Polarization independent Microlens Array by Temperature Control of Liquid Crystal Layer

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In many optical systems such as 2D/3D switchable displays, optical interconnection, and high-density data storage [1-3] microlens array (MLA) with a tunable or switchable focal length are used widely as an important element. Many approaches based on liquid crystals (LC) have been proposed because their focal lengths are tunable. However, in most LC optical devices, optical anisotropy of the LC results the dependence of incident light polarization which decreases light efficiency. In order to eliminate the polarization dependence of LC MLA, orthogonally aligned LC Fresnel lenses [4-5] or vertically aligned nematic liquid crystal (NLC) lenses [6] have been suggested. However, such MLAs require an extremely elaborate alignment technique or complicated fabrication processes. In addition, those LC MLAs cannot show the real polarization independent properties because they are switched from optically isotropic phase to anisotropic phase. Even if only one of the two states shows polarization dependent properties, the light efficiency of the incident light cannot exceed 50%.

In this paper, we report truly optically isotropic MLAs by refractive index control of LCs. The MLA structure was made of UV-curable polymer of concave shape on the bottom substrate by micro-transfer molding method. At initial state, the LC molecules are vertically aligned on the glass substrate and MLA surface which make ordinary refractive index of LC. Because the ordinary refractive index of LC is equal to polymer layers, incident light pass through MLA without focusing. When the temperature of LC is higher than the clearing temperature, the LC layer has an averaged refractive index (n_a) of the extraordinary (n_e) and ordinary (n_o) refractive indices of the LCs, which can be calculated as $n_a = (n_e+2n_o)/3$. Because that refractive index of the LC layer is higher than that of the lens structure polymer, incident light is focused. To control the temperature in this experiment, we used indium tin oxide (ITO) electrode layer as transparent electric heating layer. The ITO layer was patterned on the top substrate, which makes heat easily by high resistance.

Because the proposed MLA switches from vertical alignment to isotropic state, they have polarization independent characteristics. Therefore, this MLA shows truly optically isotropic properties on both switchable states.

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