Mechanical and Structural Characterizations of Simultaneously Aligned and Heat Treated PAN Nanofibers

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ABSTRACT: A simple and nonconventional electrospinning technique was employed for producing aligned polyacrylonitrile (PAN) nanofibers. A thermal zone was placed between syringe needles and collector in the electrospinning set up to obtain aligned and heat treated nanofibers. Suitable temperatures for heat treat process of PAN nanofibers was determined using differential scanning spectroscopy (DSC) technique. The influence of treatment temperature was investigated on morphology, internal structure and mechanical properties of collected PAN nanofibers. The average fiber diameter measured from SEM images exhibited decreasing trend at higher temperatures. FTIR spectra indicated no considerable difference between chemical structure of untreated and treated PAN nanofibers. Crystallization degree of PAN nanofibers calculated from WAXD patterns showed relatively low change with treatment temperature. Tenacity values of nanofiber bundles increased with increasing temperature while the extension values had an inverse trend. However, the modulus did not show a regular manner, but treated nanofibers had more modulus than untreated ones. The stress and modulus of PAN nanofibers increased to 112.9 MPa and 7.25 GPa at 270°C, respectively. Nanofibers treated at the highest temperature had the largest amount of crystallinity and strength. © 2011 Wiley Periodicals, Inc. J Appl Polym Sci 124: 3529–3537, 2012

Key words: polyacrylonitrile; aligned nanofibers; heat treatment; electrospinning; mechanical properties; X-ray diffraction

INTRODUCTION

Polymeric fibers with diameters in the submicron or nanometer range may be optimal candidates for various applications due to their high surface to volume ratio and their potential for mechanical properties. Polymer nanofibers are expected to have mechanical properties different from those of their conventional counterparts. Electrospinning is a quick, straightforward, simple, cost-effective method to produce novel fibers through the use of columbic forces. The electrospinning technique allows for the preparation of reproducible, continuous fibers with diameters in the micron to nanometer size range from polymer solutions and melts at room temperature in a matter of seconds. Because of initial instability of the jet, fibers are often collected as randomly oriented structures in the form of nonwoven mats, where the stationary target is used as a collector. These nanofibers are acceptable only for use in some applications, such as: filtration, wound dressings, and tissue scaffolding. However, to expand the use of electrospun fiber into commercial fiber for textile applications, researchers need to provide a mechanism to obtain a continuous single nanofiber, or uniaxial fiber bundle. Researchers have attempted to obtain aligned electrospun fibers by various approaches, including: spinning onto a rotating drum or onto the sharp edge of a thin rotating wheel, introducing an auxiliary electrode or electrical field, rapidly oscillating a grounded frame within the jet, and using a metal frame as a collector.[1,2] Various degrees of fiber alignment are obtained by these approaches, although only relatively short tows of aligned fiber are obtained. Recent studies have shown that aligned nanofibers have better molecular orientation and as a result improved mechanical properties than randomly oriented nanofibers.[3–5] These nanofibers can be used in applications such as composite reinforcement and device manufacture. Additionally, the aligned nanofibers are better suited for preparing of carbon nanofibers from electrospun PAN nanofibers precursor.[4,5] On the other hand, applying thermal treatment on textile fibers causes fiber stability and as a result better mechanical properties of them.[6–8]

There has been a tremendous growth of research activities dedicated to the generation of new nanostructure materials and their applications, but few researchers have investigated the effect of heat

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