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Short Communication

Boron Nitride Nanotube/ Polystyrene Composites

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Abstract

We report mechanical reinforcement and thermal conductivity improvement of polystyrene by boron nitride nanotubes. The boron nitride nanotubes were synthesized by a chemical vapor deposition method at high temperature. It was demonstrated clearly that the boron nitride nanotubes synthesized can effectively improve both mechanical properties and thermal conductivity of polystyrene.

INTRODUCTION

Since the discovery of carbon nanotubes (CNTs) and the full range of their unique mechanical, thermal and electrical properties, significant efforts have been made to fabricate advanced CNT composite materials which possess a good combination of those. Many polymers, such as polyacrylonitrile, polystyrene (PS), polyvinylalcohol etc., have been used to fabricate CNT reinforced composites [1]. Tensile strength and modulus enhancements have continuously been reported.

A boron nitride nanotube (BNNT) has comparable mechanical properties with a CNT [2]. The theoretical estimation of the elastic modulus of a BNNT gives ~500 to 850 GPa [3], approximately 0.8 times of that of CNT. In many other respects, BNNT possesses advantageous properties as compared with a standard CNT. For example, BNNT is chemically inert and structurally stable. The thermal conductivity of BNNTs has been predicted to be even higher than that of CNTs [4]. In addition, opposed to CNTs, BNNTs do not absorb visible light due to a wide band gap, which reveal an electrically insulating property of BNNTs. These factors should make BNNTs primarily useful as additives in composites to achieve both high thermal conductivity and high insulation [5]. However, the awaiting breakthrough on BNNT/polymer composites was hampered because it is very difficult to fabricate BNNTs in large quantities [6-8]. Here we report the fabrication of PS/BNNT composite and its mechanical reinforcement, as well as thermal conductivity improvement based on highly pure BNNTs grown by a chemical vapor deposition method using metal oxide and boron powder as reactants (BOCVD) [9].

EXPERIMENTAL

The detailed procedure for BNNTs' growth is described elsewhere. The purified BNNTs possess very high purity, as shown in (Figure 1), the scanning electron microscopy (SEM) image of BNNTs synthesized. In order to fabricate a composite, firstly, the BNNTs were mixed with solvents, typically chloroform and *N, N*-dimethylformamide (DMF). Then, the mixture was sonicated over 200 min to disperse BNNTs. PS was dissolved in the mixture *via* magnetic stirring. The mixture was then cast into a glass plate and the solvent was completely evaporated under film heating to 60ºC and annealing over 4 hours [10,11].

The composite films were dismounted from the glass plate for *ex situ* mechanical tensile tests on a RTC-1225A apparatus. Thermal conductivity measurements were performed on a Hot Disk thermal constant analyzer.

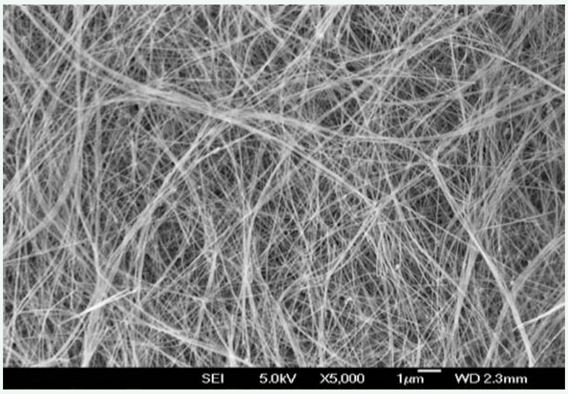

Figure 1 SEM image of BNNTs synthesized by BOCVD method.

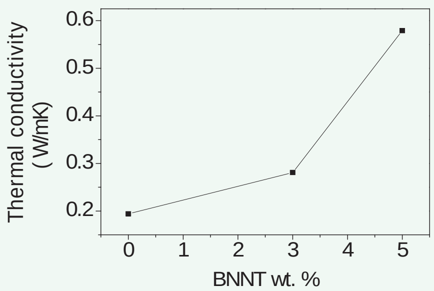

Figure 2 Thermal conductivity of pure PS and PS/BNNT composite.

RESULTS AND DISCUSSION

In contrast to CNT composites, BNNTs/polymer composites possess good transparency. Mechanical reinforcement was achieved with the BNNTs with very high Young's modulus. For the films made with DMF as a solvent, an elastic modulus increase of 7% and 20% was obtained when a 1 wt.% and 3 wt.% BNNTs fractions were used, respectively. It is further proposed here that some better results may be obtained using covalently functionalized BNNTs. In fact, the functionalization can improve the dispersibility of BNNTs without harmful influence on PS. Similar technique is widely utilized for the CNT/polymer composites [12]. A simple calculation predicts that if the external tensile load can be transmitted from matrix to BNNTs ideally, 110% modulus increase can be achieved with 3 wt.% BNNTs fraction, which indicates that BNNT is a very promising material for polymer mechanical enhancement.

The thermal conductivity of PS can also be improved by using BNNT as additive, as shown in (Figure 2). With 5 wt.% BNNTs fraction, the thermal conductivity of PS can be improved from 0.19 to 0.58 W/mK. The fabrication of PS/BNNT composites with higher BNNT concentration for thermal conductivity measurement is still underway.

CONCLUSION

PS/BNNT composite was fabricated for mechanical and thermal property measurements. It was revealed that 1 wt.% BNNT fraction may result in 21% increase in elastic modulus of PS. The thermal conductivity can be tripled with a 5 wt.% BNNT fraction. Our results indicate that BNNT is a very promising material for polymeric composites

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