National Aeronautics and Space Administration

Nanoengineered Thermal Materials Based On Carbon Nanotube Array Composites

NASA has developed a method for providing thermal conduction using an array of carbon nanotubes (CNTs). An array of vertically oriented CNTs is grown on a substrate and interstitial regions between adjacent CNTs in the array are filled with a filler material, such as copper, that has a high thermal conductivity. The CNT-filler composite provides improved mechanical strength to anchor CNTs in place, and also serves as a heat spreader to improve diffusion of heat flux from the smaller volume (CNTs) to a larger heat sink. The invention uses an embedded carbon nanotube array for applications that require large heat dissipation. This approach also improves the mechanical strength of CNTs so that the CNT array can remain stable and make good contact to the surface of objects that generate a large amount of heat. An embedded CNT array can be reused without damage or compromise of its heat transport characteristics, in contrast to an approach that relies upon eutectic bonding.

This invention is available for licensing from NASA’s space program to benefit U.S. industry.

Patent

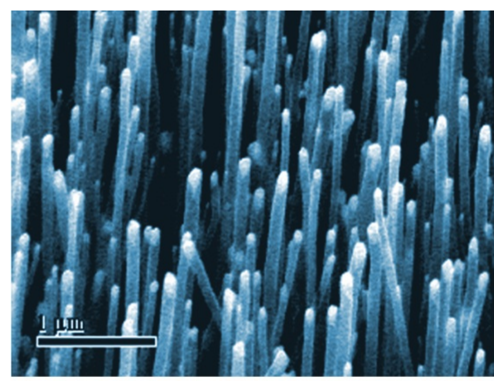
This technology is protected by U.S Patent No. 7,784,531 (Reference No. ARC-15173-2)

Benefits

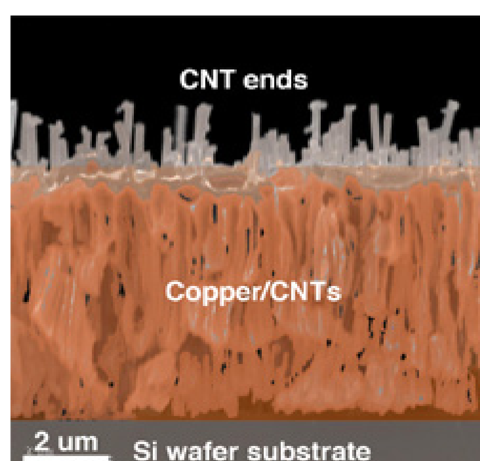
- Improved mechanical stability
- Maximized thermal conductivity
- Improved diffusion of heat flux
- Reusable thermal conductor
- Works with any surface, rough or smooth
- Vertically oriented CNT arrays to increase effective contact area

Technology Details

The fabrication involves four steps: (1) Substantially vertically aligned CNT arrays are grown on a solid substrate (serving as a heat sink) that has good thermal conductivity, such as Si wafers and metal blocks/films; (2) a portion, or all of, interstitial spaces between adjacent CNTs are filled with high-thermal-conductivity materials such as Cu, Ag, Au, Pt by chemical vapor deposition (CVD), physical vapor deposition (PVD), plasma deposition, ion sputtering, electrochemical deposition, or casting from liquid phase; (3) filler materials are removed from a second portion of the interstitial spaces by mechanical polishing (MP), chemical mechanical polishing (CMP), wet chemical etching, electrochemical etching, or dry plasma etching so that the top portion of the CNT array is exposed, with the bottom pail remaining embedded in the filler materials; and (4) the embedded CNT array is applied against an object that is to be cooled. CNTs can reversibly buckle or bend one-by-one under low loading pressure so that a CNT can make maximum contact with the object to be cooled, even an object with a very rough surface. Heat can be effectively transferred from the contacting spots along the tube axis to the filler materials as well as the substrates. Choosing highly thermal conductive materials as the filler matrix maximizes the heat transfer from the contact spots to the substrate (i.e., the heat sink or cooling reservoir).



Vertically aligned carbon nanotubes about 100 nm diameter, 3 μm tall



Carbon nanotubes intercalated with copper

Commercial Applications

- Spacecraft
- Energy Applications
- Commercial microprocessor systems
- Heat dissipation in integrated circuits (IC) chips
- Nanoelectronics

Contact the Ames Technology Partnerships Office at 1-855-627-2249 or ARC-TechTransfer@mail.nasa.gov