Bistable Microlens Array Using Ferroelectric Liquid Crystals

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ABSTRACT

Fast switching ferroelectric liquid crystal microlens arrays have been fabricated using the process of anisotropic phase separation of liquid crystal from its solution in an ultra-violet curable prepolymer. The microlenses can be electrically controlled to modulate the transmitted light and change their focal length within few microseconds, i.e., ~1000 times faster than the nematic liquid crystal based microlenses. These microlenses also exhibit the memory effect.

INTRODUCTION

A number of attempts have been made to construct liquid crystal (LC) based real-time reconfigurable microlens array[1,2] to perform real-time optical interconnection in optical computing and photonic switching circuit. The technology required to realize such active microlens is fundamentally different from that used in passive devices built using surface relief structures[3-5]. Methods employed in the previous studies to build electrically controllable microlens array include (i) a combination of passive solid state lens array and a LC modulator[6] and (ii) gradient refractive index (GRI) profile of liquid crystal (LC) produced with axially symmetric electric field generated by specially designed electrode patterns for each microlens[1,2].

Recently, a new type of switchable microlens array using nematic LC (NLC) has been fabricated using the phase separation method[7]. The microlenses in these arrays are switchable on command and have variable focal length which depends on the applied field. The switching time, however, is of the order of 100 ms due to the intrinsic speed of nematic LCs. These speeds are slow in the range of the speeds required for application in optical communication or wavefront shaping devices.

In this report, we report construction of a switchable microlens arrays which use ferroelectric liquid crystal (FLC). The microlenses can be switched bistably with speeds of a few microseconds, i.e., nearly 1000 times faster than that of microlens incorporating NLCs.

EXPERIMENTAL

The materials used in this study are commercial FLC Felix 15-100 from Clariant and photocurable prepolymer NOA65 from Norland. The ordinary n_o and extraordinary n_e refractive indices of the Felix 15-100 at room temperature are 1.490 and 1.664, respectively, at 590 nm. The refractive index of the cured NOA 65 n_p is 1.524 lies in the middle of the values of FLC's indices of refraction. To align the FLC, cells are made using substrates coated with rubbed films of Nylon 6 (N6). The N6 film was unidirectionally rubbed after drying to achieve homogeneous LC alignment. Cell spacing is controlled with the use of glass spacers of 3 μm diameter. A solution of the LC and prepolymer with weight ratio of 60:40, respectively, is introduced in to the cell by capillary action at a temperature higher than the clearing point of the FLC. The cells are exposed to UV light of λ = 350 nm to initiate polymerization. The source of UV light is a Xenon lamp operated at 300 W of electrical power.

As reported[8] previously, when a cell filled with a mixture of LC and prepolymer is exposed to normally incident UV light, an intensity gradient in the (z-) direction perpendicular to the cell is switching times of FLC microlenses are about 1000 times faster than the NLC microlenses. We believe that these devices will find applications in optical communications technology in near future.

CONCLUDING REMARKS

To summariz, two-dimensional FLC microlens arrays have been fabricated using the method of 3-dimensional anisotropic phase separation of FLC from its solution in a UV curable prepolymer. The switching time is found to be three orders of magnitude faster than for similar devices built using nematic liquid crystals. Fruthermore, the FLCs exhibit the memory effect.

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