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CARBON NANOTUBES IN THE CONSTRUCTION INDUSTRY

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Introduction

Carbon nanotubes (CNT) are the subject of one of the most important areas of research in nanotechnology. Their unique properties and potential for valuable commercial applications ranging from electronics to chemical process control have meant that an enormous amount of effort has been undertaken on the investigation of nanotubes in the last five years. Despite this high level of research activity, very little attention has been paid to potential applications in the construction industry. This paper describes properties carbon nanotubes and their applications in the construction industry.

Properties

CNT have a number of unique properties. Their electronic behavior varies depending on their hilarity. Armchair tubes are metallic, while other tubes are semiconductors. In addition, the degree of conductivity or semi conductivity can be controlled by doping. As an example, recent research has shown that the presence of oxygen can dramatically affect the conductivity of CNT. Changes in size or mechanical deformation have also been shown to affect their electronic properties. CNT are also high quality field emitters. Placing a carbon nanotube in a strong electric field will cause electrons to be emitted at high efficiency without damaging the tubes. A summary of the electronic behavior of carbon nanotubes can be found in Louie. Mechanically, CNT appear to be the strongest material yet to be discovered. Experimental results have shown that they have module of elasticity that exceed 1TPa in value. Measurements of ultimate strength and strain have been more difficult to make, but measurements of the yield strength of single walled nanotubes of 63GPa have been reported as well as yield strains are on the order of 6%. CNT are also highly flexible, being capable of bending in circles or forming knots. Like macroscopic tubes, they can buckle or flatten under appropriate loadings. Yakobson and Avouris summarize CNT mechanical behavior. Less work has been done on the thermal behavior of CNT, but theoretical work as well as experimental measurements performed on CNT suspended in liquids suggest that their thermal conductivity may also be remarkably high, approaching the theoretical limit for carbon materials. If these estimates are accurate, CNT are the most thermally conductive material at room temperatures yet discovered. An additional feature is that the thermal conductivity of CNT is believed to be much higher along the tubes than across them, creating the potential for materials that have anisotropic heat conduction properties. However, direct measurements on CNT have yet to confirm these predictions

Applications of carbon nanotubes in the construction industry

While many of the CNT applications developed for other industries will also find uses in construction, there are at least three broad areas of research that will lead to products intended specifically for the construction industry. These areas include CNT composites made with existing construction materials, CNT ropes for use as structural components and CNT heat transfer systems. The first applications are likely to be in CNT composite materials. As noted earlier, CNT are excellent reinforcing materials because of their extremely high strength, toughness and aspect ratios. Polymer, cement and glass are all potential candidates for CNT matrix materials. Current work on polymer/CNT composites has been discussed above, while cement/CNT composites will be covered in more detail in the following sections. Glass reinforced with CNT or other nanofibres are of interest due to the possibility that nanofibres or tubes may be able to provide reinforcement without interfering with light transmittance. However, little work has been done on this aspect of the optical behavior of nanofibres and the success of this approach remains to be seen. The production of longer CNTs that can be formed into ropes would create obvious possibilities for applications such as suspension bridges, where CNT strengths and module of elasticity would allow for the design of significantly longer spans than existing technology makes possible. Similarly, the use of CNT ropes can be envisioned in improved pre- or post- tensioned concrete structures. Carbon nanotubes have also been discussed as materials for the construction of very large, space based structures; including space elevators. These cable systems have the theoretical capability of reaching from the earth's surface to far beyond geosynchronous orbit. Elevator cars running simultaneously up and down the cable would allow cargo and goods to be transferred from space to the earth and vice-versa with minimal energy requirements. While it remains to be seen whether such structures can be engineered and constructed, CNT appear to be the only material capable of bearing the immense structural loads that would be required. The thermal conductivity of carbon nanotubes presents other applications. Improved thermally resistant composite materials may be possible, since a sufficient density of carbon nanotubes could allow heat to be conducted rapidly away from the contact surface to heat sinks. In the longer term, it may also be possible to develop insulating materials and heat pipes, taking advantage of the differences in thermal conductivity across the tubes and along their lengths. One application would be in the heating of buildings through the replacement of existing liquid based systems for eating floors.

Conclusion

Carbon nanotubes are one of the most important materials under investigation for nanotechnology applications. Their unique properties, ranging from ultra high strength through unusual electronic behavior and high thermal conductivity to an ability to store nanoparticles inside the tubes themselves has suggested potential applications in many different fields of scientific and engineering endeavor. As was the case with silicon transistor technology, these applications will grow in time as the capacity for industrial production and manipulation of CNT is created and as understanding of the physics of CNT continues to improve.