Sustainability of superhydrophobicity under pressure

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Prior studies have demonstrated that superhydrophobicity of submerged surfaces is influenced by hydrostatic pressure and other environmental effects. Sustainability of a superhydrophobic surface could be characterized by both how long it maintains the trapped air in its surface pores, so-called "longevity," and the pressure beyond which it undergoes a global wetting transition, so-called "terminal pressure." In this work, we investigate the effects of pressure on the performance of electrospun polystyrene fibrous coatings. The time-dependent hydrophobicity of the submerged coating in a pressure vessel is optically measured under elevated pressures. Rheological studies are also performed to determine the effects of pressure on drag reduction and slip length. The measurements indicate that surface longevity exponentially decays with increasing pressure in perfect agreement with the studies reported in the literature at lower pressures. It is found, however, that fibrous coatings could resist hydrostatic pressures significantly higher than those of previously reported surfaces. Our observations indicate that superhydrophobic fibrous coatings could potentially be used for underwater applications. © *2012 American Institute of Physics*. [http://dx.doi.org/10.1063/1.4766200]

I. INTRODUCTION

Exposing a rough hydrophobic surface to water could result in an effect known as superhydrophobicity, which is characterized by water droplets beading on the surface at contact angles exceeding 150°. According to Lafuma and Quéré,[1] superhydrophobicity could be explained using the model independently developed by Wenzel[2] and Cassie.[3] Microscopically, rough hydrophobic surfaces could entrap air in their pores resulting in a surface with both air–water and solid–water interfaces. The presence of the air–water interface is responsible for the slip effect, characterized by an effective "slip length."[4] This in turn results in a significant reduction in the skin-friction drag exerted on a moving, submerged surface.[5,6] As long as air pockets are entrapped in the surface pores, the surface remains superhydrophobic. In other words, the degree of hydrophobicity depends on the amount of air entrapped on the surface. The longevity of a superhydrophobic surface—how long the surface could maintain the entrapped air—is critical, especially in underwater applications. Several approaches have been developed recently to estimate the longevity of superhydrophobic surfaces under hydrostatic pressure.[7–10] This area is the focus of the present research.

Early manmade superhydrophobic surfaces were produced using the same microfabrication techniques developed for the computer industry. The coatings typically consisted of a regular array of microposts, shallow microcavities, or microridges.[11–14] The orientation of microroughness, flow characteristics, and shape of air–water interface (meniscus) could all significantly affect the slip condition and hence the drag reduction. For example, Woolford *et al.*[14] demonstrated that in a

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