



Short communication

Polystyrene–acrylonitrile–CNTs nanocomposites preparations and tribological behavior research

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ABSTRACT

Polystyrene–acrylonitrile mixed with different carbon nanotube (CNT) fractions has been successfully prepared by means of in situ polymerization method. The tribological behaviors of the nanocomposites are investigated by friction and wear tester under dry conditions. Compared with the polystyrene–acrylonitrile, polystyrene–acrylonitrile–CNTs shows not only the lower friction coefficient but also the higher wear resistance, which reveals that CNT could reduce the friction and improve the wear resistance behaviors of the nanocomposites dramatically. According to the results of the microhardness measurements, CNT is found to be able to improve the microhardness of the nanocomposites effectively. The mechanism of the reinforced tribological properties and microhardness for the polystyrene–acrylonitrile–CNTs nanocomposites is also discussed in detail.

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1. Introduction

Both polyacrylonitrile (PAN) and polystyrene (PS) are important thermoplastic and are widely used in architecture, automotive industry, aerospace and railway transport systems because of their favorable properties. Polystyrene–polyacrylonitrile (SAN) copolymer could enhance mechanical properties comparable to the pure PAN and PS. The copolymer can effectively improve the monomer characters including heat-resistant, wear resistance, anti-burning, low temperature friable and machining performance, etc. In addition, SAN is widely used in the home wiring, automobile making, commodity and other productions. However, its applications are limited by its relatively weak tribological properties.

It is well known that carbon nanotube (CNT) [1] can be used to prepare the nanocomposites with excellent tribological properties. The research has sprung up world widely with respect to the intriguing properties of CNT. A large quantity of increasing scientific and technological interests in their novel properties and potential applications have been proposed and investigated in the past decade. Many researchers have investigated the solid particle erosion behaviors of polymers and their composites [2–16]. It is widely accepted that the wear resistance of poly-

mer composites is usually higher than that of neat polymers [17–19].

Recently, CNT as fillers in polymer matrix are attracting considerable interests due to their unique carbon structure and extraordinary mechanical, thermal, and electrical properties, and various polymer–CNT nanocomposites have been studied [20–23]. Because CNT can withstand repeated bending, buckling and twisting to build excellent nanocomposites matrix, it shows lower friction coefficient and wear rate compared with the pure substrates matrix. As we know, exceptionally stiff and strong are CNT which indicate that they have high Young's modulus and high tensile strength. The Young's modulus of single-walled carbon nanotube (SWNT) is theoretically estimated to be up to 5 TPa [24]. The average value of Young's modulus of isolated multi-walled carbon nanotube (MWNT) has been measured to be 1.8 TPa and its bending strength is as high as 14.2 GPa [25]. The tensile strength of CNT is 100 times stronger than that of steel, while their density is only one-sixth to one-seventh of that of steel. Thus, CNT is believed to be a potential and ideal candidate to fabricate excellent composites with remarkable performance [26–30].

According to the factors mentioned above, polystyrene–acrylonitrile–CNTs (SAN–CNTs) copolymer nanocomposites with outstanding tribological properties have been proposed and studied. In this paper SAN–CNTs copolymer nanocomposites are successfully prepared by means of in situ polymerization. The investigation has been done in detail about

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the influences of CNT on the improved tribological behaviors of the nanocomposites. The enhanced friction and wear mechanisms of SAN–CNT in dry sliding against a plain carbon steel counterpart were also discussed.

2. Experimental

2.1. Purification and modification of CNT

CNT is easy to agglomerate due to their high surface energy, so it must be purified before reaction. In this course, CNT was modified with various oxide functional groups at the same moment, such as quinoids, carbonyls, and carbocylates, at the defect sites which located at the ends or the sidewalls of the CNT [31].

2.2. Distilling of the monomer

Before polymerization, the analytical grade AN monomer and ST monomer must be distilled under reduced pressure in order to eliminate the inhibitors, details of which have been described in the literature [21,32].

2.3. Fabrication of SAN–CNTs copolymer nanocomposites and characterization

In this work, SAN was produced in a process of addition polymerization. During the process, the free radical initiator, BPO (benzoyl peroxide), was added into the ST and AN mixtures at the reaction temperature of 70 °C. A BPO molecule formed two free radicals, the C=C double bonds in ST and AN molecule would be opened, and then linked with each other to form long chain of SAN molecules. The reaction lasted for 30 min before CNT was added into reacting mixtures. The SAN–CNT samples were synthesized by using 0.1, 0.5, 1.0, 1.5, 2.0, 3.0 wt.% CNT material (weight percent with respect to ST and AN mixtures), Then the SAN–CNTs viscous mixtures were fully mixed ultrasonically, stirred for 30 min. In this case, SAN molecules could grow more and CNT would be better dispersed in polymer matrix. After being poured into the mold, the mixture was heated to 40 °C at a rate of 1 °C/h, being held there for 20 h. Then the mixtures were stepped up to 80 °C for 72 h, and cooled to room temperature. Thus the homogeneous mixtures were molded into the block specimens. Finally, the specimens were prepared in size of 30 mm × 7 mm × 6 mm for tribological property tests and microhardness measurements.

The friction and wear tests for evaluating the tribological properties of SAN–CNTs were conducted on an M-2000 model friction and wear tester under dry-sliding contact conditions. The friction force is measured using a torque shaft equipped with strain gauges, and then the friction coefficient is calculated by taking into account the normal load applied and the friction force measured. The friction coefficient is recorded under steady-state conditions by a personal computer, which controlled the friction and wear tester. At the end of each test, the width of the wear scar on the block specimen is measured with a digital optical microscope with an accuracy of 0.01 mm, and then the wear volume loss (V) of the block specimen is calculated from the following equation:

$$V = B \left[\frac{\pi R^2}{180} \arcsin \left(\frac{b}{2R} \right) - \frac{b}{2} \sqrt{R^2 - \frac{b^2}{4}} \right] \quad (\text{mm}^2) \quad (1)$$

where V refers to the volume loss (mm^3), B to the width of the block specimen (mm), R to the radius of the steel ring (mm), and b to the width of the wear scar (mm). According to the wear volume loss

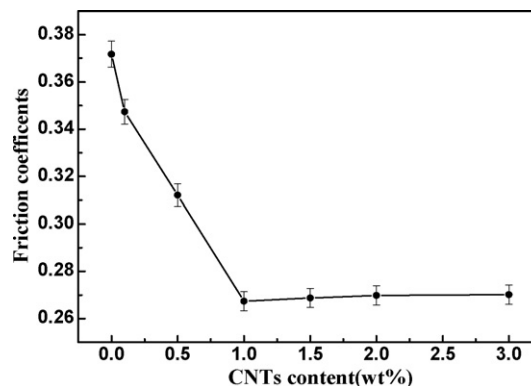


Fig. 1. The friction coefficients of SAN–CNTs as a function of CNT content.

(V), the wear rate (ω) is calculated from the following equation:

$$\omega = \frac{V}{NL} \quad (\text{mm}^3 \text{N}^{-1} \text{m}^{-1}) \quad (2)$$

where N is the applied load (N) and L is the sliding distance (m). Three replicate friction and wear tests were carried out so as to minimize data scattering. The average result of the three replicate tests was reported in this paper.

The microhardness measurements of specimens were performed using a microhardness indenter (VDMH-5 Version 2.01, China). A load of 10 g with a loading time of 5 s was used. Each specimen was measured ten times, respectively. The average result of measurements was taken as the reported hardness value in this paper.

In order to explain the effects of CNT on tribological behaviors, the structure of SAN–CNTs was characterized by field emission scanning electron microscopy (FE-SEM JSM-6335F-NT) and the morphologies of the worn surfaces of the composites blocks were observed using scanning electron microscope (SEM, JOEL, JSM-5600LV).

3. Results and discussion

Fig. 1 shows the friction coefficient of SAN–CNTs as a function of CNTs fraction for steady-state sliding against the stainless steel ring under dry-sliding contact conditions. It is apparent that the friction coefficient of the nanocomposites decreases with increasing CNT fraction. The friction coefficient values sharply decrease from 0.37 to 0.26 when CNT fraction is below 1.0 wt.%. The friction coefficient value decreases nearly 30%. As the fraction of CNT

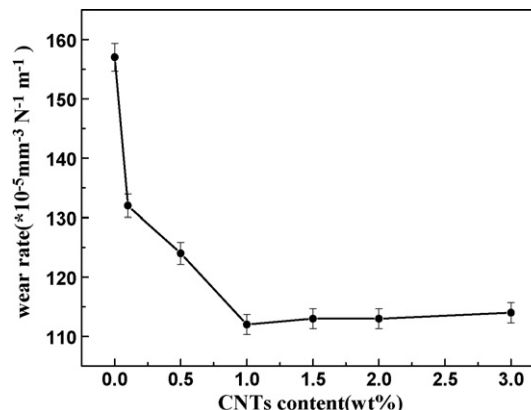


Fig. 2. Effects of CNT content on the wear rate of SAN–CNTs.

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