Carbon Nanotubes at Interface of Electronics, Aeronautics Show Exceptional Ability to Diffuse Damaging Heat

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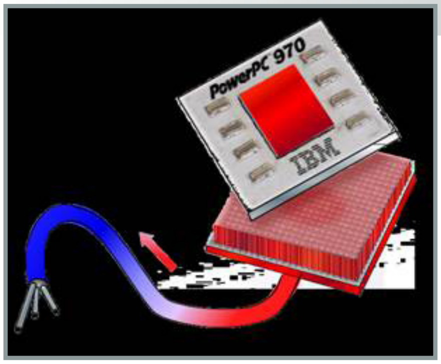

Technology Summary

Managing the heat in microelectronics is an ever-increasing problem. Shearing the heat from the superhot leading edges of hypersonic vehicles such as the Space Shuttle is another high priority research challenge. Scientists at ORNL have discovered that when vertically aligned carbon nanotube arrays are placed at the thermal interface with materials in applications such as these, they display a remarkable capacity to diffuse the critical buildup of heat. The researchers have developed carbon nanotube compositions that, when spaced at optimal distances from one another to minimize thermal transfer losses, yield high thermal diffusivities. The arrays are composed of vertically aligned, mult-walled or single-walled carbon nanotubes. The growth rate can be adjusted and measured, and tailored to the needs of the applications. Annealing treatments are used to increase the tubes' crystalline properties.

The researchers developed methods to monitor and control the compositions and dimensions of nanotube arrays as they grow, so that they can be tailored specifically for applications requiring high thermal conductivity. They found that optimal compositions require high densities of aligned nanotubes, with an inter-nanotube spacing of a few nanometers. Using Raman spectroscopy, they ensure that the nanotubes maintain a high degree of crystallinity and order. For maximum efficiency, a high fraction of the tubes are single-walled and have a smooth surface, to facilitate effective interface with both smooth and rough surfaces.

The tubes are grown to arbitrary, predetermined lengths and feature high thermal diffusivities (>2 cm^2/s) and thermal conductivities (600–1000 W/m K). If desired, the nanotubes can be made to highly anisotropic thermal diffusivity requirements (>70:1, longitudinal to transverse ratio).

Until now, fabrication of such carbon nanotubes has been impossible. The novelty of the invention is the ability to control the composition of arrays to yield extremely high thermal diffusivities. The ability to synthesize long arrays of nanotubes, with continuous fibers from top to bottom, in macroscopic quantities sufficient for flash diffusivity measurements is an enabling feature of the invention and allows the thermal properties of the arrays to be measured in their as-synthesized state for the first time.

Advantages

This is a new class of nanostructured thermal interface material whose main advantages over existing attempts are a high innate thermal diffusivity; the ability to be infiltrated with conductive pastes, polymers, or resins; good thermal contact, as both the top and bottom surfaces can be configured; and the capacity for multiple thermal cycles without losing contact with the interfacing surface.

Potential Applications

This invention is of direct interest for thermal interface materials in microelectronics, which channel heat from highly integrated transistor chips to cooling fans. The nanostructured carbon tubes are also a potentially important material in aeronautics, where heat must be continuously drained from very hot surfaces.

Patent

David B, Geohegan, Ilia N. Ivanov, and Alexander A. Puretsky, *Fabrication of High Thermal Conductivity Arrays of Carbon Nanotubes and their Composites,* U.S. Patent 7, 763, 353, issued July 27, 2010.

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