Electrowetting on Microbowl-Array Patterned SU-8 Surfaces Generated by Electron-Beam Lithography

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Electrowetting on dielectric (EWOD) is well known and widely utilized in scientific and engineering applications, such as variable-focus liquid lens[1], electrically-assisted micro/nano-molding[2], and so forth. Many have investigated the EWOD effect on dielectric coated smooth substrates[3], but seldom have paid attention to that on rough surfaces[4]. Different from the reversible transition from superhydrophobic to hydrophilic wetting in conventional EWOD applications, in this study, we present a micro-structure featured by microbowl-array (MA) with irreversible wetting transition potentially for intriguing applications.

The MA structures with periodicity of 3μm and ridge-width in submicron-scale are generated by Electron beam lithography (EBL)[5] on a 5μm-thick SU-8 film coated on a gold-plated slide glass. The MA is resulted from proximity effect of e-beam exposed cross-line patterns. The morphology of the MA can be varied by tuning EBL dosage from 2 to 4μC cm^{-2}, as shown in Figure 1. Fluorocarbon coating by ICP-CVD is done to enable the hydrophobicity[2]. Such MA surfaces behave as a rose-petal, which can hold large aqueous droplet in vertical or inverse position at a high contact angle (CA). The highly hydrophobic and adhesive wetting properties can be caused by large CA hysteresis[6] due to van der Waals interaction and energy barriers from the submicron-ridges of the MA.

Therefore, it is natural to infer that the EWOD effect on the MA patterned surface is irreversible. Figure 2(a)-(d) show the decrease of CA with increasing DC voltage, roughly from 140° to 70°. Transition occurs from partial Cassie-Baxter's to Wenzel's model. Figure 2(e) shows the relationship between the cosine of CA and the applied voltage, indicating the saturation of CA. Also, numerical simulation with COMSOL Multiphysics v4.3a has been done to verify the modified EWOD effect on rough surfaces, adopting the modified Lippmann-Young's Equation[4] (Figure 2(f)). Due to the high adhesion, the reduced CA would not recover to normal. However, this may provide insight into fabricating variable-focus microlens of UV-curable polymer as well as replica molding.

References:
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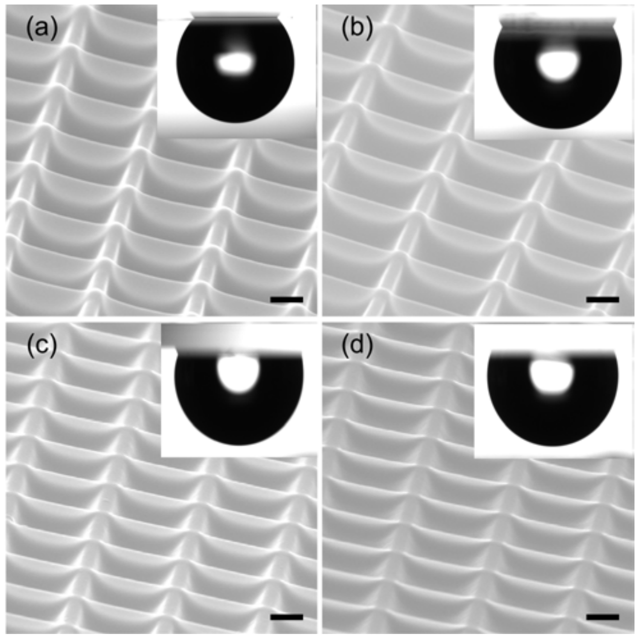

Figure 1: SEM imgages of the microbowl-array patterns formed by varying e-beam dosage ranging from 2 to 4μC cm^{-2}: (a) 2μC cm^{-2}, (b) 2.6μC cm^{-2}, (c) 3.2μC cm^{-2} and (d) 4μC cm^{-2}, respectively. Insets are the shapes of water droplets on the microbowl-arrayed surfaces in the inverse position. Scale bars are 1 μm.

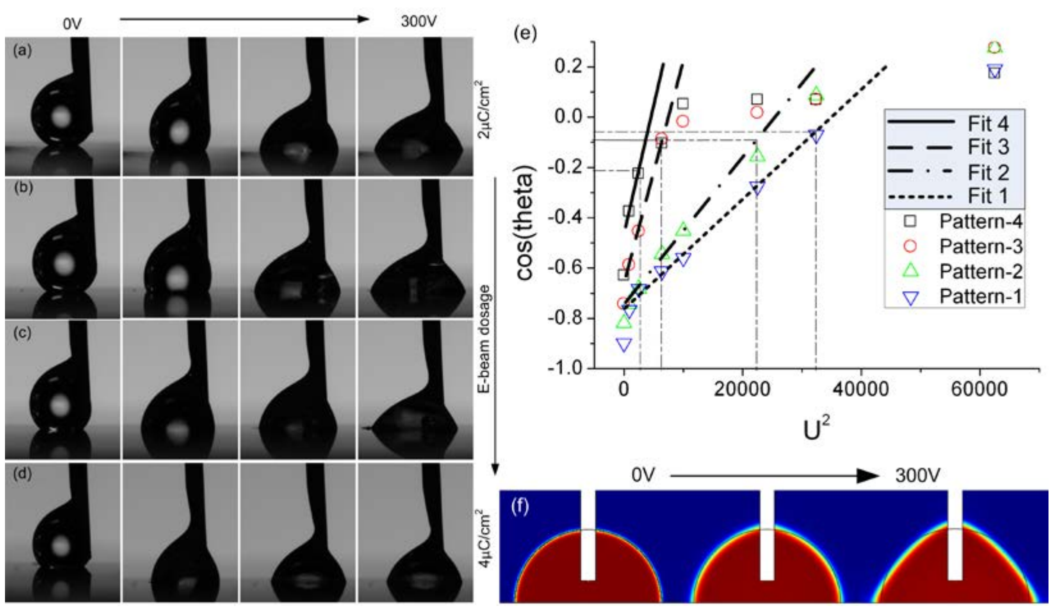

Figure 2: Shape of water droplet with irreversible electrowetting on the microbowl-array patterned surfaces formed by varying e-beam dosage from 2 to 4μC cm^{-2}, corresponding to pattern 1~4 respectively. (e)Relationship between cosine of contact angles and the square applied voltage, with straight lines as the linear fits for the four different patterns corresponding to (a)-(d) respectively. (f) Numerical simulation of modified EWOD for water droplets on rough surfaces indicating variations with applied voltage obtained by COMSOL Multiphysics v4.3a.