) and flakes, with two-micron scale dimensions (i.e., length and height), both exhibited linear increases in interconnectivity and effective thermal conductivity. Graphene interconnectivity in PTFE is six times that of CNT and thermal conductivity is 0.5 W/mK, two times that of CNT, respectively. These results provide new insights on how to optimize nanoparticle structure to enhance thermal energy transport.

KEY WORDS: Carbon nanotubes; Nano particles; Thermal properties; Polymer-matrix composites (PMCs); Modelling