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Study of the Effective Thermal Conductivity of Polymer Composites with Varying Filler Arrangements

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ABSTRACT

Alternative thermal management solutions for electronic devices are being widely explored due to the increasing heat concentration that results from shrinking sizes and increasing power of modern electronics. Clearly, there is a need to spread the heat effectively in these systems, and polymer composites can potentially provide high thermal conductivity at low filler fraction while maintaining desirable mechanical properties for electronic packaging. The present study aims to investigate the effective thermal conductivity of various copper filler arrangements in a polymer matrix. The polymer composites are fabricated using laser cut acrylic templates to imbed aligned copper rods in epoxy and create different configurations, from ordered to random arrangements, while maintaining a constant volume fraction. Heat conduction through the cross-section of the composites is studied using an infrared (IR) camera that enables 2D mapping of temperatures. The effective thermal conductivity of the composites is obtained using a simplified 1-D reference-bar type technique. The experimentally obtained effective thermal conductivity is validated using both simulation software and relationships from the effective medium theory. The resulting effective thermal conductivity of the different configurations are compared to obtain an optimum filler configuration. Furthermore, the experimental and simulation results help provide an understanding of the effect percolation networks have on the effective thermal behavior of composite materials. Such polymer composites, with enhanced conductive properties, can be implemented in electronic packaging as an alternative to conventional heat dissipation methods (i.e. mechanical fans, heat sinks, fins, etc.).

KEYWORDS

Thermal conductivity, Polymer composites, Percolating networks, Infrared microscopy, Effective medium theory, Electronics thermal management