Fabrication of Switchable Microlens Arrays Based on a Liquid Crystal

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SUMMARY

With the technological progress in optics, the need of microlenses has been increased for various optical applications such as in optical interconnection, photonic, and optical communication systems. Both the focal length variation and tuning capabilities in microlens arrays play a critical role in use as an active component under various circumstances. Several attempts have been made to achieve those properties in microlens arrays so far [1]. Especially, it is very important that the switching properties can be achieved by combining a solid-state planar optical passive component and a liquid crystal (LC) optical modulator into an active part [2].

In this work, we report on a novel method of fabricating LC microlens arrays using a LC layer on a surface relief structure of the UV curable polymer. This surface structure can be easily obtained, compared to the conventional method, for example, a photolithographic process or an ion-beam etching. It should be noted that the large birefringence of the LC being used makes it possible to achieve a wide range of the switching characteristics of the microlens.

In order to make a surface relief structure, we first spin-coated the UV curable polymer on the glass substrates deposited with indium-tin-oxide. We then irradiated the spatially modulated UV light onto the polymer through a photomask. The intensity modulation creates the diffusion of monomers in polymer composites from unexposed to exposed regions, giving the formation of the surface relief structure. The microlens arrays were fabricated by filling the LC between the two sandwiched-glass substrates with capillary. One of the substrates has surface relief structures (with or without the alignment layer) on which the optical axis of the LC may be defined along a predetermined direction, i.e., the rubbing direction. The other has only an alignment layer, i.e., no surface relief structure is present. The alignment layer was prepared from the poly vinyl alcohol solution (1 wt%). The schematic diagram of the LC microlens structure and the operating mechanism are shown in Fig. 1. In our study, a commercial nematic LC of ZLI-2293 (Merck Chemical Co.) and a photo-curable prepolymer NOA 65 (Norland) were used.

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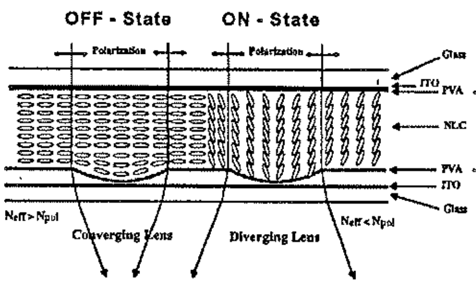

Fig 1. Schematic diagram of the LC mircolens structure and two operating states. The LC was homogeneously aligned on both surfaces.

The ordinary (n_o) and extraordinary (n_e) refractive indices of the LC at room temperature are 1.499 and 1.632, respectably. The refractive index of the cured NOA 65 (n_p) is 1.524. In a simple model, the focal length of microlens, f, is easily obtained from $f = R / [\, n_{lc} - n_p \,]$, where n_{lc} is the effective refractive index of the LC layer and the curvature (R) is the radius of the surface relief structure. From the above relationship, it is expected that the microlens acts as either a convex or a concave lens depending on the values of n_p and n_{lc} , one of which (n_{lc}) varies with the applied voltage. Fig.2. shows a focused image in the OFF state. As the voltage increases, the LC director is deformed to reduce the effective refractive index of the LC layer, and thus the focal length of microlens increases (see Fig.2 (b)). The focal length variation is linear in the voltage above a certain threshold at which the LC director starts to be distorted.

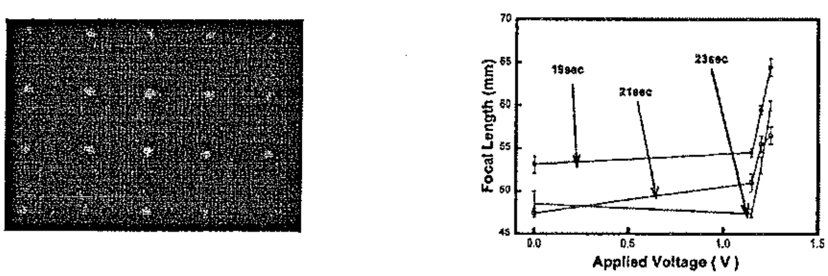

Fig 2. (a) Focused beam image from CCD (b) Focal length as a function of the applied voltage

However, there exists an aberration from non-uniform distortions of the LC director, arising from the local voltage variation around the microlens because of the cell thickness.

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