Modeling resistance of nanofibrous superhydrophobic coatings to hydrostatic pressures: The role of microstructure

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In this paper, we present a numerical study devised to investigate the influence of microstructural parameters on the performance of fibrous superhydrophobic coatings manufactured via dc and ac electrospinning. In particular, our study is focused on predicting the resistance of such coatings against elevated hydrostatic pressures, which is of crucial importance for submersible applications. In our study, we generate 3D virtual geometries composed of randomly or orthogonally oriented horizontal fibers with bimodal diameter distributions resembling the microstructure of our electrospun coatings. These virtual geometries are then used as the computational domain for performing full morphology numerical simulations to establish a relationship between the coatings' critical pressure (pressure beyond which the surface may depart from the Cassie state) and their microstructures. For coatings with ordered microstructures, we have also derived analytical expressions for the critical pressure based on the balance of forces acting on the water–air interface. Predictions of our force balance analysis are compared with those of our FM simulations as well as the equations proposed by Tuteja *et al.* [Proc. Natl. Acad. Sci. U.S.A. **105**, 18200 (2008)], and discussed in detail. Our numerical simulations are aimed at providing useful information with regards to the tolerance of fibrous superhydrophobic coatings against elevated pressures, and helping with the design and optimization of the coatings' microstructures. Our results show considerably higher pressure tolerance for the case of coatings with orthogonally oriented fibers as compared to those with randomly laid fibers when other microstructural parameters are held constant. Moreover, it is demonstrated that thickness of the coating has less influence on performance in the case of orthogonal microstructures. Coatings' responses to other variations favor those that yield smaller-sized inter-fiber spaces. Studies are also performed investigating the effect of subtle permutations in the layer configurations of our ac-electrospun coatings, as well as the use of a hybrid coating that utilizes advantages from both dc and ac electrospinning.
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I. INTRODUCTION

A surface is considered superhydrophobic if its contact angle with water is greater than 150°. Superhydrophobicity typically requires a hydrophobic material with surface roughness on the micro- or nano-scale.[1] To date, most synthetic superhydrophobic surfaces are produced by first microfabricating a series of ridges or posts on a surface, and then making them hydrophobic via surface treatment. These microridges or microposts form a microporous surface at the wall in which air (wetting fluid)

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