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Morphological, mechanical and AC electrical conductivity of polyvinyl alcohol loaded with single walled carbon nanotubes

Naziha Suliman Alghunaim

Department of Physics, Faulty of Science, King Abdulaziz University, Jeddah, Saudi Arabia

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ABSTRACT

Two series of polyvinyl alcohol/single walled carbon nanotubes (PVA/SWCNTs) nanocomposite films were prepared using sonicator in double distilled water solution to obtain a well dispersion of SWCNTs in polyvinyl alcohol as a host material using casting techniques. The mechanical properties are significantly improved and enhanced as compared to the pure PVA film after adding the SWCNTs. Young's modulus and tensile strength are increased after adding SWCNTs. The prepared films are studied by TEM and AC conductivity measurements. The TEM demonstrated that SWCNTs is well distributed in PVA matrices with some broken of SWCNTs revealing that SWCNTs broke aside as opposed to being pulled out from fracture surface suggest an interfacial bonding with some wrapped around PVA. The maximum values of AC conductivity are observed at the higher frequency. Both dielectric constant (ε′) and dielectric loss (ε″) are decreased with an increase of the frequency related to the direction of dipoles in PVA matrices orient toward applied field. Decrease trend at maximum frequency has seemed stable due to difficult of dipoles rotation. The values of dielectric parameters are increased gradually with the increase in both the temperature and the concentration of SWCNTs.

1. Introduction

The polymer is taken into consideration to be great basic matrices for nanocomposite materials due to the actuality may be without much of a stretch to item an assortment of mass physical properties with preparing. Nanoparticles are used as a filler in polymeric systems to manufacture commercial for many various applications. The unique combination of the nanomaterial's characteristics, such as size, mechanical properties and low concentrations necessary to effect change in a polymer matrix, coupled with advanced characterization and simulation techniques [1,2]. The properties of nanocomposites depends not just on properties of their individual folks additionally on their morphology and interfacial attributes [3]. The asset in nanotechnology are coordinated toward novel and enhanced results of nanocomposites for an extensive variety of uses [4]. Nanocomposites materials are a multi-phase material, one of the components has nanosize added materials [5]. They are relied upon to show surprising properties rising out of the blend of every [6].

Nanoparticles are used as a filler with the polymer in polymeric systems to manufacture commercial for many various applications [7]. Carbon nanotubes (CNTs) are perceived as the stiffest and most grounded man-made materials known not. Perceived by high adaptability, lower mass thickness and substantial perspective proportion and to a great degree high ductile moduli and quality [8]. Moreover, single-walled carbon nanotubes (SWCNTs) can transport current for long length without noteworthy loss of quality making them more conductive than copper [9,10].

Depending on the way of inorganic particles and properties to be refined, an assortment of courses can be utilized to plan polymer nanocomposites with high homogeneity. The key point is to discover the best conditions to enhance the connection between the polymer network and the scattered particles. Also, there is not a general course that permits us to create materials with homogeneous scattering, it is important to upgrade the different strides to come to the focused-on properties.

In general, SWCNTs have created high research and activity due to the properties that used in a wide types of application [11]. The unique characterization of CNTs like structural, thermal properties, electrical conductivity and high strength has considerable research with embedded of SWCNTs inside the polymer to obtain nanocomposite [12]. The adding of a few ratio of SWCNTs as a nanofiller is strongly improves properties of the polymer [13].

Numerous studies related to handling and coming about mechanical and/or electrical properties of polymer/CNTs have been distributed [14,15]. In this work, we prepared two series nanocomposites containing low contents of single-walled carbon nanotube (SWCNTs) embedded in polyvinyl alcohol (PVA) by sonication and casting method and enhancement of morphological, mechanical properties and AC

E-mail address: n-al-ghunaim@hotmail.com.

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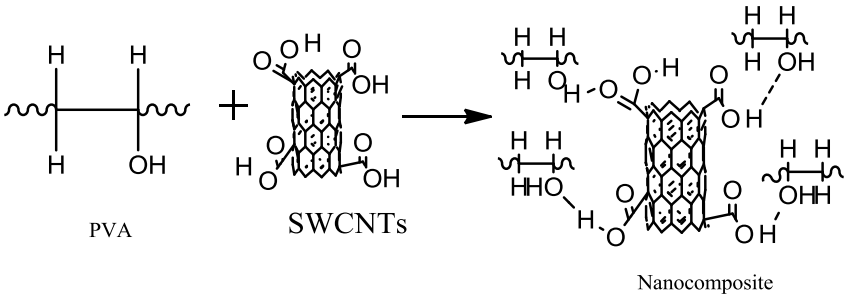

Scheme 1. The possible interaction mechanism between PVA and SWCNTs.

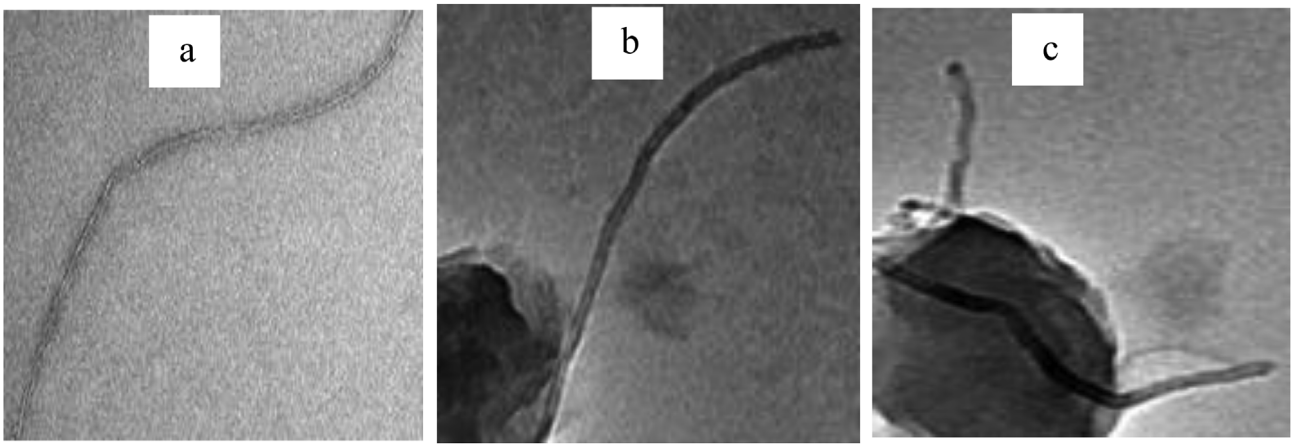

Fig. 1. TEM micrograph of: a) pure SWCNTs, b) 0.02 SWCNTS/PVA and c) 0.04 wt% of SWCNTs/PVA.

Table 1
The values of Young's modulus and Tensile strength of PVA and PVA films containing 0.02, and 0.04 wt% of single walled carbon nanotubes (SWCNTs).

Sample	Young's modulus (MPa)	Tensile strength (MPa)
PVA	0.121	7.32
0.02 SWCNTs/PVA	0.307	15.2
0.04 SWCNTs/PVA	0.285	18.4

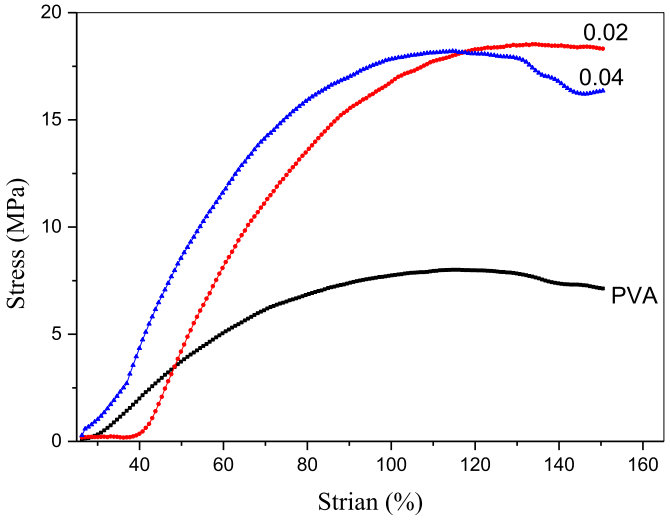

Fig. 2. The stress-strain curves for the films containing 0, 0.02, and 0.04 of SWCNTs of SWCNTs/PVA.

electrical conductivity at different frequencies and temperatures to use the prepared nanocomposites in technological application like rechargeable batteries.

2. Experimental work

2.1. Materials and preparation

Functionalized single-wall carbon nanotubes (SWCNTs-COOH) is obtained from Nanothinx (Greece). SWCNTs have diameter ~0.8–1.4, length ≥5 μm and purity 85%. Polyvinyl alcohol (PVA) has M_w = 146000 is supplied by Sigma-Aldrich. The chemicals are used without purifications.

The calculated amount of PVA polymer is potted in a glass beaker and solubilized distilled water with stirring at 60 °C about 6 h to obtain 20% solution of PVA. The solution of PVA is cooled to room temperature to remove any air bubbles. After that, 2 and 4 mg of SWCNTs-COOH are added double distilled water with stirring. Suspension solutions of SWCNTs-COOH are added dropwise to the PVA solution with continuous stirring. The SWCNTs/PVA solution is cast in Petri dishes and it left at 40 °C to dry about 36 h. The films of the nanocomposites are stored until measurements. The morphological of the nanocomposites is investigated using TEM (JEOL-JEM-1011, Japan). The mechanical testing is measured by a computer-controlled Lloyd LRX5K (Lloyd Instruments Ltd, UK). The AC electrical parameters are investigated using utilizing programmable automatic (Model Hioki 3531Z Hitester) to study the following parameters, loss tangent (tan δ), capacitance C and impedance Z with the frequencies from 0.1 Hz to 20 MHz. The possible interaction mechanism between PVA as a host material and SWCNTs is given in Scheme 1.

3. Results and discussion

3.1. TEM

The TEM images for pure SWCNTs and SWCNTs doped 0.02 and