기능성이 부여된 금속표면의 제작 및 분석
Fabrication and analysis of functionalized metallic surface

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1. Introduction

After extensive researches on the mystery of the exceptional wettability of lotus leaves, it is now accepted that one of the effective methods to control the wettability of a surface is to manipulating the surface geometry; in order to have a superhydrophobic surface like that of lotus leaves, hierarchical structures in micro/nanoscale should exist on a surface.[1] Recently, the focus on the attention has been shifted from the academic researches on the functionalized surfaces in laboratory scale to the industrial application in a large scale with the robustness enough to be used in our life: despite the success of previous methods for extremely high contact angle (CA) (> 150°) and low hysteresis (< 5°), most structures have been made of soft materials such as polymers and colloids, limiting the widespread uses in industrial applications.

We introduce a robust method to realize a functionalized metallic surface possessing hierarchical structures of micro/nanoscale by wire electrical discharge machining (WEDM), which can replace conventional methods. One of the notable merits of this method is that nano-sized craters are derived while machining the surface of a workpiece. This is due to the extremely high thermal energy from the sparks between the electrode and the surface of a workpiece where a high electrical potential difference exists, which melts and evaporates a portion of surface material. This eventually leads to the existence of craters, nanoscale roughness on the surface. By exploiting this mechanism, we fabricated a functionalized metallic surface with superhydrophobic/oleophilic properties with an excellent robustness enough for industrial use as can be seen in Figure 1.

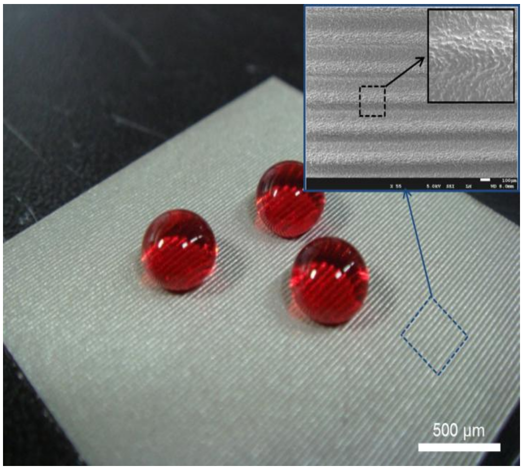

Fig 1. The optical image of the functionalized metallic surface with superhydrophobic/oleophilic characteristics. A SEM (Scanning Electron Microscope, S-4800, Hitachi, Japan) image is shown in the inset.

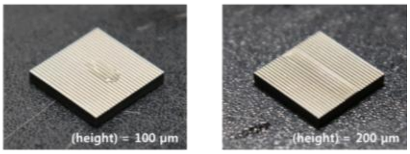

Fig 2. The sizes of the specimens are same except heights. The different characteristic of wetting phenomenon between the 100μm and 200μm height samples.

2. Result and discussion

Here we focus on the oleophilic property of the two samples which differs significantly depending on the geometry of the structures on the surface. We used the same material (Al 7075) and fabricated the samples with the same process so that we could obtain the two samples with the same geometry, except for the height of the grooves, one of which is 100 μm and the other is 200 μm (Figure 2a and 2b). From the preliminary experiment to observe the wetting property of each sample to the silicone oil (viscosity: 10 cSt, Sigma-Aldrich) with the same volume of 5 μl, we could find that there only exist the wicking flow of silicone oil on the surface with the higher grooves (200 μm) whereas a droplet of silicone oil didn't flow on the surface with the lower grooves (100 μm).

we can calculate the critical contact angle in 100μm and 200μm height samples:

$$\theta_c = \cos^{-1}\left(\frac{a}{2h_0 + a}\right) = \cos^{-1}\left(\frac{500}{2\times 100 + 500}\right) = 44.4°$$

$$\theta_c = \cos^{-1}\left(\frac{a}{2h_0 + a}\right) = \cos^{-1}\left(\frac{500}{2\times 200 + 500}\right) = 56.3°$$

Thus, the liquid in the channel can flow when the static contact angles in each sample are less than 44.4° and 56.3°. However, the contact angle in the specimen having 100μm height is between 44.4° and 56.3° as shown in

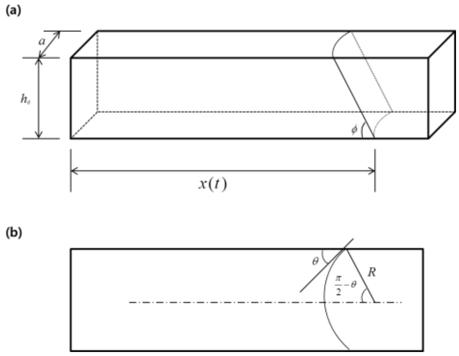

Fig 3. (a) Schematic representation of the flow in the rectangular open channel (b) The bottom-view of Figure 3(a).

Figure 3, so the liquid in the 100μm height channel could not flow through the channel. On the other hand, the 200μm height channel has a contact angle less than the critical angle, so the fluid flow shows the wicking phenomenon and we could apply a dynamic approach.

References

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