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THE MECHANISM FOR THE FORMATION OF POLYMER WALL IN HIGHER POLYMER CONTENT CHOLESTERIC LIQUID CRYSTAL MIXTURE

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Abstract We have investigated the formation of polymer walls in higher polymer content cholesteric liquid crystal formulations.[1] The mechanism of polymer wall formation including phase separation and polymer diffusion are complex. We found that it is possible to regulate the polymer wall morphology by controlling the photopolymerization process. The polymer wall density increases with increasing concentration of monomer(s) in the mixture. Also, the temperature, UV light intensity, exposure time, and the ratio of the exposure area and the masked area all affect the wall formation process.

INTRODUCTION

Bistable reflective cholesteric liquid crystal materials show considerable promise for flat panel displays and other applications. These materials have two stable states at zero field: a selectively reflective planar state and a weakly scattering focal conic state. The first bistable reflective cholesteric devices utilized rubbed polyimide surfaces and a low concentration of photopolymer dispersed in the cholesteric liquid crystal mixture.[2,3] The dispersed polymer not only improved the viewing angle in the reflective state but also stabilized the focal conic state. Later reports showed that the bistable reflective displays can also be constructed using homeotropic or rough surfaces in the absence of polymer dispersion.[4] Higher polymer content cholesteric formulations have also been reported and been successfully used in 320 by 320 display and writing tablet fabricated using plastic substrates.[5,6]

It is clear that the higher polymer content cholesteric formulations have several potential advantages compared to the lower polymer content or no polymer content formulations. First, they simplify the cell fabrication since neither surface treatment nor vacuum filling process is needed. Second, large area, flexible and lower cost devices are possible because the high polymer content formulations form self-adhering, self-sustaining films. However, the high polymer content formulation produces a denser polymer network which causes more light scattering in the focal conic state, reduces the color purity and brightness of reflected light in the planar state, and therefore reduces the contrast of the display.

Recently, Sharp reported fabricating polymer walls to form axially symmetric aligned microcells[7] and polymer matrix STN-LCDs[8]. We also successfully formed polymer walls in higher polymer content bistable reflective cholesteric displays as a means of providing the structural benefits of the polymer network while maintaining high brightness and contrast.[1]

The electro-optic performance of polymer wall structured bistable reflective cholesteric display obviously depends on the wall structure and morphology. In order to control and optimize them, it is important to understand the process whereby the polymer walls are formed.

In the present study, for the reason of time and simplicity, we focused only on one formulation and undertook a study to determine the relationship between the monomer(s) concentration or curing temperature and wall structure.

EXPERIMENTAL

In order to determine the shape and morphology of the polymer wall we recorded scanning electron micrographs of a number of samples.

The polymer wall can be formed by irradiating the UV curable polymer liquid crystal mixture through an external or internal mask.[1] For this experiment we only used an internal mask.

Materials

We studied a homogeneous mixture of CB15/CE2/E48 in a 21:21:58 weight ratio, where the CB15 and CE2 are single chiral components and E48 is a nematic mixture, all obtained from E.Merk. We used the two chiral components in equal proportions in order to achieve proper solubility and viscosity. We used Norland 65, which is a UV curable optical adhesive photopolymer and obtained from Norland Products Inc..

Samples preparation

Samples for SEM studies of the higher polymer content cholesteric liquid crystal materials were fabricated with the following configuration:

Glass/ITO/Black PI Mask/High Polymer Content CLC Material/ITO/Glass

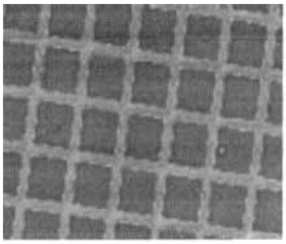

Figure 1(a)

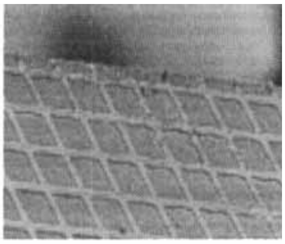

Figure 1(b)

Fig. 1(a) shows the picture of a back glass substrate with internal mask.

The chiral liquid crystal was mixed with prepolymer NOA 65 (10%-20% by weight). The mixture was sandwiched between two ITO glass plates, one of them with internal mask. There was no special treatment of the surfaces and the cell thickness was controled by 4.5 μm plastic ball spacers. The mixture is in its chiral nematic liquid crystalline phase at temperatures up to about 60°C and reflects green color.

We exposed the resulting cells for 30 minutes with UV light from an Electro-Lite ELC 4000 (25 mw/cm^2 @ 365 nm). Prolonging the UV exposure time did not show any significant difference of wall structures.

SEM Analysis

The technique for obtaining the SEM pictures included the following steps:(1) The cured sample was dissolved in hexane for several days; (2) the top glass plate was removed from the sample; (3) the sample was washed three times with hexane, then dried on a clean bench; (4) the sample was glued to an aluminium SEM stud by 5 minutes epoxy; (5) the stub was placed in a vacuum oven for 15 min. at 100°C; (6) the stud was placed in a Hummer VI-A sputtering system to coated with a thin Ag/Pd coating to provide the conductive surface required by the SEM; (7) the sample mounted on the stud was then placed in the SEM chamber and examined.

RESULTS

(1) Effect of temperature on wall formation.

Temperature plays an important role on the character of the wall formation. This is easily noticeable from an examination of the SEM pictures (Figure 2). Results of 10% prepolymer samples for three different temperatures are shown in Figure2(a), 2(b) and 2(c). Two major temperature-dependent aspects are clear: (1) Wall density dramatically increases as temperature increases from 20°C to 60°C. No significant change on wall density is observed when the temperature is raised above 60°C. This phenomena perhaps is due to the saturation of the polymer in the wall with this concentration. (2) The higher the temperature, the sharper the wall edge.

It is not the purpose of the present work to examine in detail the reasons for this temperature-related change in behaviors. However, two competing processes are apparently involved: polymer diffusion and liquid crystal/polymer phase separation. These two processes have different temperature dependence. At lower temperatures the two processes occur at very much different rates, perhaps, the phase separation rate is much faster than polymer diffusion. After photopolymerization, the polymer network blocks the UV light and dramatically reduces diffusion speed, and leads more uncured monomer(s) in the masked area. This can be examined by measuring the clearing temperature of the material, which reflects the concentrate of monomer(s) remaining in the pixel area. At this point, if UV irradiation continues the polymer diffuses to the wall edge and the polymerization only occurs near the edge of the masked area. This causes an irregular shaped wall. At high temperatures, both processes are rapid, resulting in a more desirable structure of polymer wall.

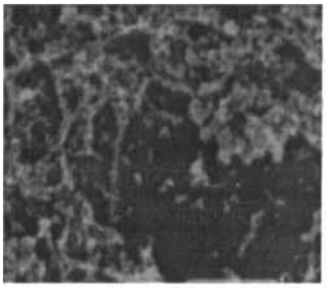

Figure 2(a)

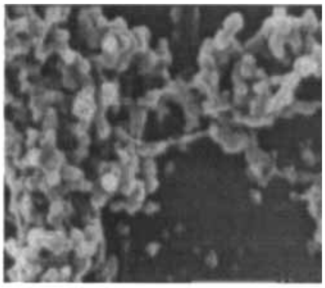

Figure 2(b)

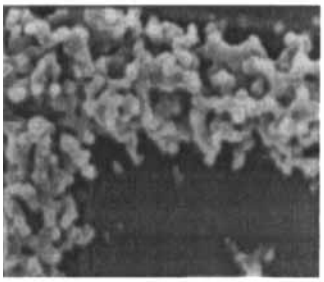

Figure 2(c)

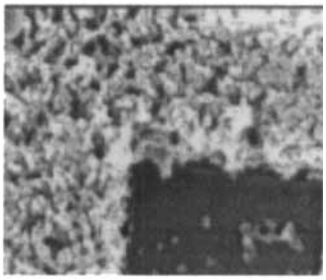

Figure 2(d)

(2) Effect of concentrations of monomer(s) and chiral liquid crystal on wall formation.

We have also studied the effect of monomer(s) concentration. In this experiment the concentration of the monomers varied from 10% to 20% while the curing temperature was fixed (80°C). The SEM pictures of samples with 10% and 20% monomers are shown in Fig.2(c) and Fig.2(d) respectively. The results indicated the wall density increases as the concentration of monomer(s) increases. However, for keeping the bistability of the display, the concentration of the monomer(s) in the mixture is limited. Optimum concentrations of monomer(s) and chiral material are expected to maximize the contrast, brightness and bistability of the display.

A scanning electron micrograph showing a good polymer wall is given in figure 1(b) as an example.

CONCLUSION

1) Polymer diffusion and phase separation processes are involved in the polymer wall formation. Initially a liquid photopolymer precursor and the cholesteric liquid crystal are stirred together to produce a homogeneous mixture. Upon exposured to UV light, the polymer migrates from the masked area to the exposed area. During the UV curing, the solubility of the liquid crystal in the mixture decreases resulting in phase separation.

2) In order to optimize the electro-optic performance, it is important to understand and control the wall formation process.

3) Results show:

- As expected, the polymer wall density increased with increasing concentration of monomer(s) in the mixture.
- Temperature has a significant effect on the character of the wall formation. This is readily apparent from an examination of the SEM pictures.

4) Formulation, curing temperature, UV light intensity, exposure time, and the ratio of the exposed area and the masked area all affect the wall formation process. To control and optimize these factors, further experiments are under way.

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