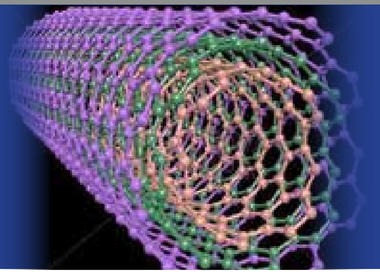
National Aeronautics and Space Administration



Control of Carbon Nanotube (CNT) Density and Tower Height in an Array

technology opportunity

Method uses electricity and temperature to control CNT growth density

Recently, interest has grown in use of arrays of carbon nanotubes ("CNTs") as an intermediary for transport of electrical particles (e.g., electrons) and/or transport of thermal energy from one body to another. For example, a CNT array may be used for dissipation of thermal energy or accumulated electrical charge associated with operation of an electronics device or system. However, the device or system connected to the CNT array(s) may require use of different CNT array densities in different regions, because of differing transport requirements. What is needed is an approach that allows control of CNT growth density on a coarse scale and on a fine scale simultaneously, preferably with two or more substantially different and adjustable scales (coarse and fine) for the CNT density. The CNT density is allowed to vary from one location to another, if desired. Preferably, the approach should allow variation and control, over a factor of about 1 to 1,000, in the coarse scale local CNT density and should allow variation and control over a factor of about 1 to 10 in the fine scale local CNT density. These needs are satisfied by this invention.

BENEFITS

- **The commercial market for a heat generation mechanism for an integrated chip (IC), where the heat removal capacity varies with the local temperature, is conservatively estimated at several billion dollars per year**
- **Use of higher density ICs will increase the need for such a device**

Control of Carbon Nanotube (CNT) Density and Tower Height in an Array: Technology Detail

This method provides control over the growth density or tower height of carbon nanotubes (CNTs) on a relatively coarse scale, with density adjustment over several orders of magnitude, using an applied electrical field or voltage difference that is aligned substantially perpendicular to the substrate surface, which is adjacent to the surface during growth. Control or influence of CNT growth density on a finer scale, estimated at a factor of 2 to 10, is provided using temperature control for the CNT growth process. For example, an application of a modest electrical field of between 5 and 20 volts over a transverse electrode-to-electrode gap of about 25 m (electrical field value IEI=(2–8) x 103 volts/cm) is estimated to change CNT growth density by 1 to 3 orders of magnitude (coarse scale); and variation of CNT source average temperature between 700 °C and 850 °C is estimated to change CNT growth density by a multiplicative factor of 2 to 10 (fine scale). A first region may have a first range of CNT densities, and an adjacent region, spaced apart from the first region, may have a second range of CNT densities that partly overlap, or has no overlap at all, with the density range of the first region. The second region has a higher CNT density, and uses variable heating and/or a reduced electrical field to provide the higher CNT density based on an experimentally determined growth curve and experimental configuration of a device. This approach should be distinguished from masking of regions on a substrate, where the result is binary — where either a CNT array with a fixed density appears, or no CNTs appear in that region at all. The all-or-nothing approach is fine if the goal is thermal transport because maximum thermal transport benefits if the CNT concentrations are as high as possible. However, if the need is for electron transport (e.g., between adjacent signal processing components on a semiconductor chip), the desired CNT density may lie in an intermediate range, with both a lower bound and an upper bound.

APPLICATIONS

- **High density semiconductor integrated chip (IC) fabricators**
- **Heat dissipation and thermal conduction in electronic systems such as personal computers, smart phones, televisions, etc.**
- **Micro energy storage devices**
- **Heat exchangers in electrical circuits**
- **Efficient transfer of thermal energy for targeted "hot zones" in vehicles**

Patents

This technology has been patented (U.S. Patent 7,704,547 and 7,718,223). Reference: ARC-15314-1 and ARC-15314-2.

Licensing and Partnering Opportunities

NASA's Technology Transfer Program seeks to transfer this technology out of NASA's space program to benefit U.S. industry. NASA invites companies to inquire about licensing possibilities for this technology for commercial applications.

Learn More

For more information on this technology, and to discuss licensing and partnering opportunities, please contact:

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