NATO LECTURES

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Nanotechnology in Aerospace Applications

Abstract

The aerospace applications for nanotechnology include high strength, low weight composites, improved electronics and displays with low power consumption, variety of physical sensors, multifunctional materials with embedded sensors, large surface area materials and novel filters and membranes for air purification, nanomaterials in tires and brakes and numerous others. This lecture will introduce nanomaterials particularly carbon nanotubes, and discuss their properties. The status of composite preparation – polymer matrix, ceramic matrix and metal matrix – will be presented. Examples of current developments in the above application areas, particularly physical sensors, actuators, nanoelectromechanical systems etc. will be presented to show what the aerospace industry can expect from the field of nanotechnology.

Of all the nanoscale materials, carbon nanotubes (CNTs) have received the most attention across the world. These are configurationally equivalent to a two-dimensional graphene sheet rolled up into a tubular structure. With only one wall in the cylinder, the structure is called a single-walled carbon nanotube (SWCNT). The structure that looks like a concentric set of cylinders with a constant interlayer separation of 0.34 A is called a multiwalled carbon nanotube (MWCNT).

The CNT's structure is characterized by a chiral vector (m, n). When m-n/3 is an integer, the resulting structure is metallic; otherwise, it is a semiconducting nanotube. This is a very unique electronic property that has excited the physics and device community

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leading to numerous possibilities in nanoelectronics. CNTs also exhibit extraordinary mechanical properties. The Young's modulus is over 1 TPa and the tensile strength is about 200 GPa. The thermal conductivity can be as high as 3000 W/mK. With an ideal aspect ratio, small tip radius of curvature and good emission properties, CNTs also have proved to be excellent candidates for field emission. CNTs can be chemically functionalized, i.e. it is possible to attach a variety of atomic and molecular groups to the ends of sidewalls of the nanotubes.

The impressive properties alluded above have led to investigations of various applications. The most important aerospace application is high strength, low weight composites. Investigation of metal and ceramic matrix composites with CNTs as a constituent materials is in its infancy. A status update will be provided. CNTs have been shown to provide desirable electrical properties for polymer matrix composites. In many cases, the current problem is the inability to disperse the nanotubes homogeneously across the host matrix.

Other applications for CNTs include electronic components, logic and memory chips, sensors, catalyst support, adsorption media, actuators, etc. All early works in nanoelectronics use CNTs as a conducting channel in an otherwise silicon CMOS configuration. This approach may not really have a future as the use of CNTs, while inherently not solving any of the serious problems of CMOS downscaling (such as lithography, heat dissipation, etc.), it doesn't show an order of magnitude performance improvement either. The critical issue now is to develop alternative architectures in addition to novel materials. In contrast, the opportunities for CNTs in sensors – both physical and chemical sensors – are better and near-term.

The opportunities for aerospace industry are through thermal barrier and wear resistant coatings, sensors that can perform at high temperature and other physical and chemical sensors, sensors that can perform safety inspection cost effectively, quickly, and efficiently than the present procedures, composites, wear resistant tires, improved avionics, satellite, communication and radar technologies.