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Effect of Aggregation and Particle Size on the Thermal Conductivity of Nickel-Epoxy Nanocomposites

Jacob M. Faulkner, Xiangyu Li, and Xiulin Ruan
School of Mechanical Engineering and Birck Nanotechnology Center, Purdue University

ABSTRACT

Microprocessor advancements have been stunted in recent years by inadequate means of heat dissipation as power continues to grow and size continues to shrink. One way to increase thermal conductivity while maintaining electrical insulation is to add metal nanoparticles to a polymer matrix. This cheap material has become a popular thermal interface for this reason. However, optimization of the interface is dependent upon a number of factors including particle size, shape, orientation, and aggregation. Various theoretical models and numerical approximations have been developed to find the effective thermal conductivity of such nanocomposites, but none has been able to fully incorporate each factor, specifically aggregation, due to the complexity of heat transfer in multiple dimensions without idealistic assumptions. In order to address this issue, nickel nanoparticles spread throughout an epoxy matrix were tested using the 3ω method to determine how particle size and aggregation influence effective thermal conductivity. Viscosity, the limiting factor to nanoparticle concentration in solution, was also measured and recorded. It was determined that the thermal conductivity was higher than predicted by previous effective medium approximations or EMA models and thermal conductivity increased with decreasing particle size. A two-level EMA model was developed in order to account for both particle size and aggregation. The higher thermal conductivity is caused by the effect of aggregation, and the presented EMA model accounts for this effect by using local concentration as a fitting parameter.

KEYWORDS

Heat transfer; nanocomposites; thermal conductivity; aggregation; nanoparticles