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Effect of height of micro textures fabricated by deep X-Ray lithography on surface wettablility

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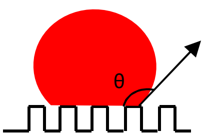
Abstract

In this study, wettability of micro textured surfaces fabricated by deep X-Ray lithography have been carried out with respect to height of micro textures to understand the degree of wetting between solid and liquid in contact. A total of 16 micro textured surfaces were fabricated which were segregated into two groups with respect to their heights viz. 50 µm and 200 µm. Measurement of water contact angles on each of the micro textured surfaces indicated that with increase in height of micro textures, water contact angle increases. Water adhesion on micro textured surface (contact angle <<90^0) was observed where the peripheral distance between micro textures was higher than its height indicating that water droplet can easily adhere to the base of micro texture. Highest water contact angle was observed in the case of micro textured surface with maximum height of micro textures. Hence, water repellency behaviour increases with respect to increase in height of micro texture.

Surface wettability; Deep X-Ray Lithography; Contact angle; Micro textures

1. Introduction

Surface wettability plays a key role in many industrial processes viz. spray painting, lubrication, liquid coating, printing, quenching etc. [1]. Wettability includes measurement of contact angles which shows the extent of interaction of solid with liquid droplet. Small contact angles ($\theta<<90^0$) leads to high wettability whereas high contact angles ($\theta>>90^0$) indicates low wettability (**Figure 1.(a)**). Most of the studies on surface wettability have been conducted by taking into account the geometrical parameters of the micro-nano textures viz. its cross sectional dimensions and pitch [2]. Very few studies deal with the effect of height of micro textures on surface wettability. In this study, wettability of micro textured surfaces fabricated by deep X-Ray lithography have been carried out with respect to height of micro textures to understand the degree of wetting between solid and liquid in contact. Deep X-Ray lithography has the capability of generating high aspect ratio micro textures (upto 500:1) on polymeric surfaces. **Figure 1.(b)** shows the schematic of top view of unit cell of micro features showing the geometrical parameters (viz. micro texture cross sectional dimensions '**a**' and peripheral distance between micro textures '**p**').



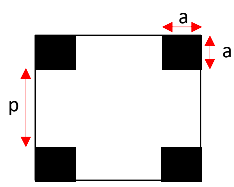


Figure 1. (a) Contact angle (b) Unit cell containing four micro textures (top view)

2. Fabrication of micro textured surface

Deep X-Ray lithography (DXRL) consists of a very high-energy, parallel X-rays from a synchrotron radiation source (SRS). It is a shadow printing process in which patterns coated on a mask are transferred into a third dimension in a resist material. Substrate material considered for DXRL was PMMA. Subsequently, developers were used to dissolve away the volume of material irradiated by the x-rays. The quality of the remaining structure is dependent on the beam exposure, the precision of patterning on the mask and the purity and processing of the resist material. **Figure 2.(a)** shows the fabricated micro textures on PMMA using DXRL. A total of 16 micro textured surfaces were fabricated; each divided into two sets based on their heights viz. 50 µm and 200 µm respectively. The geometrical parameters (**a** and **p**) of fabricated micro textures are shown in **Table 1**.

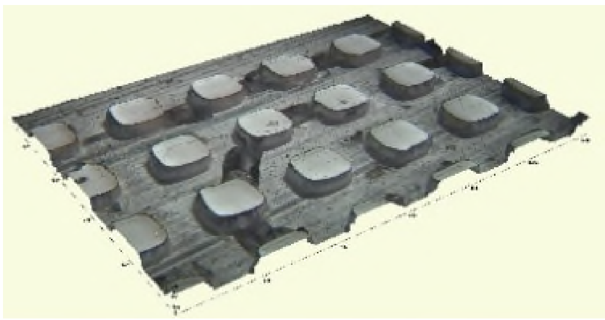


Figure 2. Micro textures fabricated by DXRL

Table 1 Geometrical parameters of micro textures

Serial No. (x)	'a' (μm)	'p' (μm)	Height, h (μm)
1	20	20	50, 200
2	20	40	
3	30	30	
4	30	60	
5	40	40	
6	40	80	
7	100	100	
8	100	200	

3. Measurement procedure

Contact angle measurement setup was created based on the principle of direct measurement of the tangent angle at the three-phase contact point on a sessile drop profile. The setup consists of a horizontal X-Y stage, micrometer pipette, digital microscope with an illuminating source (magnification upto 470X) attached to a computer (**Figure 3**). Validation of contact angle measurements were done using goniometer.

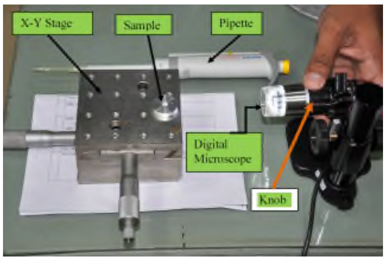


Figure 3. Contact angle measurement setup

4. Data collection

Contact angles (CA) were measured for each sample using the setup described in **Section 3**. **Figure 4.(a)** shows the water contact angle (both left and right) on micro textured surface (corresponding to Serial no. 7 of **Table 1** with height 50 μm) by the developed measurement setup. **Figure 4.(b)** shows the validation of the measurement setup by comparing with goniometer readings. It can be seen that the maximum error in measurement is 2^0.

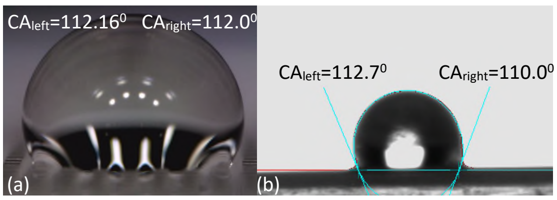


Figure 4. Water droplet on micro textures with Serial No. 7 (**Table 1**) and height 50 μm (a) by developed setup (b)

5. Results and discussion

Figure 5 shows the variation of contact angle of micro textures based on their height. It can be seen that micro textures with 200 μm height have higher water contact angles as compared to micro textures wit height 50 μm. Corresponding to micro texture with Serial no. 8 and height 50 μm, it can be seen that the water contact angle is less than 90^0 indicating an inclination towards wetting of micro textured surface. This is because the geometrical parameter, **p** (100 μm) in this case is twice as large as its height, **h** (50 μm), therefore, water droplet has a higher chance of adhering to the micro textured surface (**Figure 6.(a)**). With increasing height, the water contact angle increases and the surface is always hydrophobic irrespective of geometrical parameters. The highest water contact angle was observed for Serial no. 4 with height 200 μm indicating highest water repellency (**Figure. 6 (b)**). Hence it can be seen that water repellency increases with respect to increase in height of micro texture.

A quadratic model was developed to determine the relation between height of micro textures with respct to the geometrical parameters. Eq. (1) describes the model corresponding to **h** = 50 μm. R^2 value obtained for this model is 88% whereas Eq. (2) describes the model corresponding to **h** = 200 μm. R^2 value obtained in this model is 75% which is comparatively less than that obtained for the case with **h** = 50 μm.

$$h = -2.5931x^2 + 22.72x + 72.055 \quad (1)$$
$$h = -1.5308x^2 + 15.221x + 89.606 \quad (2)$$

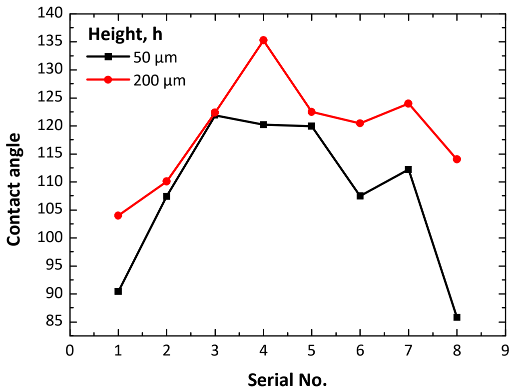


Figure 5. Contact angle variation with respect to height

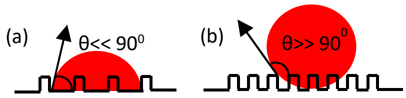


Figure 6. (a) High wettability (b) Low wettability of micro texture

6. Conclusion

A study was conducted to examine the effect of height of micro textures fabricated by deep X-Ray lithography on surface wettability. Corresponding to smallest height of micro textures (50 μm) and larger comparable peripheral distance between micro textures (**p**), water contact angle decreased below 90^0 indicating water adhesion on micro textured surface. With respect to height of micro textures irrespective of its geometrical parameters viz. **a** and **p**, water contact angle always increases with respect to height; thereby indicating that height of micro texture plays a crucial role in determining wettability of surfaces with regard to water adhesion or repellency behaviour. Hence, this study can further be utilized in developing micro textured surfaces for applications like anti-bio-fouling, water proofing, self-cleaning etc.

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