

**High Thermal Conductivity Composites Based on Self-constructed Metallic
Networks in Epoxy**

by

Kamyar Pashayi

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Approved by the
Examining Committee:

Prof. Theodorian Borca-Tasciuc, Thesis Adviser

Prof. Joel L. Plawsky, Thesis Co-adviser

Prof. Catalin Picu, Member

Prof. Yoav Peles, Member

Rensselaer Polytechnic Institute
Troy, New York

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ABSTRACT

This research is focused on detailed investigation of heat transfer inside a silver-epoxy composite by studying the relationship between processing procedures, microstructure shapes, and thermal conductivity in order to reach an efficient high thermally conductive, κ , composite. The idea is to form a self-constructed metallic network in the polymer matrix via low temperature sintering of nanoparticle fillers during the curing of the polymer. The sintered silver nanoparticles inside epoxy matrix have considerably enhanced the κ value from 0.2 W/mK for pure epoxy to 26.94 W/mK for 45 vol% of silver-epoxy nanocomposite. In comparison with microcomposites, the formation of self-constructed nanostructured networks (SCNN) with high aspect ratio structures leads to enhancements in the measured κ of the composite by more than two orders of magnitude. The κ trends are qualitatively explained using a percolating threshold thermal conductivity model for the microcomposites and the Hashin and Shtrikman (H-S) theory for nanocomposites.

We also studied the effects of particle surface coating, annealing time, and temperature on the morphology and thermal conductivity of silver-epoxy nanocomposite. The morphological and thermal conductivity results reveal that dispersion, agglomeration, or aggregation of particles can change the κ of nanocomposites from 0.66 W/mK to 35.08 W/mK. Maximum κ is achieved when the processing of nanocomposites produces fractal shapes of connected network of nanoparticles. This network generates thermally conductive pathways through the following stages: nanoparticles concentrate in epoxy matrix, PVP melts on the surface of nanoparticles and finally, silver nanoparticles sinter while epoxy cures.

We also experimentally and theoretically (using COMSOL and available κ modeling methods) analyze the κ of nanocomposites at 10 vol% loading of silver in epoxy. The COMSOL simulations illustrate that at a constant volume loading of filler particles, with decreasing particles size, thermal conductivity is increasing. Also the effective κ of composite is higher when particles are ordered in row(s) in comparison with the case that particles are dispersed in the second media. In addition the results of COMSOL simulation are in agreement with the κ predictions of Maxwell-Eucken and Lewis-Nielson model. The presented COMSOL simulations are unable to explain the experimental κ results. This due to complex shapes of particles after processing of composite.