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A review on polymer nanofibers by electrospinning and their applications in nanocomposites

Zheng-Ming Huang[a,*], Y.-Z. Zhang[b], M. Kotaki[c], S. Ramakrishna[b,c,d]

[a]*Department of Engineering Mechanics, Tongji University, 1239 Siping Road, Shanghai, PR China*
[b]*Division of Bioengineering, National University of Singapore, 10 Kent Ridge Crescent 119260, Singapore*
[c]*Nanoscience and Nanotechnology Initiative, National University of Singapore, 10 Kent Ridge Crescent 119260, Singapore*
[d]*Department of Mechanical Engineering, National University of Singapore, 10 Kent Ridge Crescent 119260, Singapore*

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Abstract

Electrospinning has been recognized as an efficient technique for the fabrication of polymer nanofibers. Various polymers have been successfully electrospun into ultrafine fibers in recent years mostly in solvent solution and some in melt form. Potential applications based on such fibers specifically their use as reinforcement in nanocomposite development have been realized. In this paper, a comprehensive review is presented on the researches and developments related to electrospun polymer nanofibers including processing, structure and property characterization, applications, and modeling and simulations. Information of those polymers together with their processing conditions for electrospinning of ultrafine fibers has been summarized in the paper. Other issues regarding the technology limitations, research challenges, and future trends are also discussed.

Keywords: Electrospinning

1. Introduction

When the diameters of polymer fiber materials are shrunk from micrometers (e.g. 10–100 μm) to submicrons or nanometers (e.g. 10×10^{-3}–100×10^{-3} μm), there appear several amazing characteristics such as very large surface area to volume ratio (this ratio for a nanofiber can be as large as 10^3 times of that of a microfiber), flexibility in surface functionalities, and superior mechanical performance (e.g. stiffness and tensile strength) compared with any other known form of the material. These outstanding properties make the polymer nanofibers to be optimal candidates for many important applications. A number of processing techniques such as drawing [118], template synthesis [45,108], phase separation [106], self-assembly [104,161], electrospinning [29,49], etc. have been used to prepare polymer nanofibers in recent years. The drawing is a process similar to dry spinning in fiber industry, which can make one-by-one very long single nanofibers. However, only a viscoelastic material that can undergo strong deformations while being cohesive enough to support the stresses developed during pulling can be made into nanofibers through drawing. The template synthesis, as the name suggests, uses a nanoporous membrane as a template to make nanofibers of solid (a fibril) or hollow (a tubule) shape. The most important feature of this method may lie in that nanometer tubules and fibrils of various raw materials such as electronically conducting polymers, metals, semiconductors, and carbons can be fabricated. On the other hand, the method cannot make one-by-one continuous nanofibers. The phase separation consists of dissolution, gelation, extraction using a different solvent, freezing, and drying resulting in a nanoscale porous foam. The process takes relatively long period of time to transfer the solid polymer into the nano-porous foam. The self-assembly is a process in which individual, pre-existing components organize themselves into desired patterns and functions. However, similarly to the phase separation the self-assembly is time-consuming in processing continuous polymer nanofibers. Thus, the electrospinning process seems to

* Corresponding author. Tel.: +86-21-65985373; fax: +86-21-65982914.

E-mail address: huangzm@mail.tongji.edu.cn (Z.-M. Huang).

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