Fabrication of Superhydrophobic Fiber Coatings by DC-Biased AC-Electrospinning

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ABSTRACT: Mesh-like fiber mats of polystyrene (PS) were deposited using DC-biased AC-electrospinning. Superhydrophobic surfaces with water contact angles greater than 150° and gas fraction values of up to 97% were obtained. Rheological study was conducted on these fiber surfaces and showed a decrease in shear stress when compared with a noncoated surface (no slip), making them excellent candidates for applications requiring the reduction of skin-friction drag in submerged surfaces. We have also shown that addition of a second, low-surface energy polymer to a solution of PS can be used to control the fiber internal porosity depending on the concentration of the second polymer. Contact-angle measurements on mats consisting of porous and nonporous fibers have been used to evaluate the role of the larger spaces between the fibers and the pores on individual fibers on superhydrophobicity. © 2011 Wiley Periodicals, Inc. J Appl Polym Sci 123: 1112–1119, 2012

Key words: superhydrophobic surfaces; electrospinning; DC-biased AC-electrospinning; superhydrophobic fibrous coatings; fabrication and characterization of superhydrophobic surfaces

INTRODUCTION

Superhydrophobicity is achieved by combining nano- or microscale roughness with a low-surface free energy material. As water flows over such a surface, a "slip effect" is generated, resulting in a reduction in the skin-friction drag exerted on the surface.[1] Several methods have been used to fabricate superhydrophobic surfaces, including sol–gel processing[2] and solution casting,[3] chemical vapor deposition,[4] laser/plasma/chemical etching,[5] lithography,[6] electrical/chemical reaction and deposition,[7] layer-by-layer and self-assembly,[8] and electrospinning. Except for the last, all of these methods are complicated and require special equipment, high temperature or vacuum conditions, or low-surface energy material modification involving multiple steps, which makes it difficult for practical applications in large-scale coatings.

Electrospinning is a simple, low-cost method that can be used to deposit micro- to nanotextured coatings of a hydrophobic polymer onto substrates of arbitrary geometry. The resulting superhydrophobic surfaces can be applied in diverse applications, including self-cleaning glasses and clothes, protection against corrosion of metallic parts (in bridges, marines, under water constructions, etc.), antisnow sticking, and reducing skin-friction drag in underwater vessels such as submarines. Superhydrophobic coatings can be utilized as a passive method of flow control and may potentially become a viable alternative to the more complex and energy consuming active or reactive flow control techniques such as wall suction/blowing.[9] Conventionally, electrospinning is performed by applying a large DC-potential between the electrospinning source (typically a hypodermic syringe) and the substrate, resulting in a randomly oriented nonwoven fiber mats. The random orientation of the fibers is the result of the inherent electrostatic instability of the charged jet as it travels from the spinneret to the collection substrate. This instability can be overcome by applying a DC-biased AC-potential that induces short segments of alternating polarity, thereby reducing the magnitude of the destabilizing force on the fiber.[10] In addition, the presence of both positive and negative charges on the surface of the rotating collector minimizes the local electric field perturbations caused by residual charge accumulation on the fibers.

Different groups have fabricated superhydrophobic surfaces using electrospinning and other wet chemical approaches.[11–13] Sun and coworkers[14] demonstrated the preparation of superhydrophobic, anisotropically aligned carbon nanotube films by chemical vapor deposition on silicon substrates with quadrate micropillar arrays prepared by photo-lithography. Grid-like "nanograss" and "nanobrick"

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