Thermal Conductivity of Nanocomposites with High Volume Fractions of Particles: Experiment and Theory

J. Ordonez-Miranda [S] and C. Vales-Pinzón
Departamento de Física Aplicada, Centro de Investigación y de Estudios Avanzados del I.P.N., Unidad Mérida, Mérida, Yucatán, México

R. Medina-Esquivel
Facultad de Ingeniería-UADY, Mérida, Yucatán, México

J.J. Alvarado-Gil [C]
Departamento de Física Aplicada, Centro de Investigación y de Estudios Avanzados del I.P.N., Unidad Mérida, Mérida, Yucatán, México
jjag09@yahoo.com

Over the past few decades, significant research efforts have been devoted to the thermal properties of particulate composites, due to their many technological applications ranging from mechanical structures to electronics [1]. Despite their importance, the thermal performance of these materials is not well-understood to date, especially at high volume fractions of micro/nano-sized particles. In this work, the thermal conductivity of composites made up of carbon nanotubes and spherical metallic nanoparticles embedded in a polymeric matrix is investigated from an experimental and theoretical point of view. The thermal conductivity of the samples is measured for different particle volume fractions up to 40%, by using the standard photothermal-radiometry technique, in the heat transmission configuration [2]. The recorded data are then explained and modeled based on our theoretical model, which generalizes the results of Nan et al. [3], by incorporating the effects of the energy-carrier (electron or phonon) scattering and particle interactions, which tend strongly up for nanoparticles and high concentrations of them, respectively. When the size of the particles is of the order of the mean free path of the energy carriers, it is shown that the thermal conductivity of nanocomposites depends on: 1) the collision cross-section per unit volume of the particles and 2) the mean distance that the energy carriers can travel inside the particles [4]. On the other hand, for concentrations of particles up to their maximum packing volume fraction, the proposed approach exhibits a strong dependence on the crowding factor of the particles. The predictions of the proposed analytical approach are in good agreement with the obtained and reported experimental data for the thermal conductivity of micro/nano-composites.

1. A.A. Balandin, Nature Materials 10, 569 (2011)
2. M.A. Zambrano-Arjona, R. Medina-Esquivel, J.J. Alvarado-Gil, J. Phys. D: Appl. Phys. 40, 6098 (2007)
3. C.W. Nan, R. Birringer, D.R. Clarke, H. Gleiter, J. Appl. Phys. 81, 6692 (1997)
4. J. Ordonez-Miranda, R.G. Yang, J.J. Alvarado-Gil, Appl. Phys. Lett. 98, 233111 (2011)