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Functional Ceramic Nanofibers via Electrospinning

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CONTENTS

1. INTRODUCTION

Owing to the nanoscale features and peculiar shapes, one-dimensional (1D) systems exhibit novel physical and chemical properties that can be exploited in a plethora of devices ranging from optics and catalysis to diagnostics and data storage. The ultrafine solid fibers with small diameters, large surface area–to–volume ratio, and small pore size are examples of 1D systems. Endowed with unique properties such as strength, weight, porosity, and surface functionality, polymer fibers with fine diameter have been used as selective gas separation membranes, filters, drug storage-cum-carriers, antiseptic wound dressings, protective clothing, space mirrors, and sacrificial scaffolds for the synthesis of nanotubes and nanowires. There is growing interest in introducing such nanofibrillar attributes in nanosized inorganic materials as well. The most obvious advantage of doing so is the possibility of their application as microelectromechanical system (MEMs), lab-on-a-chip sensors and detectors, structural elements in artificial organs and arteries, reinforcements for high-strength metal or polymer composites, micro–solar cell electrodes, photocatalysts, deactivators and neutralizers of chemical and biological weapons, quantum dots, and so on. The 100-year-old technique of electrospinning has been revived in the past decade and a half to fabricate a host of polymeric nanofibers. For the past five years, it is paving a very convenient path for making a host of ceramic counterparts ranging from simple one-component metal oxide semiconducting nanowires to multicomponent functional metal oxides whose properties (such as optical transparency, ionic and electronic conductivity, ferroelectric and piezoelectric behavior, giant magnetoresistance, and gas sensitivity) in the nanofibrillar format surpass those produced by conventional or even by sol–gel techniques, by several orders of magnitude. This chapter highlights some of these epoch-making developments and the possible innovation of the technique to take it beyond the current stage for the synthesis of two-dimensional (2D) and three-dimensional (3D) nanostructures consisting of functionally homogenous or graded ceramic nanofibers and nonwoven mats.

One aspect of current interest and great relevance to the fundamental understanding of the behavior of materials is the role of dimensionality and size on their optical, chemical, and mechanical properties for application in a wide range of devices. In this regard, 1D systems with nanoscale attributes are being synthesized and studied in great detail. 1D materials or structures are those which exhibit at least one dimension less than 100 nm; for comparison, the average thickness of a human hair is ~50,000 nm. Owing to the nanoscale features and peculiar shapes, one dimensional systems exhibit novel physical and chemical properties that can be exploited in optics, catalysis, and data storage devices. Thus, they become model systems to study and correlate the theoretical explanations that are still in progress. The ultrafine solid fibers are notable for small diameters, large surface area–to–volume ratio, and small pore size. Fiber properties such as strength, weight, porosity, and surface functionality depend on the specific polymer used. Polymer fibers with fine diameter are used as selective gas separation membranes, filters, biomedical materials (drug carriers and wound dressings), protective clothing, space mirrors, and precursor platforms or scaffolds

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