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ORIGINAL PAPER

Preparation, morphology and conductivity of polyacrylonitrile/multi-wall carbon nanotubes composite nanofibers

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Abstract Composite nanofibers of polyacrylonitrile/multi-wall carbon nanotubes (PAN/MWCNTs) were prepared via electrospinning. Samples contained 0, 0.5, 1, 2, 3, and 3.5 wt% of MWCNTs. The viscosity and electrical conductivity of electrospinning solutions were measured. Results revealed that, with the addition of multi-wall carbon nanotubes, viscosity was increased and electrical conductivity was improved. Rheological behavior was studied using two different viscometers. Moreover, morphology and diameters of the composite nanofibers were studied by scanning electron microscopy (SEM) and nanofiber diameter distributions were presented. SEM micrographs showed that by adding MWCNTs, the average diameter of nanofibers was increased. Furthermore, the effect of MWCNTs on glass transition temperature, T_g, was investigated using differential scanning calorimetry (DSC) technique. The results showed that T_g was increased with the addition of MWCNTs. In addition, Fourier transform infrared spectroscopy (FTIR) results showed that MWCNTs can affect the orientation ability of polymer chains. The effects of adding salt, increasing voltage and changing the tip-to-collector distance on the morphology and diameters of composite nanofibers were examined. The electrical conductivity results of electrospun mats were measured by a two-probe method. Electrical conductivity was increased by addition of MWCNTs and its behavior followed the percolation theory. Finally, it was observed that mats with smaller diameters have higher electrical conductivity.

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Introduction

Nanofibers are fibers with diameters under 400 nm. A distinguishing property of nanofibers is their large surface area to volume ratio. Hence, nanofibers have been considered for many applications [1, 2] such as scaffolding [3], filters [4], sensors [5–7] and nanomembranes [8].

Although, there are various methods for producing nanofibers, electrospinning is a simple and efficient method to produce continuous polymer nanofibers [1]. In this method, nanofibers are created by applying an external electric field to a polymer solution. An electrically charged solution jet is generated and a randomly oriented mat is collected on a grounded plate [3, 9].

Producing composite nanofibers has been suggested by researchers as a way to enhance the properties of nanofibers [10]. To do so, particles [11] or nanoparticles are incorporated into final nanofibers by suspending them in polymer solutions [3]. Consequently, there is improvement in electrical [12], thermal [10] and mechanical properties [3, 13]. Carbon nanotubes (CNTs), was first reported by [14] and have been used in many applications, e.g., composite fabrication, because of their high length-to-diameter ratio and their outstanding electrical, thermal and mechanical properties [10]. Due to low conductivity of polymers, polymer/CNTs composite nanofibers have been produced, mainly for the enhancement of thermal and electrical properties [13, 15].

In a critical concentration of CNTs, the polymer matrix becomes conductive [15]. This critical concentration is called the percolation threshold concentration [9, 15–17].