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# A novel route for fabrication of the corrosion-resistant superhydrophobic surface by turning operation

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ABSTRACT

In this paper, a novel route has been developed to create a corrosion-resistant superhydrophobic surface. Regular micro-scaled rough surface was first fabricated by turning operation on the copper substrates and then stearic acid was used to reduce the low-surface energy. The obtained surface possesses excellent superhydrophobicity with a contact angle higher than 150°. Scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR) and contact angle measurement were employed to characterize the surface. The formation mechanism was discussed. Tests also proved that the superhydrophobic surface demonstrated good corrosion resistance and stability. This simple, low-cost and environment-friendly method will broaden the research of superhydrophobic surfaces and be advantageous in their industrial applications.



## 1. Introduction

In nature superhydrophobicity is an amazing property for many surfaces such as lotus leaf, the wings of butterfly and legs of water strider [1,2]. Inspired by these natural examples, artificial superhydrophobic surfaces have drawn wide attention both in the academic research and industrial applications due to their remarkable properties in self-cleaning [3], anti-icing [4], antifouling [5], corrosion resistance [6] and oil/water separation [7], etc. Generally the unusual water-repellent property of a superhydrophobic surface is attributed to two ingredients: micro/nanostructure roughness and low surface energy. Therefore the fabrication of a superhydrophobic surface usually involves two steps: first, formation of surface roughness on substrates and second, chemical modification by low surface energy materials [8]. A variety of surfaces with superhydrophobic property have been successfully fabricated by different methods including etching [9], chemical vapor deposition [10], electrodeposition [11], electrospinning [5], sol-gel methods [12], lithography [13], layer-by-layer assembly [14], phase separation [15] and so on. Although in recent years great advancements have been made on the fabrication of superhydrophobic surfaces with the above-mentioned methods, certain limitations have hindered their applications. Most methods reported are cost-consuming and complicated as they require sophisticated instruments, complex process control and expensive reagents [16–18], which makes practical engineering production of superhydrophobic surfaces hard to become true [19]. Meanwhile, the most common surface energy materials used are fluorocarbons, silicones, and some organic materials [20]. Some of them such as fluorosilanes, polyvinylidene fluoride, Teflon coatings [21,22] can create potential hazards to human or the environment. Last, many tests have proved superhydrophobic surfaces could effectively improve the anti-corrosion performance of various engineering materials. However, a drawback merged from the tested superhydrophobic surfaces was that the surface roughness created was random which has poor controllability of the structure dimensions and shapes [20]. Furthermore, when exposed to harsh working environment, superhydrophobic surfaces are easily degraded by organic solvent, water, acid rain, etc. [23,24]. Poor anticorrosion performance and surface stability are still problems for the practical applications of artificial superhydrophobic surfaces. Therefore it is highly desirable to fabricate durable and corrosion-resistant superhydrophobic surfaces for the practical application.

In this study, we present a novel way to generate superhydrophobic surface via mechanical approach and modifying it with low surface energy material. Regular micro-scaled rough surface was fabricated by turning operation through a 60° thread cutter and after modification with stearic acid, the obtained surface shows superhydrophobicity. The corrosion resistance and stability of the surface were tested and proved to be excellent. The equipment we use is common and the reagents are cheap and non-toxic. To the best of our knowledge, the fabrication of superhydrophobic surfaces via this approach is still a novel attempt. It broadens the academic research of the field. Meanwhile its convenience and efficiency in fabrication process would be advantageous in practice and bring huge benefits to the industrial applications of superhydrophobic surfaces.

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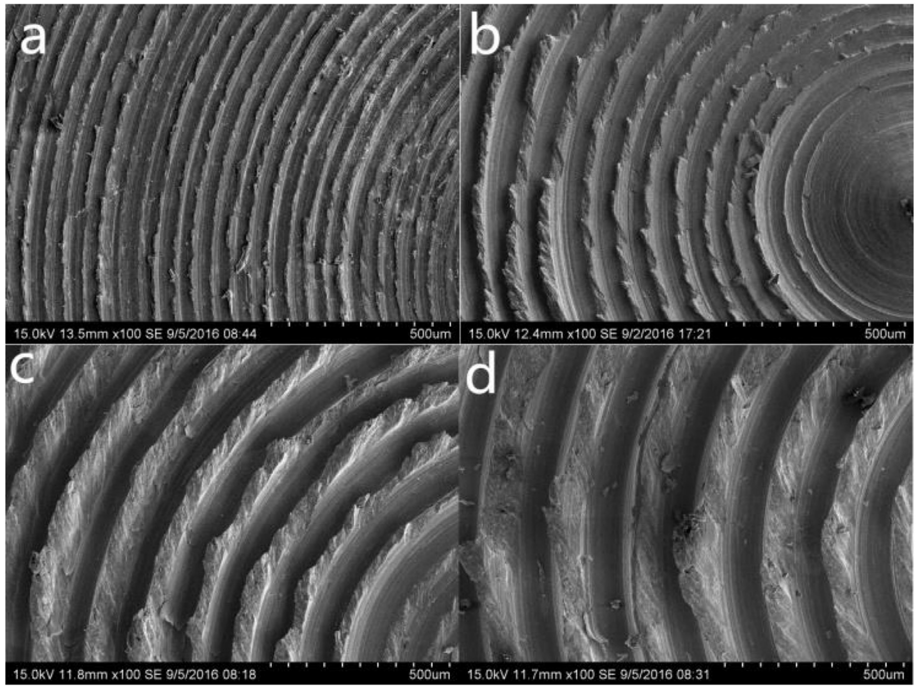


**Fig. 1.** SEM images of the superhydrophobic surfaces with different feeds (a) f = 0.05 mm/rev; (b) f = 0.1 mm/rev; (c) f = 0.15 mm/rev; (d) f = 0.2 mm/rev.

## 2. Experiment

### 2.1. Materials and preparation

Commercial H62 copper bars were used as substrates and purchased from Guangzong Qiyue Metals Co., Ltd., China. Stearic acid was obtained from Guangdong Shantou Chemical Reagent Co. China. Ethanol absolute was purchased from Sigma-Aldrich, China. Self-made deionized water was used for preparation of all aqueous solutions.

Turning operation was applied to the end-faces of the copper bars on Lathe C6140 equipped with 60° external thread cutting tools. Adjust the speed of spindle and feeding during the operation and vary the feed rate into 0.05, 0.1, 0.15, 0.2 mm/rev, respectively. The finished products were cut into the size of φ25 mm × 5 mm as samples. To clean the impurities, acetone and ethanol solution were used to clean the samples each for three times. The samples were then immersed in a 1 wt% aqueous solution containing 0.1 g stearic acid, 30 mL ethanol, 30 mL water for 24 h at 60 °C. Subsequently, the samples were ultrasonically cleaned with ethanol and deionized water for 5 min each. The dried samples were used for further experiments.

### 2.2. Characterization

The surface morphology of the obtained samples was observed by field emission scanning electron microscopy (Phenom proX, Phenom-World BV). The corresponding chemical composition was analyzed by Fourier-transform infrared (FT-IR) spectroscopy (VERTEX 70, Bruker). The contact angles (CA) were measured by a Dataphysics OCA20 CA system with 4 μL drops of distilled water at ambient temperature. The average value of water contact angles was determined by measuring the same sample at three different positions. The corrosion resistance of the samples were measured by polarization curves in a 3.5 wt% NaCl aqueous solution at room temperature via an electrochemical workstation (IM6ex, Zahner). The measurements were conducted in a three-electrode system with an Ag/AgCl reference electrode, a platinum mesh as the counter electrode, and the sample with an exposed area of 1 $cm^2$ as the working electrode. Polarization curves were obtained at a scan rate of 5 mV/s.

## 3. Results and discussion

### 3.1. SEM

SEM images, as given in Fig. 1, show that the as-prepared superhydrophobic samples are composed of highly ordered spiral deep pits after the turning. It is obvious to know the distances between these pits are equal to the feeds provided. As the feeds provided are 0.05, 0.1, 0.15, and 0.2 mm/rev, the distances vary from 0.05 to 0.2 mm. Therefore by turning processing and friction of the cutter, asperities in micro scale are yielded on the convex surfaces of the copper substrate. So rough surface of the copper substrate after turning operation is of a hierarchical microstructure.

### 3.2. FTIR

The FTIR spectra of the as-prepared superhydrophobic sample and the pure stearic acid are displayed in Fig. 2. In the spectrum of superhydrophobic sample, the absorption peaks at 2919 $cm^{-1}$ and 2850 $cm^{-1}$ correspond to the C—H asymmetric and symmetric stretching. The peak detected at 1701 $cm^{-1}$ in the stearic acid spectrum is assigned to the carboxyl group (−COOH), which is no longer present

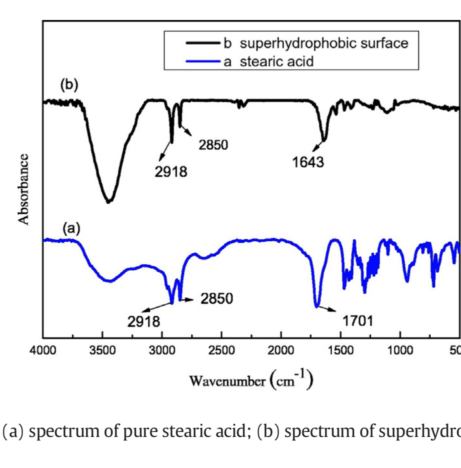


**Fig. 2.** FT-IR (a) spectrum of pure stearic acid; (b) spectrum of superhydrophobic surface.