

HIGH DENSITY CARBON NANOTUBE ARRAYS FOR VERTICAL INTERCONNECTS

A method for forming small catalytic nanoparticles at high densities over a substrate to serve as nuclei for the growth of carbon nanotubes (or CNTs). The inventors have experimentally grown CNTs with densities of $5 \cdot 10^{12} \text{ cm}^{-2}$ (five times greater than the closest rival technology), and expect that arrays of CNTs with densities of 10^{13} cm^{-2} or higher can be grown using this method.

Uses :

- The growth of dense bundles of CNTs to act as vertical electrical interconnects (or vias) in integrated circuits

Benefits:

- Simple, practical method for growing dense arrays of CNTs in situ on a surface
- High density arrays of CNTs can support high electrical current densities. They are therefore excellent candidates as a replacement for copper conductors in integrated circuits

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Background

The size of electronic components in integrated circuits has steadily reduced over the years. Copper is currently the main material used to make the “interconnects” (ie the “flat” connectors in a circuit) and the “vias” (ie the “vertical” connectors between the different layers of an integrated circuit). The size of interconnects and vias are now so small that current density is a limiting factor.

Carbon nanotubes (or CNTs) can support very high current densities, and are therefore proposed as a replacement for copper in the vias and interconnects on integrated circuits. For CNTs to be used for vias, the CNTs need to be grown in situ in high density bundles with a density of at least 10^{13} per cm^2 .

The simplest approach to growing CNTs is to deposit a thin film of catalyst (eg iron) onto the substrate (eg Al_2O_3), and then restructure the catalytic layer by annealing, so that it forms a series of nanoparticles, that are the nuclei for the growth of each CNT. However simple calculations show that the nanoparticle (and therefore CNT) densities using this method have an upper limit of about 10^{12} per cm^2 . Other methods of growing CNTs on a substrate have similar density limitations.

Technology

The inventors realised that higher densities of catalytic nanoparticles (and therefore CNTs) could be produced by carrying out multiple deposition/annealing steps. Surprisingly, the nanoparticles formed in each successive deposition/annealing step are largely independent of the existence of the previously-formed nanoparticles on the substrate surface, resulting in successive increases in the density of the nanoparticles.

The inventors have used this method to produce nanoparticles of iron on an Al_2O_3 substrate with densities of $5 \cdot 10^{12}$ cm^{-2} .

The resulting CNTs are also of $5 \cdot 10^{12}$ cm^{-2} (as shown by weight gain and electron microscopy) – a CNT density 5x greater than that rival processes. The inventors expect that method can be improved to grow CNT densities of at least 10^{13} cm^{-2} and perhaps higher.

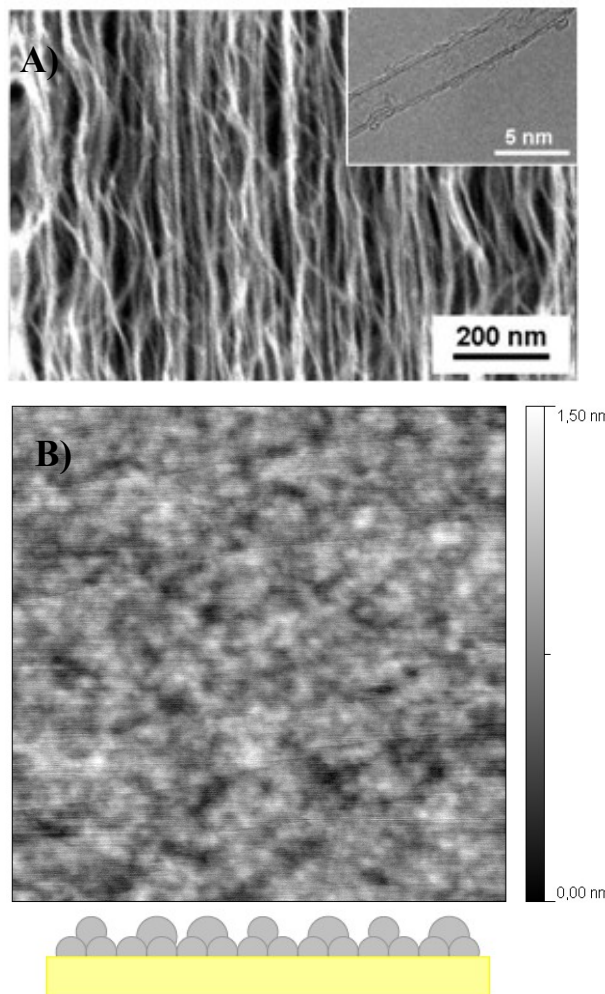


Figure 1. A) SEM side picture of high density grown CNTs. B) SEM top picture of high density catalytic nanoparticles.

Commercialisation

This technology is protected by patent number GB1012098.8. We are seeking a commercial partner for licensing, collaboration and development of this technology.