Structural Characteristics and Selected Properties of Polyacrylonitrile Nanofiber Mats

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Received 11 June 2007; accepted 26 November 2007
DOI 10.1002/app.27904
Published online 27 February 2008 in Wiley InterScience (www.interscience.wiley.com).

ABSTRACT: In electrospinning, the structure of nanofibers, which is affected by polymer solution parameters and processing conditions, influences the physical characteristics of nanofiber mats. In this study, under optimum conditions of electrospinning, the concentration of polyacrylonitrile (PAN) was changed from 11 to 15 wt %, and its effects on the nanofiber diameter and surface porosity of nanofiber mats were studied. The results showed that increasing the PAN polymer concentration enhanced the nanofiber diameter but reduced the surface porosity of nanofiber mats. Because the diameter and surface porosity are parameters that possess mutual effects, a structural parameter (Q) was introduced, and then its relation to some of the physical characteristics, such as the air permeability and surface roughness, was investigated. To evaluate the surface roughness, atomic force microscopy (AFM) and entropy (ENT) methods were used. The surface roughness of nanofiber mats was measured by AFM in a surface noncontact mode and by ENT with an image analysis technique and co-occurrence matrix. The correlation coefficient of the surface roughness obtained from these two methods was 94%. The results also present a strong dependence between Q and the surface roughness and air permeability of nanofiber mats. J Appl Polym Sci 108: 2994–3000, 2008

Key words: atomic force microscopy (AFM); fibers; nanolayers

INTRODUCTION

Fibrous materials used for filter media provide advantages of higher filtration efficiency and lower air resistance, which are closely associated with fiber fineness.[1,2] Filtration efficiency is one of the most important concerns for filter performance.[3–9] There are various methods used to produce ultrafine fibers.[1,2] Recently, much attention has been directed toward electrospinning as a unique technique for the fabrication of nanofibers.[1–13] In electrospinning, a high voltage is applied to a capillary containing a polymer solution. At a voltage sufficient to overcome surface tension forces, a charged fluid jet is ejected from the needle tip. The jet is stretched and elongated before it reaches the target and then dried and collected as randomly oriented structures in the form of a nonwoven mat.

Nanofiber is a broad term that generally refers to a fiber with a diameter less than 1 μm.[4,5] Nanofibers, because of their unique properties, such as a small diameter, a high specific surface area, and the potential to incorporate active chemistry, have many applications.[1,2]

Electrospun nanofiber mats can be produced with a wide range of porosity values. These nanowebs have good aerosol particle obstruction and comparatively low air resistance. Because of these properties, nanofiber mats are unique candidates for filtration and protective clothing. Recently, the filtration properties of electrospun mats have been studied.[3–11] To provide appropriate mechanical properties, nanofiber webs have been applied to various substrates. Substrates are often chosen to resemble conventional filter materials.[10]

Gibson et al.[6,7] reported some properties of electrospun mats. They compared performances of electrospun fiber mats with properties of textiles and membranes currently used in protective clothing systems and showed that electrospun layers are extremely efficient for trapping airborne particles. Also, they reported that the air flow resistance and aerosol filtration properties correlate with the electrospun coating add-on weight. They showed that an extremely thin layer of electrospun nanofibers eliminated particle penetration through the layer. Transport properties of electrospun nylon 6 mats were investigated by Ryu et al.[12] They found that

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Contract grant sponsor: Center of Excellence for Environmental Nanotechnology and Research Center of Fiber Science and Technology, Isfahan University of Technology (Isfahan, Iran).