Fabrication of Microlens Arrays with Controllable Numerical Aperture Based on Electrically Induced Dewetting by Spatially Modulcated Electric Field

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The ability to fabricate a microlens or a microlens array (MLA) with proper numerical aperture (NA) allows for a great improvement for increasing the light collection efficiency of CCDs, to couping optical fibers, to reducing the screen-dorr effect in digital projector.

An economic and straightforwardstretagy for fabricating MLAs with controlable numerical aperture or curvature is proposed in this study. In our strategy (Fig. 1), a voltage is applied between a pair of electrodes, i.e. a conductor substrate coated with a UV-curable prepolymer film and a hole-arrayed Si-mold over the film with an air gap, to dewet the prepolymer film to leave a curved air-liquid interface. At or beyond a critical voltage, the curved prepolymer can quicklytouch the upper Si-mold. By curing the prepolymer and separating the mold from the solidified polymer, a concave MLA is obtained. The curvature of the MLAs does not depend on the voltage anymore, but can be tuned by varying air gap between the mold and the prepolymer film. Besides, using the generated concave MLA as a mold, a corresponding convex MLA can be easily duplicated (Fig. 2).

The approach described in this paper for generating concave MLA has some desirable and unique features for industrial application, including process cost effectiveness due to the ease with which a microhole-arrayed silicon template can be economically fabricated by the conventional microfabrication technology, a high efficiency due to the capability of producing large-area MLAs without the need for a large preload on the substrate, and, most importantly, an exact controllability of the numerical aperture or curvature due to the fact that the curvature for a concave MLA to be generated can be predetermined by its simple and geometrical relationship to the air gap and prepolymer thickness.

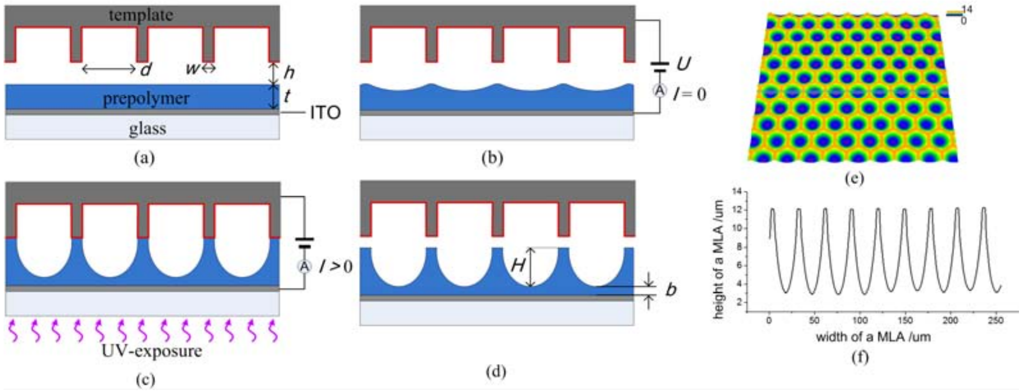

Fig. 1 Electrically induced dewetting process for generation of concave MLAs: (a) a microhole-arrayed silicon template is separated from the liquid prepolymer (with a thickness t) by an air gap h ; (b) a dc voltage is applied between the silicon template and ITO/glass substrate to electrically dewet the initially flat prepolymer film, and the leaking current is monitored between the substrate and template; (c) the prepolymer rises into a final contact with the protrusive underside of the silicon template (a microampere scale leaking current through the prepolymer, I , can then be detected) and is cured by UV exposure; (d) removal of the template leads to a solidified concave MLA. Experimentally measured 3D profile of the generated concave MLA (e) and the its cross profile (f) acquired by LSCM).

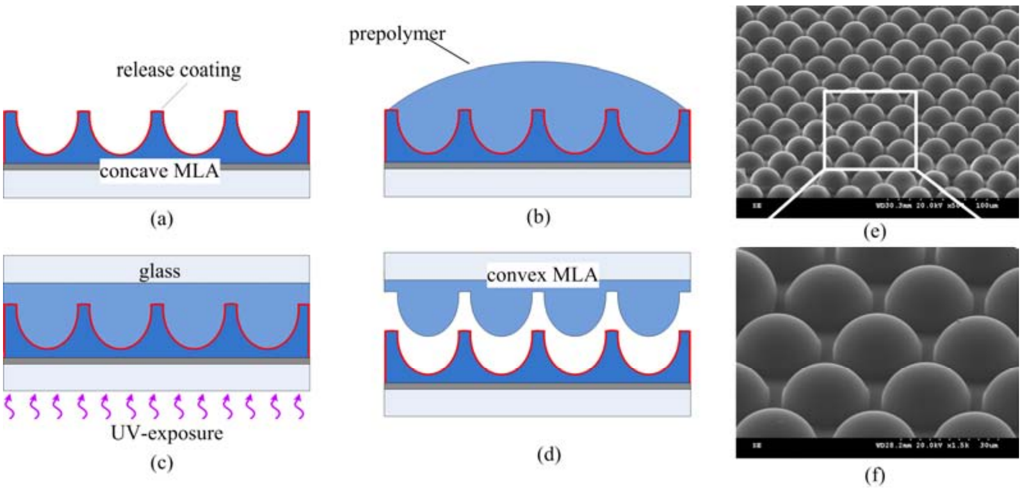

Fig. 2 Duplication of convex MLA: A releasing layer is coated onto a concave MLA (a); a UV-curable prepolymer is dropped onto the concave MLA to allow for a completely filling of the cavities of concave MLA (b); UV-exposure of the prepolymer after a glass substrate is covered on the prepolymer (c); Separation of the convex MLA from the concave MLA (d). SEM images of the duplicated convex MLA (e) and (f), where the MLA has a NA of 0.84 measured.