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Evaluation of mechanical properties of functionalized carbon nanotube reinforced PMMA polymer nanocomposite

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Abstract

In this paper, the multi-walled carbon nanotubes (MWCNT) were functionalized by chemical treatment for surface modification to create a better interfacial adhesion between polymer and nanotubes. Functionalization has proved to be an effective method to modulate different physical and chemical properties of the carbon nanotubes, facilitates dispersion and processing. The goal of this study is to determine the mechanical properties of the nanocomposite using experimental methods. Various mechanical tests such as tensile strength and impact strength were carried out to study the effect of functionalized filler content in the nanotube-reinforced Poly (methyl methacrylate) (PMMA) nanocomposite. The surface morphology of MWCNT and of the fractured surface of the fabricated MWCNT/PMMA were analyzed by Scanning Electron Microscope (SEM).

Keywords: Nanocomposite; Carbon nanotube; Mechanical properties; SEM

1. Introduction

Composite materials are the main substitute for the conventional engineering materials due to its good characteristics of strength to density, low-cost, eco-friendly manufacturing processes [1−3]. Composites are light and have comparatively enhanced physical properties than their constituent materials [4]. Since the discovery of the carbon nanotube (CNT) [5], it has been the center of attractions due to its interesting properties. It has managed to capture the attention of researchers for its wide range of applications, including field emission, energy storage, molecular electronics and so on [6−8]. Nanocomposite with good CNT dispersion exhibits an exceptional combination of mechanical, electrical, thermal and tribological properties [9,10]. Polymer nanocomposites, which are endowed with many important properties such as nonlinear optical properties, electrical conductivity and luminescence, represent a new alternative to conventionally filled polymer composites. These have been proposed for their use in various applications including chemical sensors, electroluminescent devices, electro catalysis, batteries, biosensors, photovoltaic devices, smart windows and memory devices. CNTs have many advantages over other carbon materials in terms of

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electrical conductivity and thermal properties for which these have numerous applications in electronics and advanced materials. However, nanocomposites have had dispersion problems, which affect the inherent properties of the composites. The electron movement and the dipole–dipole interactions are influenced by the C–C bond structure of the carbon nanoparticles. But, the readily entangled carbon nanoparticles develop attractive forces among themselves, which eventually needs physical and chemical dispersion to break-up and reduce agglomeration [11,12,4]. The poor dispersion of CNTs in the polymer matrix results in poorer interfacial interaction. Nanotubes are functionalized to activate its surfaces to form a better adhesion between polymer and CNTs via the interface. The CNTs have found their applications as one of the best reinforcements in the composites, providing excellent mechanical, thermal and electrical properties [13–20]. In literature, various composite fabrication techniques have been reported for polymeric nanocomposites. Melt-mixing [21] and solution processing [22] are common for thermoplastics and thermosetting polymer. To have a better dispersion shear mixing [23] or ultrasonication method is used. To improve the bonding between the phases techniques like in situ polymerization [24], attachment of functional group [25] or surfactant application [26] may be employed. The process of fabrication affects much more than the grade of CNTs and polymer [27–32]. Better fabrication techniques enhance the above properties tremendously. Nowadays, researchers are much more focused on discovering the novel approaches to fabricate nanocomposite with good dispersion of reinforcements [33–36]. However, the controlling parameters can be optimized to get the best set of factors to prepare a composite. In this work, a fibrous composite has been prepared by taking multiwall carbon nanotube as reinforcement and polymethyl methacrylate as a matrix. Many specimens have been prepared by taking different compositions of MWCNT varying from 0.3 to 1.5% weight. The tensile properties have been studied. Finally, the scanning electron microscope image is taken to study the microstructure of the composite samples.

2. Experimental method

This section describes the manufacturing and testing procedures. The tensile modulus E, tensile strength, and impact strength are measured. Specimens fabricated by injection molding taking PMMA with different weight percentages of MWCNTs were tested.

2.1. Materials

2.1.1. Poly (methyl methacrylate) (PMMA)

The thermoplastic polymer, PMMA is highly hygroscopic for which it must be dehydrated prior to micro compounding. An appropriate amount of PMMA is preheated in a vacuum oven at 60 °C for 1 h. This heating process extracts all the moisture from the PMMA otherwise this will react with MWCNT and form voids inside the composite. This process is done in a vacuum medium to avoid reaction with atmospheric moisture.

2.1.2. Functionalization of CNT

The carbon nanotubes produced in the laboratory were chemically treated for the functionalization of tubes. Chemical treatment makes the end of the tubes fragmented and facilitates the attachment of functional groups to the tube surface. This results in a better adhesion between the tube surface to the matrix occurs. The end caps of the nanotubes are supposed to be composed of the highly reactive fullerenes-like hemisphere in contrast with the side walls. The side walls themselves have a pentagon–heptagon pair called Stone-Walls defect, sp^3-hybridized defects and vacancies in the carbon nanotube lattice as shown in Fig. 1. This results in improved mechanical properties by effective load transfer from the matrix to the tube. The electrical conductivity also depends on the good interconnection of the tube in the matrix. The carbon nanotubes are treated with concentrated H_2SO_4 and HNO_3 in the ratio of 3:1 by volume. Then the solution is stirred to disperse the hydrophobic f-MWCNTs completely using a magnetic stirrer at room temperature with a low stirring speed.

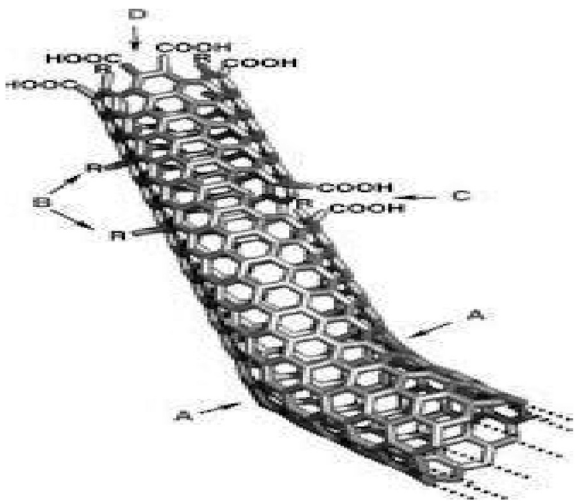

Fig. 1. Various defects in a Single-walled nanotube.

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