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Synthesis, thermal, mechanical and rheological properties of multiwall carbon nanotube/waterborne polyurethane nanocomposite

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Abstract

A novel nanocomposite consists of multiwall carbon nanotube (CNT)/waterborne polyurethane (WPU) nanocomposite has been successfully prepared. Carbon nanotube was modified, to compatibilize with waterborne polyurethane via covalent bonding or ionic bonding. Thermal properties show that adding carbon nanotube enhanced the thermal stability by 26 °C (from 315 to 341 °C) when carbon nanotube content was 2.5 phr (*p*art per *h*undred parts of *r*esin). After the surface modification, carbon nanotube can be dispersed effectively, and improve the interfacial strength between it and waterborne polyurethane matrix. Consequently, the physical properties of nanocomposite are enhanced, especially in the covalent bonding system. Mechanical property tests show that adding multiwall carbon nanotubes improve the tensile properties very significantly (370% in tensile strength). SEM and TEM microphotographs prove that carbon nanotube can be effectively dispersed in waterborne polyurethane matrix. Rheological tests show that carbon nanotube can increase the melt viscosity and reduce the variation of processing viscosity.

Keywords: Waterborne polyurethane; Multiwall carbon nanotube; Thermal property; Mechanical property; Rheological property

1. Introduction

Polyurethane (PU) is one of the most interesting synthetic elastomers. Due to its unique properties, more attention has been attracted to the synthesis, morphology, chemical and mechanical properties [1,2]. The linear structure of segmented PU appears in the form of $(A–B)_n$. The soft-segment part B is normally polyester or polyether macrogel of molecular weight between 1000 and 3000, and the hard-segment part A is consisted of a low-molecular weight diol or diamine reacted with diisocyanate. Owing to the difference in the chemical structure, the soft and hard segment form microdomains by mutual attractions involving intermolecular hydrogen bonding [1]. For waterborne polyurethane (WPU) systems, only water was evaporated during the drying process, thus rendering these systems safe with regard to the environment. They are non-toxic, non-flammable and do not generate polluted air or wastewater [3–5].

Carbon nanotube (CNT) generates a great potential in the synthesis of polymer composite due to its excellent axial tensile strength. In addition to the exceptional mechanical properties, CNT possesses superior thermal and electrical properties such as high thermal stability up to 2800 °C in vacuum, thermal conductivity about twice as high as diamond, and is 1000 times higher than copper wires in electric-current-carrying capacity [6–8].

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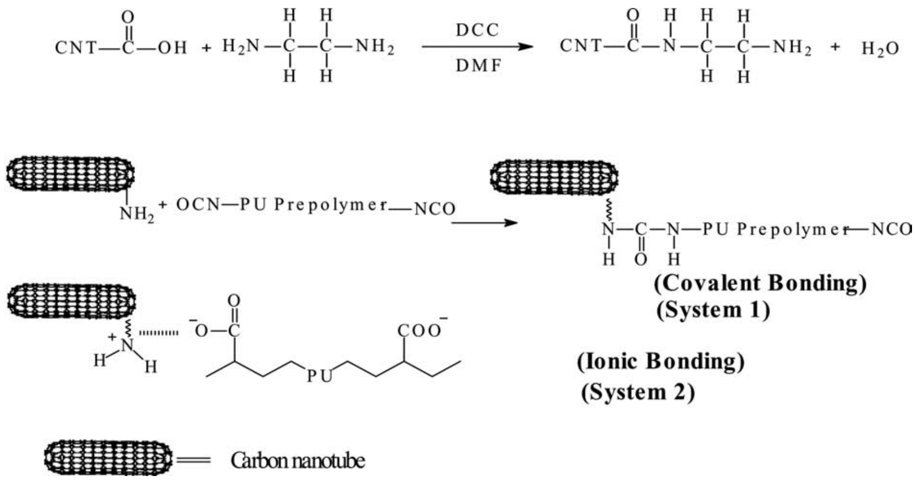

Scheme 1. Covalent bonding and ionic bonding between the carbon nanotube and waterborne polyurethane.

The CNT-based composites have been intensively studied using different matrix polymer materials [9–18]. Rahul Sen and co-workers [10] reports single-walled carbon nanotube (SWNT) reinforced polyurethane composite membranes. All the membranes show a non-linear elastic behavior in the low stress region (0–2 MPa) and plastic deformation at higher stress. The tensile strength of SWNT–PU composites increases by 46% from 7.02 to 10.26 MPa. Composites fabricated with ester functionalized SWNT (EST-SWNTs) show an increase of 104% in tensile strength when compared to electrospin pure PU. The tangent modulus for AP-SWNT–PU composite membrane and EST-SWNT–PU composite membrane is enhanced by 215% and 250% respectively, when compared to pure PU membrane.

In this study, carbon nanotube/waterborne polyurethane nanocomposite was prepared, as shown in Scheme 1. Two approaches are utilizing to improve the compatibility between carbon nanotube and waterborne polyurethane; which are covalent bonding system (system 1) and ionic bonding system (system 2). Thermal, mechanical and rheological properties of composite has been characterized when the carbon nanotube content is from 0 to 4 phr.

2. Experimental

2.1. Materials

Carbon nanotube was obtained from the Nanotech Port Company, Shenzhen, China. (The diameter of CNT is 40–60 nm, length is 0.5–40 μm, special surface area is 40–3000 m^2/g). The 3-isocyanatemethyl-3,5,5-trimethyl-cyclohexylisocyanate (IPDI), neopentylglycol (NPG), and dimethylol-propionic acid (DMPA) were purchased from Lancaster Company, Esatgate, White Lund Morecambe, UK. Polycaprolactone (PCL) with

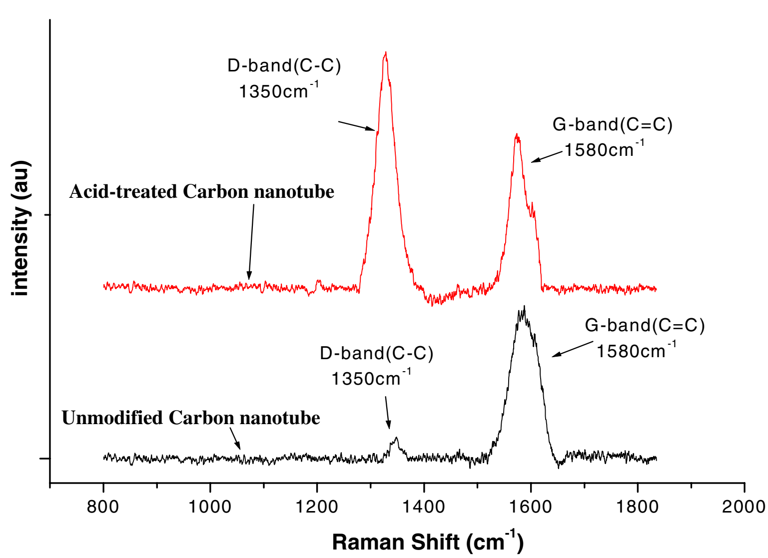

Fig. 1. Raman spectrum of the pristine carbon nanotube and the modified carbon nanotube.