Effect of Surface Wettability on the Sessile Droplet Evaporation

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Abstract. In this study, crystallized Polycarbonate (PC) surfaces are fabricated by the immersion durations in liquid acetone. Droplet evaporation on the surfaces was studied using a contact angle meter at room temperature, and the evolution of contact angle, contact diameter, droplet volume and droplet height against evaporation time are analyzed. The results showed crystallized PC surfaces (CPCS) have hydrophobic. CCR mode is appeared in the most of evaporation period as sessile droplet evaporation occurred on the crystallized PC wafer surface. For untreated PC wafer surface (UPCS), sessile droplet evaporation showed three evaporation modes. The temporal variation of the droplet volume versus time makes a difference on the crystallized and untreated PC wafer surfaces. The droplet height decreased almost linearly with time for both surfaces.

Introduction

There has been continued interest in investigating evaporation of liquid droplets on solid surfaces, because understanding this process has important role in many fields, such as pesticide spraying [1] and ink-jet printing [2].

Many investigations have been done and focused on the evolution of contact angle and droplet volume against evaporation time, and influence factor such as type of liquid droplet, solid surface structure, substrate temperature. Choi et al [3] experimentally investigated evaporation modes and kinetics of sessile droplets of water on micropillared superhydrophobic surfaces. Sefiane et al [4] studied the evaporation of a droplet on a rough polytetrafluoroethylene substrate, and analyzed influence of water–ethanol mixture concentration on sessile droplet evaporation. Lee et al [5] investigated the effects of surface morphology by oxidation and surface temperature on the behavior of an evaporating water droplet on heated surface. Despite extensive researches about droplet evaporation have been done, the mechanism of surface wettability effecting evaporation needs to be further investigated.

In this paper, hydrophobic surface is fabricated by the immersion durations in liquid acetone resulting in the crystallized PC surfaces. And droplet evaporation on the crystallized PC surfaces is studied using a contact angle meter at room temperature. Comparison of results between droplet evaporation on the crystallized PC surfaces and droplet evaporation on an untreated PC surface has been performed. The evolution of contact angle, contact diameter, droplet volume and droplet height against evaporation time are analyzed.

Experimental Investigation

In this study, 30mm ×30mm PC wafers with 3mm thicknesses were served as solid surface, on which droplet evaporate. To improve hydrophobicity of PC wafers, the wafers were crystallized via immersing in liquid acetone for 8 and 12 min, respectively. Before the immersion durations, the PC wafers were cleaned in deionized water ultrasonic bath for 15 min, and finally drying in an oven.

The drop profile (contact angle, contact diameter, height and volume) on PC wafers were measured by using the optical contact angle measuring device (DataPhysics OCA 20) and OCA20 software. Fig.1 gave diagram of experimental setup for evaporation. As shown in the figure, 1 represents camera with macro lens and barrel, 2 represents automatic syringe dosing unit, 3 represents LED backlight, 4 represents workbench. The water is used as liquid for the experiments. Water droplets with initial volume 2μL are deposited on the PC wafers substrate, as shown in Fig.2. All experiments were carried out at room temperature (20 - 22 °C). Humidity was monitored.
ranging from 44% to 49%, due to little change of temperature and humidity, experiment condition is assumed to the same conditions. The evolution of the contact angle, the based diameter, droplet volume and droplet height as a function of time were recorded, the data and image were used to analyze droplet evaporation process and characteristic.

3. Result and discuss

Fig.3 presents the contact angle and the corresponding images of water droplets on the PC substrate. It is obviously that contact angle of the crystallized PC is larger than that of the PC wafer. Specifically, according to image analyzer by OCA20 software, static contact angle of water droplets on the crystallized PC surface and untreated PC surface are about 140° (8 min), 122°(12 min) and 83°, respectively. This indicated hydrophobicity of PC wafers is improved due to the crystallized PC surface possessing microsize/nanosize spherulites [6]. In addition, immersion durations can alter the texture height and spherulite concentration at the surface. Although the results comparing with literature 6 have some difference, the discrepancy results from experiment condition etc. As shown in this figure, the surface treatment by immersing in liquid acetone made its characteristics more hydrophobic.

Figure 4. Evolutions of the contact angle and contact diameter versus time.
The experimental evolutions of the contact angle and contact diameter are given in Fig. 4. As can be seen from figure, the initial contact angle of water droplet on the crystallized PC wafer were about 140°, while the initial contact angles were about 83° for untreated PC wafer surface. The contact angle of crystallized PC wafer surface increased by about one third compared to that of untreated PC wafer surface due to the increased hydrophobicity. The contact angle declined over evaporation time for crystallized PC wafer, while the contact angle on the untreated PC wafer surface declined for most of evaporation time. The initial contact diameter of crystallized PC wafer surface was decreased by about one time than that of untreated PC wafer surface due to the contact angle increases. For crystallized PC wafer surface, contact diameter changed little over a period of time, and this stage occupied most of evaporation period. This indicated the contact line is pinned during this time. For untreated PC wafer surface, the pinned contact line (constant contact diameter) stage occupied fewer of evaporation periods. The sessile droplet evaporation mainly present three modes: constant contact radius (CCR) mode, constant contact angle (CCA) mode and mixed mode. According to describe previously, CCR mode is appeared in the most of evaporation period, and the mixed mode only appears in the last period of evaporation time, as sessile droplet evaporation occurred on the crystallized PC wafer surface. Namely, it was confirmed that the droplet evaporation in this experiment exhibited a typical pinned contact line stage. However, for untreated PC wafer surface, sessile droplet evaporation showed three evaporation modes. In addition, total evaporation time of droplets on crystallized PC wafer surface was longer than that on untreated PC wafer surface. The higher the contact angle, the slower the evaporation terminated. For two surfaces in this experiment, the contact angle tended to decrease drastically at the last stage of evaporation.

Fig. 5 presents temporal variation of the droplet volume versus time on the two surfaces. As shown, the droplet volume in the first stage of evaporation keeps a linear decreasing trend, and then deviates from this trend. The rate of droplet evaporation can be expressed by the change in volume. This indicated the droplet evaporation rate remains constant for a period of time at the initial stage of droplet evaporation. Evaporation rates make a difference as time goes on. The results can be quantificationally judged from the slope of the evaporation curve. In addition, it is also clear that the droplet evaporation time of droplets on crystallized PC wafer surface was longer than that on untreated PC wafer surface. The higher the contact angle, the slower the evaporation terminated. For two surfaces in this experiment, the contact angle tended to decrease drastically at the last stage of evaporation.

The height of droplet on the two surfaces with time is shown in Figs. 6. As shown in this figure, the initial heights of droplets were about 1.4 mm for Crystallized PC wafer surface and 0.9 mm for untreated PC wafer surface. During evaporation time, the droplet height decreased continuously, and the droplet height decreased almost linearly with time for both surfaces. But the slope of the curve is different.
Conclusion

Crystallized PC surfaces are fabricated by the immersion in liquid acetone. Droplet evaporation on the PC surfaces was studied using the optical contact angle measuring device at room temperature, and the evolution of contact angle, contact diameter, droplet volume and height against evaporation time are analyzed. The results showed crystallized PC surfaces have hydrophobic. CCR mode is appeared in the most of evaporation period as sessile droplet evaporation occurred on the crystallized PC wafer surface, and the mixed mode only appears in the last period of evaporation time. However, for untreated PC wafer surface, sessile droplet evaporation showed three evaporation modes. The temporal variation of the droplet volume versus time makes a difference on the crystallized and untreated PC wafer surfaces. During evaporation time, the droplet height decreased continuously, and the droplet height decreased almost linearly with time for both surfaces.

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