CARBON NANOTUBES AS MULTI-FUNCTIONAL FILLER IN NANOCOMPSOITE

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Abstract

A large quantity of carbon nanotubes is currently available because they were produced by the right combination of the catalytic chemical vapor deposition method and the following high-temperature thermal treatment in argon in a semi-continuous system. Since the viability of carbon nanotubes strongly depends on their commercialization and industrialization, their current status for use as multi-functional fillers in various matrix systems were reviewed

Introduction

The most distinguished nonmaterial "one-dimensional carbon nanotubes" [1, 2] have attracted a particular interest from academy and industry, and thereby their related science and technology have developed at an emerging speed, since their unique atomic structure render them to have novel physico-chemical properties: mechanical strength that is 100 times higher than steel, electrical conductivity that is as high as copper, and thermal conductivity that is as high as diamond. Those excellent properties of any reported value for any type of material make them promising in numerous applications (e.g., nanocomposite, energy storage and energy-conversion systems, sensors, filed-emission displays and lighting tubes, radiation sources, nano-devices, actuator and probes) [3]. Among the various application fields of carbon nanotubes, the largest anticipated large-consumption of carbon nanotubes is multi-functional fillers for various high performance composite materials, when exploiting the excellent mechanical and electrical properties of carbon nanotubes. In this study, I will present the current status of nanotubes-filled composites (e.g., plastic, rubber, magnesium or aluminum) with a detailed study on the effect of nanotubes texture and morphology for dispersion and composite performance.

Large-scale production of carbon nanotubes

Currently, the dominant recent trend is to synthesize CNTs using a CVD method because this technique is very powerful tool for the large-scale production of both SWNTs and also MWNTs, especially using a floating reactant technique [2]. By simultaneously feeding hydrocarbons and nanoscale catalytic particles (or precursor) such as iron in the gas phase into reaction chamber, carbon nanotubes have been synthesized in a large-scale. Growth of SWNTs and MWNTs in reactor has been proposed to involve the catalytic deposition of hydrocarbons over the surface of nano-sized metal particles and a continuous output by the particle of well-organized tubule of hexagonal *sp*^{2}-carbon [2]. Regarding the bulk production of MWNTs for industrial applications, it is important to mention that in the end of 1980, Showa-Denko Co. Ltd and Hyperion Catalysis International, Inc. (Cambridge, MA) commenced to produce several tons of catalytically grown carbon nanotubes annually. Recently, Showa Denko has announced to increase the production capacity up to 100 tons/year in 2007. Also, Applied Sciences, Inc already has a large-scale production capacity for MWNTs, which exhibits relatively large diameters and wide distribution of diameters ranging from 70 to 200 nm with specific structure. The most interesting point is that all companies selected a catalytic CVD method based on iron catalysis, and furthermore all companies adopted the floating reactant technique for the large-scale production of MWNTs. Even though a great deal of progress has been achieved related to the bulk synthesis of carbon nanotubes, carbon nanotubes are still expensive. However, a synergistic effect of large-scale production, and also newly developed end-use (e.g., nanocomposite) will cut down price by at least 10 percent of the current value.

Multi-functional filler

It has been shown that carbon nanotubes could behave as the ultimate one-dimensional material with remarkable mechanical properties. The density-based modulus and strength of highly crystalline SWNTs are 19 and -56 times that of steel. Moreover, carbon nanotube exhibit high electrical and thermal conducting properties; better than copper which. Therefore, carbon nanotubes (single- and multi-walled) have been studied intensively as fillers in various matrices, especially polymers. The best utilization of the intrinsic properties of these fibrous nanocarbons in polymers could be achieved by optimizing the interface interaction of the nanotube surface and the polymer. Therefore, surface treatments via oxidation in conjunction with the polymer or epoxy could be used in order to improve adhesion properties between the filler and the matrix. This results in a good stress transfer from the polymer to the nanotube. There are various surface oxidative processes, such electrochemical, chemical and plasma techniques. From the industrial point of view, the ozone treatment is a very attractive technique. In addition, the dispersion of the nanotubes / nanofibers in the polymer should be uniform within the matrix. The smallest working composite gear has been prepared by mixing nanotubes into molten nylon and then injecting into the tiny mold. As shown in Fig. 1 (b), this gear is as small as the diameter of human hair. This piece exhibits a high mechanical strength, high abrasion resistance and also good electrical and thermal conductivity. When polymer solutions containing cup-stacked type carbon nanotubes were coated on bolt (Fig. 1 (e)), we found that an improvement of the corrosion resistance is really remarkable. Recently, we successfully fabricated strong but ductile magnesium or aluminum composites by introducing small amount of carbon nanotubes via an optimized dispersing technique (Fig. 1 (g, h)).

Figure 1 Various carbon nanotube-filled functional nanocomposites.

Conclusions

To achieve the success story of carbon nanotubes, at least three obstacles have to be solved. First is how to obtain high purity carbon nanotubes because the remained metallic impurities were known to give rise to toxic properties. Second is how to control selectively the surface properties of carbon nanotubes for improving binding strength with various matrix systems. Finally, the most important but critical "safety" issue has to be clarified based on long-term and systematic biological studies. Even though many challenges to be solved remain, extensive and intensive efforts in both academy and industry will clear out those problems soon and finally enable carbon nanotubes to play a key innovative material of 21st century in numerous industrial processes.

References

1. Oberlin, A.; Endo, M.; Koyama, K. 1976. Filamentous growth of carbon through benzene decomposition, J. Crys. Grow. 32:335-349.
2. Endo, M. 1988. Grow carbon fibers in the vapor phase, Chem. Tech. 568-576.
3. Endo, M.; Hayashi, T.; Kim, Y.A.; Muramatsu, H. 2006. Development and application of carbon nanotubes, Jpn. J. Appl. Phys. 45:4883-4892.