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Electrically controllable microlens array using a birefringent bilayer system of liquid crystalline polymer and liquid crystal

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Recently, a liquid crystal (LC)-based microlens array have drown much attention in such several optical applications as optical switching, optical imaging, and optical signal processing since the focusing properties of the LC-based microlens array can be controlled with a moderate response time. In existing LC-based microlens arrays, a gradient refractive-index (GRIN) profile of LC is produced by a specially designed electric field pattern or a surface relief structure for obtaining and controlling focusing properties. However, in conventional approaches, the dynamic focusing properties were not satisfactory for real-time reconfigurable optical system, which originates in the reverse tilt of the LC reorientation during electrical switching.

In this paper, we demonstrate a novel type of an electronically controllable microlens array which is composed by a highly birefringent polymer convex microlens array and a LC film for polarization control of an incident light. First, a concave microlens array with a UV curable polymer was prepared by controlling curing process and a patterned UV irradiation. On the convex polymer microlens array, a homogeneous alignment layer was spin-coated and then unidirectionally rubbed. When a liquid crystalline polymer (LCP) was cast on the concave polymer microlens array and cured by UV irradiation, a highly birefringent polymer convex microlens array is produced due to the chain ordering of LCP promoted by the surface alignment layer. The focusing properties of the convex microlens array is highly sensitive to an incident polarization of light since the extraordinary refractive index of the LCP is higher than that of the UV cured polymer mold, while the ordinary refractive index of the LCP meets the index matching condition. Therefore, the focusing efficient of the convex polymer microlens array varies with the polarization state of an incident light. To control focusing properties, a twisted nematic (TN) LC layer was promoted on the convex polymer microlens array. Since the flat LCP layer acts as an LC alignment layer due to polymer chain ordering effect, no additional alignment layer was required on the LCP surface to obtain the TN configuration in the LC layer. Since the polarization state of light incident to the convex polymer microlens array is continuously controlled from the extraordinary axis of the LCP layer to the ordinary axis with increasing an applied voltage in the LC layer, the focusing efficient at a focal plane changes continuously with the voltage. The dynamic focusing properties of our structure are superior to those of conventional LC microlens arrays since the static GRIN effect is obtained by the convex polymer microlens array and the dynamic tuning effect is obtained by the LC layer which is promoted by the flat boundaries.