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Ultrafast fabrication of rough structures required by superhydrophobic surfaces on Al substrates using an immersion method

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HIGHLIGHTS

- Superhydrophobic surfaces were fabricated via the chemical substitution reaction.
- Rough Cu structures required by superhydrophobic surfaces were fabricated at 1 s.
- Rough Cu structures consist of micro/nanometer-scale particles, leaf-like structures.
- Rough Al structures required by superhydrophobic surfaces were fabricated at 3 s.
- Rough Al structures consist of rectangular-shaped plateaus and step-like structures.

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ABSTRACT

Superhydrophobic surfaces are commonly fabricated by combining micro/nanometer-scale rough structures and low-surface energy materials. The present work reported a simple, facile, and highly effective method of fabricating the rough structures required by superhydrophobic surfaces. Al plates were first immersed in 1 mol/L aqueous $CuCl_2$ solution from several seconds to tens of seconds and then immersed in 1 wt.% ethanol solution of fluoroalkylsilane to reduce the surface free energy. Scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), Fourier-transform infrared spectrophotometry (FTIR), X-ray diffraction (XRD), and contact angle measurements were performed to determine the morphological features, chemical composition, and wettability. The results show that chemical substitution occurs during the immersion process. Rough Cu structures consisting of micrometer-scale particles, submicrometer-scale leaf-like dendrites, and nanometer-scale crystals are obtained on the Al surfaces after immersion as a result of Cu deposition during the chemical substitution reaction. However, after ultrasonic cleaning, rough Al structures consisting of micrometer-scale pits, protrusions, and rectangular-shaped plateaus as well as nanometer-scale step-like structures appear as a result of the removal of Cu deposition and etching during chemical substitution. The shortest immersion times for the fabrication of hierarchical rough Cu structures and Al structures are 1 and 3 s, respectively.

1. Introduction

The control of the solid surface wettability is an important issue that has drawn increasing interest among experts in the fields of biology, physics, chemistry, materials science, and mechanics [1–4]. The primary parameter that characterizes wettability is the static contact angle, which is defined as the angle that a liquid makes with a solid. A solid surface, on which a static water contact angle is larger than 150°, is called superhydrophobic. Superhydrophobic surfaces can be divided into two classes according to the magnitude of the water rolling angle. Highly adhesive superhydrophobic surfaces allow water droplets to adhere to surfaces even when the surfaces are turned upside down. On the other hand, low-adhesive superhydrophobic surfaces have rolling angles of less than 10°, which can be used in drag reduction [5,6], anti-icing [7–11], corrosion resistance [12–14], and self-cleaning [15]. The best-known example of a low-adhesive superhydrophobic surface is the lotus leaf [16]. In the 1990s, biologists and materials scientists began studying the superhydrophobic mechanism of lotus leaves [17,18]. They found that lotus leaf surfaces were very rough because of the papillose epidermal cells that form micrometer-scale protrusions. In addition to the micrometer-scale roughness, the surfaces of the micrometer-scale protrusions are also rough and are covered with nanometer-scale asperities, which consist of hydrophobic epicuticular wax crystalloids. Water

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