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Fabrication of corrosion resistant mussel-yarn like superhydrophobic composite coating on aluminum surface

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ABSTRACT

This study presents a simple approach to fabricate superhydrophobic composite coating on aluminum surface from the hybrid assembly of inorganic–organic layers via electroless copper deposition (as roughness inducer) followed by surface modification with laurylamine (as a low surface energy material). We demonstrate the effect of immersion time on the water-repellency, upon increasing the assembly time from 1 to 3 h facilitating the transition between hydrophobic (133°) and superhydrophobic (154°) states. This transition results from the formation of mussel-yarn like texture, increases the discontinuities in the three-phase (solid–liquid–gas) thereby exhibits superhydrophobicity. The superhydrophobic composite coating possessed good chemical stability in different environments, but after exposure to heat and UV the coating loses its superhydrophobicity. Besides, after 30 days of exposure in open air, the superhydrophobic composite coating restores its water-repellent property indicating excellent weathering resistance. Electrochemical measurements demonstrated that the as-synthesized superhydrophobic composite coating significantly improved the corrosion resistance of aluminum substrate in 3.5 wt. % NaCl medium. This strategy would potentially be used in numerous applications, such as regulating the wettability of surfaces and corrosion resistance of metal substrates.

1. Introduction

Superhydrophobic surfaces, inspired by the self-cleaning lotus leaf, exhibit a water contact angle (WCA) more than 150° and sliding angle (SA) less than 10° [1]. The more accurate mechanism of non-wettability behavior of superhydrophobic surface lies on the construction of rough hierarchical micro-nanostructure on a low energy surface, which can endorse the entrapment of air in the space between the rough features [2]. Superhydrophobic surfaces have drawn much attention in both scientific research and practical applications because of their unique properties, including water repellency, self-cleaning, oil–water separation, anti-icing and anticorrosion [3–8]. In recent times, numerous methods to fabricate superhydrophobic surfaces have been described including anodization [9], electrochemical processes [10], sol–gel template [11], and electroless galvanic deposition [12], etc.

Aluminum (Al) and its alloys are imperative engineering materials due to its abundance in nature, good ductility, low specific weight and exceptional electrical conductivity. They have been widely used in various arenas, specifically in sports, aerospace, transportation and civilian industries owing to their excellent mechanical properties. The main disadvantage is exemplified by the poor corrosion resistance in aggressive environments [13]. Recently, a number of approaches have been reported to fabricate superhydrophobic surfaces on Al and its alloys with outstanding corrosion resistance. Xiong et al. [14] prepared a superhydrophobic honeycomb-like cobalt stearate thin film on aluminum by one step electrodeposition process with excellent anti-corrosion properties. Saleema et al. [15] fabricated a superhydrophobic aluminum alloy surface via a one-step process by immersing the substrates into an aqueous solution containing sodium hydroxide as well as fluoroalkylsliane. Yin et al. [16] produced a superhydrophobic coating on Al alloy for corrosion protection by chemical etching followed by surface modification. Karthik and Sethuraman [17] reported the fabrication of micro-nano composite coatings with lotus leaf

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Fig. 1. Schematic representation of electroless copper deposition (30 min) and laurylamine assembly (1 h and 3 h) over Al surface respectively.

like texture by combining electroless and candle soot depositions. Escobar and Llorca-Isern [18] fabricated a hydrophobic surface on aluminum using ethanol, etching by hydrochloric acid and modifying by lauric acid. For instance, Wang et al. [19] electrochemically prepared a superhydrophobic metal–complex film on copper as a barrier to corrosive medium.

Most of these methods involve complex processing, expensive materials and are time-consuming, limiting their industrial application [20]. Of these synthetic routes, galvanic replacement reaction (GRR) based strategy (redox displacement reaction) is the preferred choice for the selective metallization of surfaces owing to their simplicity and versatility [21]. Even though GRR strategy has been comprehensively employed for the synthesis of dendrites of Ag and Au but not much for Cu dendrites has been reported [22]. Fatty amine is a series of chemical reagent which can provide amine group to combine with metal ions and form chemically stable metal complex [23,24]. Besides, the long alkyl chain of fatty amine renders hydrophobic property, which is indispensable for the fabrication of superhydrophobic film. Thus, the advantage of using superhydrophobic film as corrosion barrier might be reinforced via fabricating rough metal-fatty amine complex film over the metal surface [25].

Based on these features, an attempt has been made to fabricate superhydrophobic composite coatings on Al surface by electroless copper deposition and then passivating it by immersing into an ethanolic solution of laurylamine. As the immersion time increases from 1 h to 3 h, the wettability of Al surface got transformed from hydrophobic (133°) to superhydrophobic (154°) and thereby exhibits mussel-yarn like texture. The as-fabricated coatings are characterized using Fourier transform infrared (FT-IR) spectroscopy, energy-dispersive X-ray (EDX) spectroscopy, X-ray photoelectron spectroscopy (XPS), and scanning electron microscopy (SEM) and transmission electron microscopy (TEM) techniques. The applications of as-fabricated superhydrophobic composite coating for anti-corrosion were also evaluated by electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization (PP) analyses. For the biomimetic mussel-yarn like texture, the synthesized surface has very good corrosion resistance but also shows unique repairable ability to recover its superhydrophobicity under various precarious environments. For the approach is accessible and low-cost, it should have a potential application in industry.

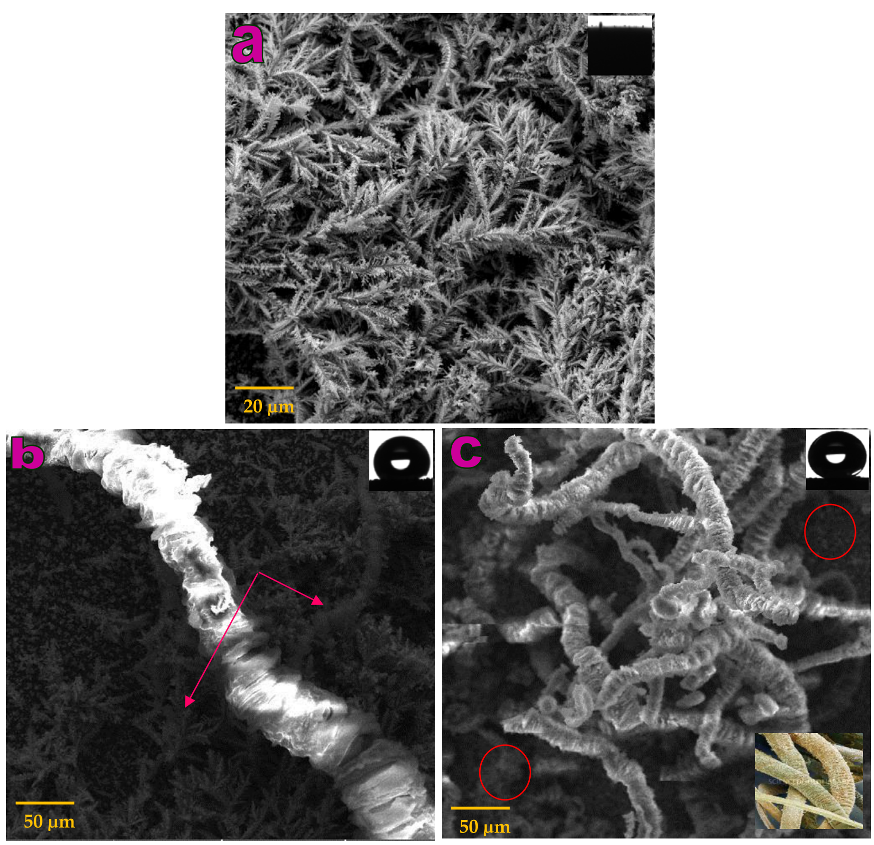

Fig. 2. SEM and WCA images of (a) Cu/Al, (b) LA/Cu/Al (assembled for 1 h) and (c) LA/Cu/Al (assembled for 3 h) surfaces. Arrow marks indicated the formation of mussel yarns and circles indicated the presence of copper dendrites. Inset: a photograph of mussel yarns.

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