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Effect of Laser Texturing Parameters on Wettability of Nickel Surface

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Abstract

Wettability is an important characteristic of solid surfaces. Enhancing the surface wettability is very important for improving the properties of materials. Superhydrophobic materials show good prospects for development in areas such as self-cleaning, anti-fog snow, anti-icing, and corrosion resistance. It has become a hot spot to develop a superhydrophobic surface with low surface free energy and good anti-adhesion properties. In this paper, nanosecond pulsed lasers were used to texture the nickel surface, and the different texturing speeds were changed. Combined with the ultrasonic treatment of low surface energy materials, nickel surfaces with different contact angles were obtained. The experimental results show that low surface energy substances can increase the contact angle of nickel surface but the extent of increase is limited. Laser microstructure induces micro & nano-structures. Ultrasonic action can adsorb certain low surface energy substances on the surface, greatly improving the hydrophobic properties of the surface, the contact angle with water up to 152˚ and the roll angle is less than 2˚, and with the increase of the laser texturing speed, the contact angle of the nickel surface shows a decreasing trend.

Keywords

Lasertexturing, Nickel Surface, Wettability, Micro/Nano Structure

1. Introduction

Wettability is an important characteristic of solid surfaces [1]. It is generally characterized by a water contact angle. When the water contact angle is less than 90˚, the solid surface is referred to as a hydrophilic surface, and conversely as a hydrophobic surface [2]. In nature, there is a special micro-structured surface with a water contact angle greater than 150˚ and a roll angle less than 10˚. This is the so-called superhydrophobic surface, such as the lotus leaf surface [3]. Superhydrophobic materials have received great attention due to their unique low surface free energy and good anti-adhesive properties, such as self-cleaning [4], anti-fog snow [5], anti-icing [6], anti-corrosion [7], microfluidic chips [8], non-destructive liquid output [9], etc. which show good prospects for development. Enhancing the surface wettability of materials is very important for improving the properties of materials, especially for the development of superhydrophobic surfaces [10]. In our experiments, we discussed the effect of laser texturing speed on wettability transition and analyzed the reason for the transformation.Finally, the superhydrophobic nickel surface was prepared with a contact angle of more than 150˚ and a roll angle of less than 10˚.

2. Experiment

2.1. Preparation of Hydrophobic Film on Nickel Surface

A 99.5% purity nickel metal sheet was used for the experiment. The dimension was 25 × 25 × 2 mm^3. Before laser processing, the surface of the nickel sample was polished to specular gloss with the $800^{\#}$, $1000^{\#}$, and $1500^{\#}$ sandpaper respectively, and then treated by ultrasound in acetone solution, anhydrous ethanol, and deionized water for 5 min, respectively. Finally, it is dried by blowing with compressed air.

The laser source used is a pulsed fiber laser (IPG Photonics, YLPN-1-4 × 200-30-M) with a center wavelength λ of 1064 nm, a pulse width τ of 100 ns, a repetition frequency f of 20 kHz, and an output beam quality factor of $M^2 < 1.5$. The scan of the laser beam on the surface of the sample was controlled by a scanning mirror driven by a galvanometer with a scan rate of xx Hz and the laser beam is focused with an 80 mm focal length lens, and the focused spot size on the surface φ was 40 μm. The laser processing is carried out in the air. The beam is scanned across each other along the X-direction and Y-direction, respectively. The two adjacent lines and two adjacent laser spots are generally overlapped (with a scanning pitch Δ = 0.05 mm).

The laser-treated sample was soaked in an acetone solution for 5 min. The acetone solution dissolved a double-sided tape with a size of 8 mm × 20 mm. The resin pressure-sensitive adhesive composition on the double-sided tape was used as a low surface energy material. Finally, the nickel sample was removed from the acetone solution and let it dry naturally.

2.2. Performance Test of Hydrophobic Film on Nickel Surface

The surface morphology and phase analysis of the sample were conducted with a FEI Helios 650 scanning electron microscope. The water contact angle of the sample surface was measured by an OCA20 contact angle meter. When measuring the contact angle, the droplet size used was 5 μL.

3. Experimental Results and Discussion

Through experiments, we discussed the effect of laser texturing on the wettability of nickel surface, the influence of laser texturing speed on wettability, and analyze the causes of wetting transition.

3.1. Effect of Laser Texturing on Wettability

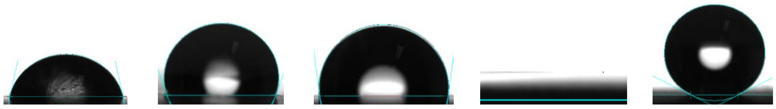
As shown in **Figure 1(a)**, the contact angle between the polished nickel surface and the water droplet before the laser texturing is 77.6˚, which shows a hydrophilic property. As shown in **Figure 1(b)**, the contact angle between the surface of the water droplet and the double-sided tape is 109.8˚. As shown in **Figure 1(c)**, the contact angle of the surface of the nickel modified by the double-sided adhesive with the water droplet is 97.8˚ before the nickel surface is treated by the laser. It can be seen that the low surface energy material can increase the contact angle of the nickel surface, but the degree of increase is limited. As shown in **Figure 1(d)**, the contact angle of the nickel surface after a laser texturing is 0˚, which shows superhydrophilicity. It can be seen that either surface laser texturing or surface modification with adhesive alone fails to achieve super-hydrophobicity. As shown in **Figure 1(e)**, the contact angle of the nickel surface and the water drop can reach to 152˚ after treated with both laser texturing and surface modification by adhesive, and the roll angle is less than 2˚, and, apparently, the super-hydrophobicity of the nickel surface is achieved. Also, it is clear that nanosecond pulsed laser-induced surface micro-nanostructures strongly enhance the adsorption of low surface energy substances during ultrasonication and achieve stable wetting characteristics.

3.2. Wettability Changes with the Laser Texturing Speed

The scan speed range is set to 1 - 200 mm/s. Three contact angles are measured and the average is taken. As shown in the broken line in **Figure 2**, the contact angle decreases linearly with the change of the texturing speed. With the texturing speed increased, the contact angle gradually decreases.

3.3. Analysis of Wettability Change

The surface morphology of the sample was observed with a scanning electron microscope (TEM), as shown in **Figure 3**, and the microstructures were 500, 4000, 15000, and 30,000 magnifications, respectively. After laser texturing, nickel



(a) (b) (c) (d) (e)

Figure 1. (a) Nickel surface before laser texturing, 77.6˚; (b) Surface of double-sided tape, 109.8˚; (c) Nickel surface modified with adhesive of double-sided tape, 97.8˚; (d) Nickel surface by laser texturing only, ≈0˚; (e) Nickel surface treated by laser texturing and adhesive modification, 152˚.

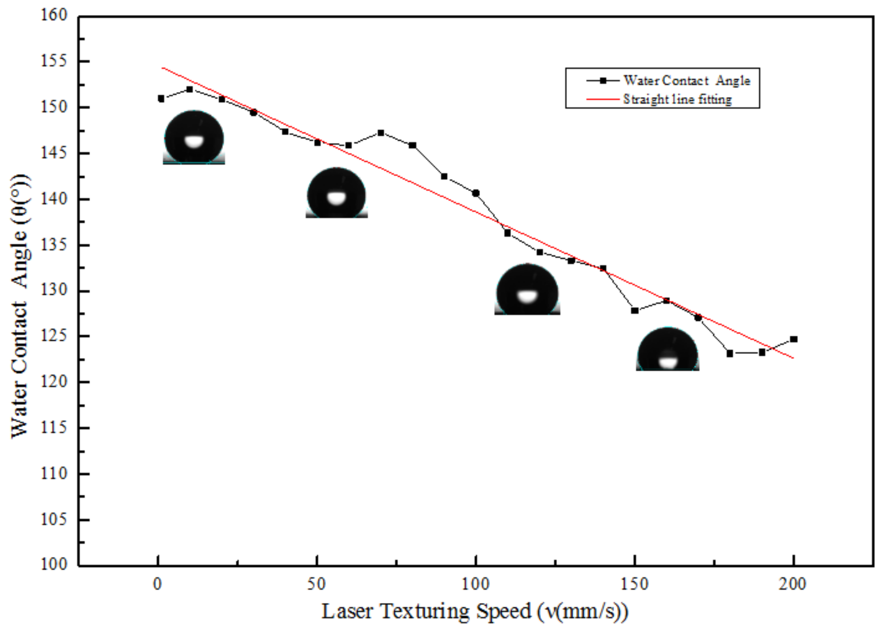


Figure 2. The water contact angles changed with the laser texturing speed.

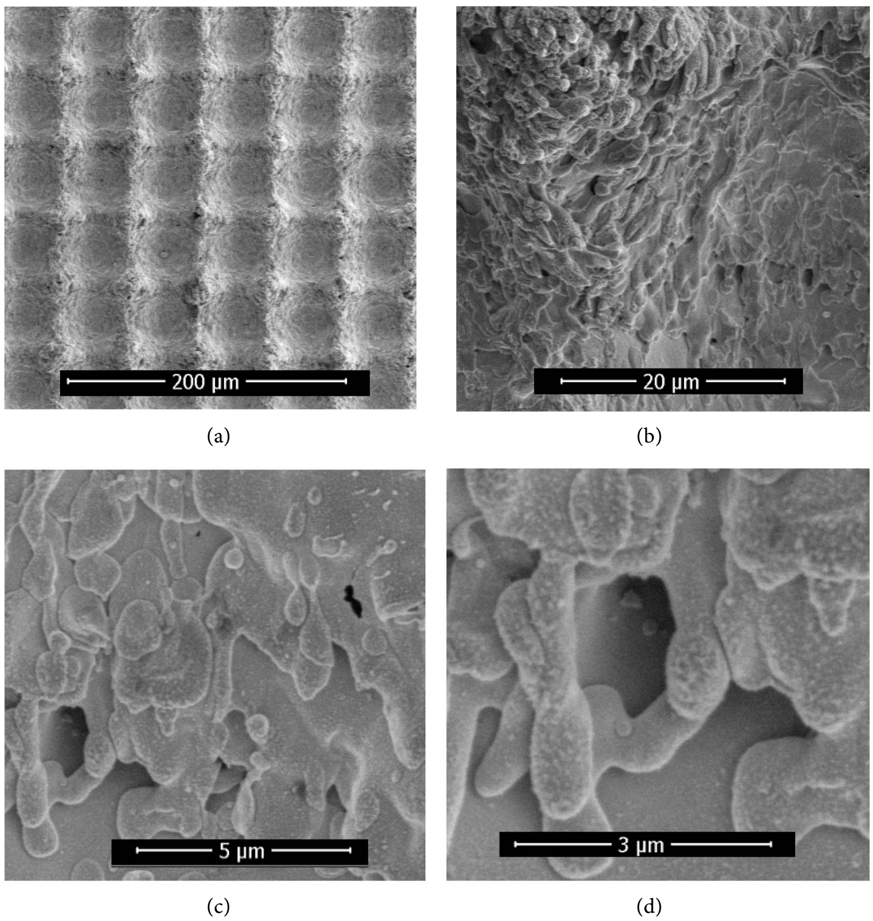


Figure 3. Scanning electron microscope observation of the surface structure of the nickel surface after laser texturing with different magnification. (a) 500; (b) 4000; (c) 15,000; (d) 30,000.

forms regular pits and bulges. Due to the illumination of the laser, the material in the illuminated area is burned and removed, resulting in regularly arranged dozens of micrometer pits, which are affected by laser irradiation [11]. In the smaller area, solidification of the liquid metal forms solidified projections in the non-irradiated area [12]. The formation of these pits and protrusions increases the surface roughness of nickel, thereby affecting wetting properties [13].

4. Conclusion

Ultrasonic nickel surface was obtained by nanosecond pulsed laser texturing of nickel surface combined with ultrasonic treatment of low surface energy materials. Low surface energy material modification can increase the contact angle on the nickel surface, but the degree of increase is limited to reach super-hydrophobic requirements; As the texturing speed increases, the contact angle tends to decrease. The nano-structure induced by the nanosecond pulsed laser on the nickel surface absorbs certain low surface energy substances on the surface through ultrasonic action. Therefore, it is suitable. The combination of laser texturing speed and low surface energy materials can greatly improve the wetting properties of nickel surfaces. Laser surface texture can make the surface of the material super-hydrophobicity [14]. Under certain conditions, the friction properties of dry friction can be improved [15], also the surface hardness of the specimen can be improved [16]. It will become a research hotspot to make the material surface performance a significant improvement [17] [18].

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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