Materials Letters 190 (2017) 115–118

Contents lists available at ScienceDirect

Materials Letters

journal homepage: www.elsevier.com/locate/mlblue

# A novel and facile fabrication of superhydrophobic surfaces on copper substrate via machined operation

Jiyuan Zhu, XiaoFang Hu *

*South China University of Technology, Guangzhou 510640, China*

ARTICLE INFO

*Article history:*
Received 1 November 2016
Received in revised form 18 December 2016
Accepted 26 December 2016
Available online 27 December 2016

*Keywords:*
Superhydrophobic
Surfaces
Microstructure
Cutting
Contact angle
Feed rate

ABSTRACT

Practical application of superhydrophobic surfaces is often hampered by the sophisticated facilities, complex process, expensive cost and harmful solvents etc. This paper reports a novel method to prepare a superhydrophobic surface via machine operation and chemical modification. Superhydrophobic copper surfaces are obtained by machine cutting using 60° thread cutters followed by modification using stearic acid solution. The surface morphologies, chemical composition and wettability were characterized using scanning electron microscopy (SEM), Fourier transformed infrared (FT-IR) spectroscopy and water contact angle measurement. The as-prepared surface displays good superhydrophobic property. The formation mechanism of the microstructure is proposed. The rough surface depends on the cutter shape and feed rate provided.



## 1. Introduction

Superhydrophobic surfaces have attracted great attention due to their advantages in self-cleaning [1], corrosion resistance [2] and anti-icing [3]etc. Various methods to fabricate superhydrophobic surfaces have been extensively studied in the past, which includes chemical vapor deposition [4], electrodeposition [5], etching [6], lithography [7] and so on. The combination of a rough surface with the micro-and nano-structure and chemical modification of the low surface energy are two key ingredients in obtaining superhydrophobic properties [8,9]. But the traditional approaches are still hampered by certain limitations such as sophisticated equipments, complicated process, limited material choice and expensive specific reagents etc. [10,11]. What's more, strong corrosive or toxic fluorine-containing reagents or fluorocarbons are always used in the process, resulting in potential hazard to the environment or health [12,13]. So it is very necessary to explore simple, convenient, economical and environment-friendly routes which can be scaled up in an industrial level.

In our work, a novel approach is being discussed by which superhydrophobic surfaces were fabricated by machine operation and chemical modification. During machined cutting, by adjusting the speed of spindle and feeding, regular microstructures were generated on copper substrates. The machine-processed surface was then modified by the low-cost and nontoxic stearic acid. To our best knowledge, there have been no reports of a superhydrophobic surface achieved by this method. So this innovative attempt presents many advantages. No expensive fabrication facilities or complex process for manufacturing are required. Another major advantage of this fabrication approach is its low energy consumption and environmental protection, thus making it possible to fabricate large-area superhydrophobic surfaces. The work is of great significance which extends the research of superhydrophobic surfaces and will bring great benefits to the practical application.

## 2. Experiment

### 2.1. Materials and preparation

The material used in this study was an H62 Copper bar. End face turning was conducted on a lathe(c6410) using 60° thread cutters. By adjusting the speed of spindle and feeding, the feed rate is set at 0.05–0.2 mm/rev. The copper substrates (ϕ25 mm × 5 mm) were prepared by cutting. Then the samples were rinsed 3 times in turn with acetone and ethanol solution. The as-prepared copper substrates were reacted with ethanolic stearic acid solution (0.1 g stearic acid, 30 ml ethanol, 30 ml water) in reaction kettle at 60 °C for 24 h, then followed by another 3 times of ultrasonic cleaning using deionized water and ethanol, and dried before using.

* Corresponding author.
*E-mail address:* xfhuscut@126.com (X. Hu).

http://dx.doi.org/10.1016/j.matlet.2016.12.081
0167-577X/

### 2.2. Characterization

The surface morphologies of the obtained surfaces were observed by scanning electron microscope (SEMs, Phenom proX, Phenom-World BV). The chemical compositions were determined using Fourier transform infrared spectroscopy (FT-IR, VERTEX 70, Bruker). The water contact angles (CA) were measured by angle measuring instrument (Dataphysics OCA20) with 4 μL drops of distilled water. The average CA value was obtained by measuring three different positions of the same sample.

## 3. Results and discussion

### 3.1. SEM

Scanning electron microscopy (SEM) images of the superhydrophobic surfaces were shown in Fig. 1. It could be observed the copper surfaces were evenly distributed with spiral microstructure of deep pits after turning. The interspaces of these pits are equal to the different feeds per revolution, which are 50–200 μm. When f (feed) = 0.05 mm/rev, the interval is 0.05 mm (Fig. 1a). When f = 0.1 mm/rev, it is 0.1 mm (Fig. 1b) and so on. Due to the cutting and friction of the tool, the convex surfaces are covered with micro-sized or even smaller asperities. So the surface is characterized by uniform rough structure.

### 3.2. FTIR

Fig. 2 shows the IR spectra of the as-prepared superhydrophobic surface and stearic acid powders. Fig. 2a is the IR spectra of the sample soaked in 0.05 mol/L ethanol solution with stearic acid for 8 h. Fig. 2b is the spectra of stearic acid powders. Due to the symmetric and asymmetric vibration of C—H bond, adsorption peaks of stearic acid emerged at around 2919 $cm^{-1}$ and 2850 $cm^{-1}$. The peak at 1701 $cm^{-1}$ was attributed to carboxyl group in stearic acid. When the copper bars were immerged in ethanolic stearic acid solution, FTIR also showed two peaks at 2919 $cm^{-1}$ and 2850 $cm^{-1}$ the same with that of stearic acid. A new peak appeared at 1643 $cm^{-1}$ corresponding to the characteristic peak of —COO— group. FTIR spectrum clearly indicated chemical reactions took place between copper substrates and stearic acid.

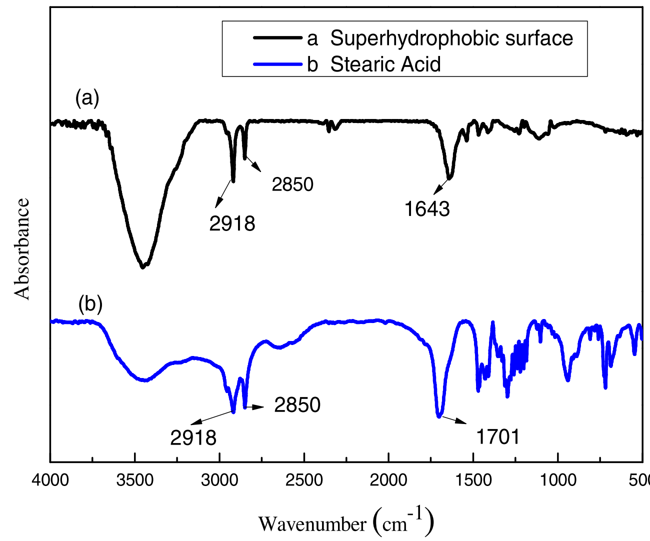


**Fig. 2.** FTIR spectra (a) superhydrophobic surface (b) stearic acid powders.

### 3.3. Surface wettability

To evaluate the surface wettability, we examined the water contact angles of the water droplet (4 μL) on different substrates. The contact angles of the pure copper substrate and the machine-processed copper substrate were 81.2° and 117.9° in Fig. 3(a–b), respectively. After the modification with stearic acid, all the samples with different feeds possessed a contact angle higher than 150°, 151.6°, 155.3°, 152.9°, 152°(Fig. 3(c–f)), respec-

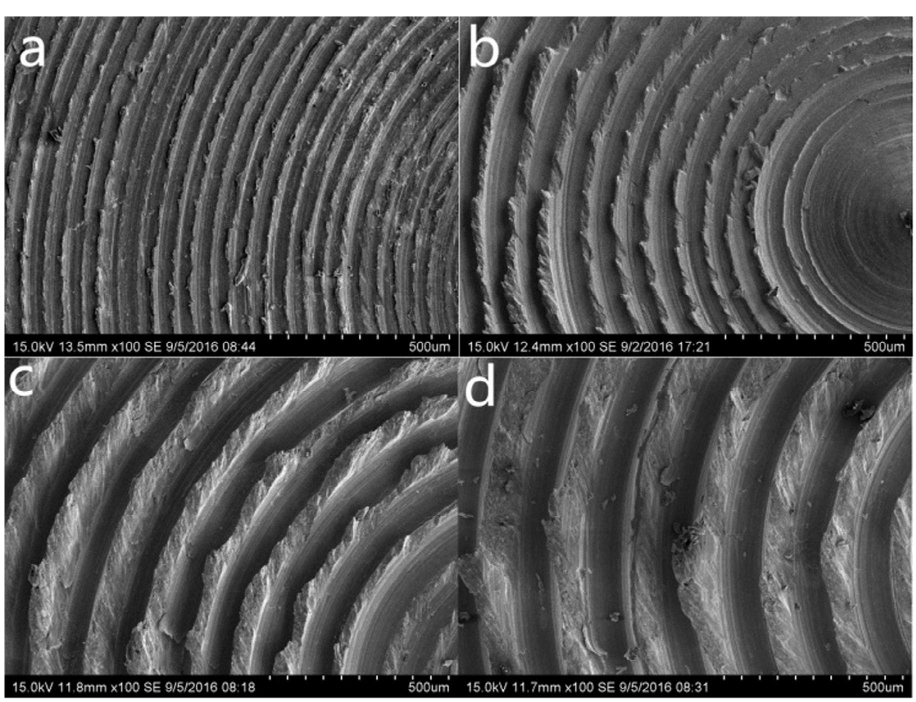


**Fig. 1.** SEM images of the superhydrophobic surface with different feeds (a) f = 0.05 mm/rev; (b) f = 0.1 mm/rev; (c) f = 0.15 mm/rev; (d) f = 0.2 mm/rev.