Mechanical Properties and Morphology of Hot Drawn Polyacrylonitrile Nanofibrous Yarn

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ABSTRACT: In this study PAN nanofibrous yarn was produced by two-nozzle conjugated electrospinning method. The nanofibrous yarns were drawn continuously in boiling water with drawing ratios of 1, 2, 3, and 4. The morphology of drawn yarns was investigated by scanning electron microscopy and tested for tensile properties as well as untreated yarn. The results showed that the nanofiber alignment in the yarn axis direction, the tensile strength, and tensile modulus of yarn increases as a result of drawing while the tensile strain and work of rapture decrease. X-ray diffraction patterns of the produced yarns were analyzed as well. It was found that crystallinity index increases as the draw ratio increases. © 2011 Wiley Periodicals, Inc. J Appl Polym Sci 124: 5002–5009, 2012

Key words: nanofiber; drawing; mechanical properties

INTRODUCTION

Polymeric nanofibers can be produced by a number of techniques such as drawing,[1] template synthesis,[2,3] phase separation,[4] self-assembly,[5,6] and electrospinning.[7,8] Electrospinning is currently the simplest, versatile, applicable, and high potential technique for fabricating continuous nanofibers with diameters down to a few nanometers.[9] In a typical electrospinning setup, a reservoir is used to contain a polymeric solution. The solution is transferred from the reservoir to a spinneret which is generally a blunt tip needle commonly using a syringe pump.[10] A pendant drop of the polymer solution is allowed to form at the needle tip. A high voltage bias is then applied to the solution such that at a critical voltage the electrostatic repulsive forces within the solution will cause a fine jet of solution to erupt from the tip of the pendent drop. The distance between the collector and needle can be adjusted depending on many factors including the ability of the solvent to evaporate although it usually varies between 10 and 20 cm. Although the initial portion of the electrospun jet is stable, this jet soon enters into a bending instability region where further stretching, bending, spiraling, evaporation of the jet, and looping paths with growing amplitude cause the formation of a nonwoven mesh on collector.[11–13]

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An attractive feature of electrospinning is the simplicity and inexpensive nature of setup.[14] Electrospun nanofiber exhibit a range of unique features and properties that distinguish themselves from nanofiber fabricated using other techniques. Electrospinning has the following advantages: it can produce continuous nanofibers; it can be applied to a wide range of polymers; the dimensions and surface morphologies of the electrospun nanofibers can be varied by altering the solution properties and processing parameters[15]; very large surface area to volume ratio, and superior mechanical performance of the electrospun nanofibers.[16]

The electrospun nanofibers are often collected as randomly oriented structure in the form of nonwoven mats due to the bending instability of the highly charged jet. The electrospun nanofiber is highly charged after they have been ejected from the nozzle, and therefore it is possible to control its trajectory electrostatically by applying an external electric field.[10] The uniaxially aligned arrays of electrospun nanofibers are suitable for applications where isotropic/anisotropic behavior well-aligned and highly ordered architectures for isotropic behaviors are required: these are, for examples, microelectronics, photonics, and blood vessel scaffolds.[17] Even for applications as simple as nanofiber based yarn, it is also critical to control the alignment of nanofibers to improve mechanical performance.[7]

Many trials have been done to advise approaches for collecting electrospun nanofibers as aligned arrays.[18–22] They are a rotating drum collector technique,[23,24] an auxiliary electrode, and electrical field technique,[25,26] a spinning thin wheel with a sharp