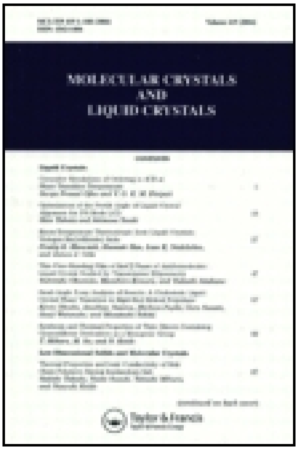

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Effects of Polymer Network with Electric Field to the Ferroelectric Liquid Crystal Molecular Alignments

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Effects of Polymer Network with Electric Field to the Ferroelectric Liquid Crystal Molecular Alignments

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The effects of polymer networks with electric field application to the electro-optic characteristics of ferroelectric liquid crystal devices have been studied. The polymer networks formed in SmC* phase are anisotropic and fibrils-like. Scanning electron microscopy (SEM) and optical microscopy were used to study the polymer networks and the stabilized panels. The electro-optic characteristics of cells were also measured. The experimental results show that presence of anisotropic polymer networks have great effects on the FLC molecules orientation and electro-optic characteristics. The E-O curve of the device is like "V" shape when the monomer concentration is 4%, so it is easier to get gray scales than SSFLC in devices.

Keywords: ferroelectric liquid crystal; polymer networks, "V" shape

INTRODUCTION

Since the surface stabilized ferroelectric liquid crystal display (SSFLC) was discovered by N.A. Clark and S.T. Lagerwall[1], its characteristics caused many people's interest. SSFLC devices have many attractive features such as fast switching speed, wide viewing angle, high contrast ratio and memory ability. However, there also exists some disadvantages, for example, it is difficult to get a uniform alignment as in nematic liquid crystal displays due to zigzag defects, and difficult to realize grayscales due to the bistability. But the most serious problem is that irreversible alignment destruction can be easily caused by mechanical shock. Many experiments have been performed to solve the problem[2,3]. Recently great improvements[4] have been achieved using plastic substrates. Following the polymer dispersed ferroelectric liquid crystal devices research's development[5,6] anisotropic gels of ferroelectric liquid crystals were demonstrated recently[7,8]. That changes liquid crystal molecules alignment method from surface anchored to bulk anchored. In these devices the behavior of the free FLC molecule is dominated by the networks and the molecules behave in a different way from SSFLC whose behavior is dominated by the cell walls. Thus the special devices have many interesting characteristics to be studied.

In the present research, we actually succeeded in fabricating a polymer network stabilized ferroelectric liquid crystal device (PNSFLCD) applying a high electric field with high contrast ratio. It also exhibits good uniform textures and an excellent E-O performance with low threshold voltage of about 2-3 Volts. Especially the E-O curve is V-like shape when the monomer concentration is 4wt% so that it is easier to get gray scales than in the traditional SSFLC devices.

EXPERIMENTAL

The ferroelectric liquid crystal mixture (FLC) used in the experiment is SCE-9 (supplied from Merck Ltd.). The monomer used is a mixture of liquid crystalline diacrylate (from Jilin University). The polymer monomer structure is shown in figure 1

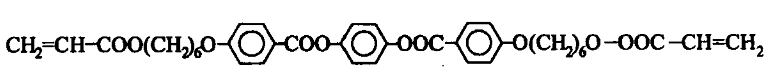

FIGURE 1 The chemical structure of LC diacrylate

The fabrication process of the PNSFLC cells is as follows: the polymer monomer and the photoinitiator IRG-184 (provided by KaYaKu Ltd.)

were dropped into the FLC at 2wt% - 5wt% concentration in a semi-dark room with minimum lighting conditions. The mixture was stirred for 30 minutes on a magnetic stirrer and filled into cells with about 2 μm thickness in the isotropic state. The experimental cells were constructed of two glass plates with ITO electrodes and PI aligning films which cause a low pretilt angle of about 5^o in TN cells, the thickness of PI films was 20 nm. The rubbing direction on the two glasses was parallel. Then the temperature was lowered very slowly, especially at the phase transition point from $S_A - S_C^*$. We put the cells filled with FLC-polymer composite under an ultrviolet light source for 20 minutes for curing the monomer to form a polymer network when the FLC is in the S_C^* phase at the same time a high electric filed (± 50 V, 5 Hz) was applied. The UV power was about 5 mW/cm^2 at 365 nm; finally, after PNSFLC panels were made, the structure of the polymer networks were investigated by scanning electron microscope (SEM) measurements. The textures of PNSFLC cells were studied by polarized microscopy. Meantime the E-O performance of the device was measured with our homemade LCD parameter tester in our laboratory.

EXPERIMENTAL RESULTS AND DISCUSSION

SEM measurements

Having polymerized under UV irradiation, the cells were immersed in hexane to remove the liquid crystal while the polymer network was left on the substrates. After the FLC was dissolved in the solvent, we split the cells with great care and dropped the cells into liquid nitrogen by freezing fracture in order not to disrupt the structure of the polymer network. Removing the FLCs was very slow, it took a few days. After the samples were prepared, SEM photos were got from a 1000B SEM equipment to clarify the polymer network structure formed in PNSFLC cells. A SEM photogaph is shown in fig.2. From fig.2 one can see that the size of most

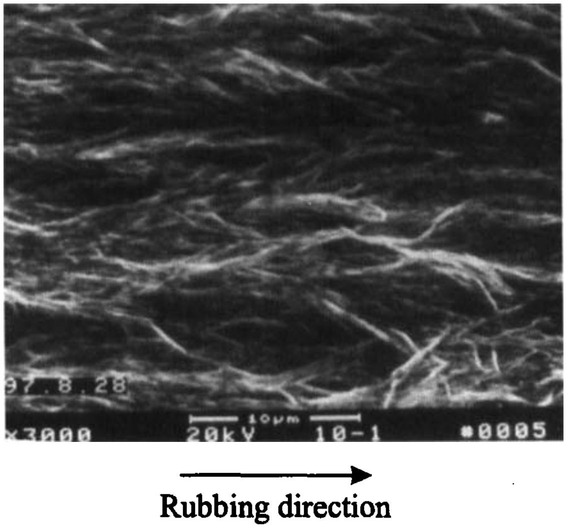

FIGURE 2 SEM photograph of the polymer network structure formed in PNSFLC cells.

polymer networks is less than 10 μm while the polymer networks formed are anisotropic and fibrils-like. The fibrils of the polymer networks are parallel to the rubbing direction. Furthermore the density of the polymer network became larger with the increase of monomer concentration. So the polymer networks can provide strong bulk anchoring strength to align the molecules. Under such conditions, the free FLC molecules are dominated by the polymer network not by the surface orienting film. Thus the FLC molecule alignment and layer structure were affected by the network greatly.

Texture observations

The textures of PNSFLC were studied by polarized microscopy. The textures are shown in fig.3. From the photos, one can see that uniform states are obtained for all different concentrations of the polymer monomer and photoinitiator. But the details are not all the same; to 2wt% the texture is just like conventional SSFLCD. Whereas, only the stripped textures of

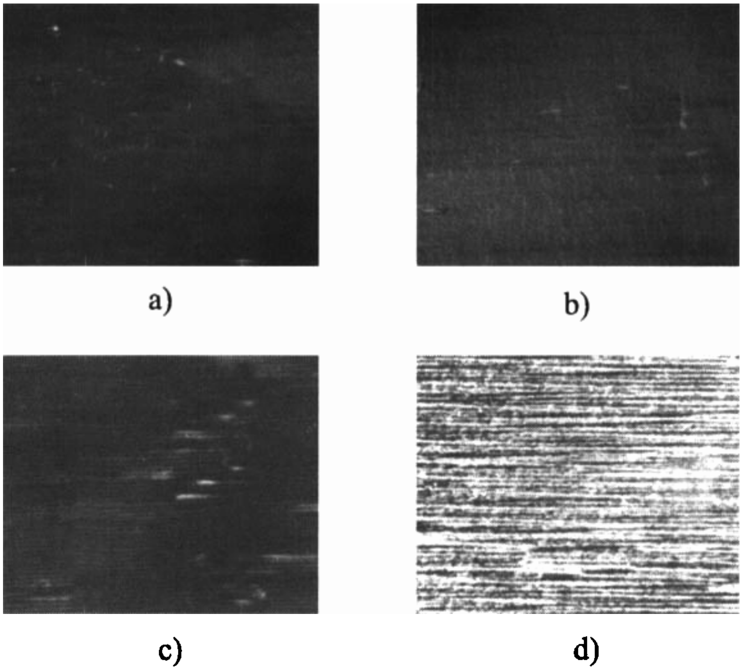

FIGURE 3 Micrograph of PNSFLC texture in S_C^* phase. Monomer concentration a) 2wt%; b) 3wt%; c) 4wt%; d) 5wt%;

uniform state were observed when the monomer concentration was larger than 3wt%. This predominant apearance of stripped texture may be explained as follows: As the monomer was UV polarized in the S_C^* phase sequence with high electric field application, for the strong electric field effect, the quasi-bookshelf layer structure can be gained[9]. Consequently the configuration of the polymer network can be controlled by the FLC molecules. After the polymerization, because of the strong interation between the polymer network and FLC molecules[10], the polymer network in true affects the orientation of the FLC molecules and may play a role in suppressing the formation of the chevron layer structure and hence maintain the quasi-bookshelf layer structure in accordance with the stripped texture[11] during the course of cooling within the SmC* phase.

E-O characteristics of PNSFLC cells

The existence of the polymer network in the device is shown to be effective to reduce the threshold voltage and to improve the contrast ratio of FLC devices. Fig.4a shows an excellent EO performance of the PNSFLC cells exhibiting a contrast ration of 20:1, whereas the contrast ratio of the conventional FLC device is only 9:1. This is mainly due to the quasi-bookshelf layer structure existing in PNSFLC cells. Furthermore, fig.4b shows a very interesting result that the curve of EO charateristic is V-like shape when the monomer concentration is 3wt%. So this PNSFLC device has no threshold voltage. Different transmission is dominated by the different values of the driving voltage. Therefore, with PNSFLC devices it is much easier to get gray scales than with SSFLCDs. This phenomena is explained as follows: As the polymer network exists in the PNSFLCD, the quasi-bookshelf layer structure formed by the high electric field effect can be maintained, which has been demonstrated by the stripped texture observed in the cell. When the PNSFLC device is driven, the optical switching behavior is like field induce electroclinic effect[12], so the E-O curve is like V-shape. More detailed research on this new effect is underway, and the results will be published elsewhere.

CONCLUSION

From the experimental results, it is shown that the presence of anisotropic polymer networks have great effects on the FLC molecules alignment with high electric field application and forming quasi-bookshelf layer structure in the PNSFLC device effectively. The E-O curve shape of the PNSFLC device is like "V", so it is easier to get gray scales than in SSFLC devices. Furthermore the PNSFLC devices exhibit high contrast ratio with low threshold voltage.

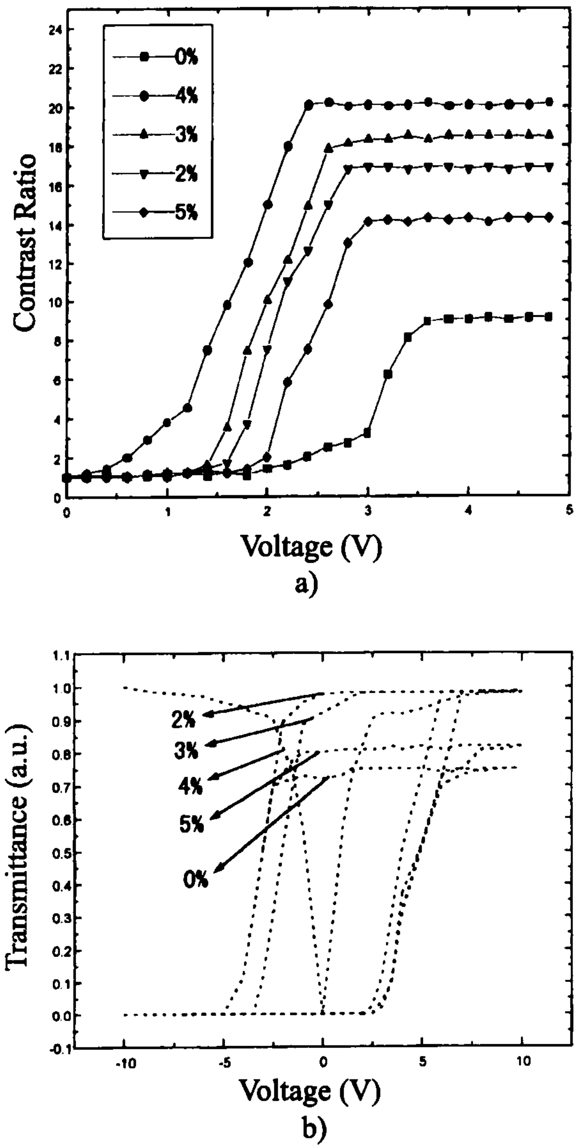

FIGURE 4 The electro-optic properties of PNSFLC device in comparison with a conventional FLC device without polymer network: a) relationship of contrast ratio and driving voltage; b) transmittance change with voltage amplitude.

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References

[1.] N.A. Clark, S.T. Lagerwall, *Appl. Phys. Lett.*,**36**, 69 (1980).
[2.] P.W. Ross, et. al., *Ferroelectrics*, **144**, 3 (1991)
[3.] J. Kanbe, et. al., *SID DIGEST*, p.147 (1994)
[4.] N. Wakita, T. Uemura, et. al., *Ferroelectrics*, **149**, 229 (1993)
[5.] H.S. Kitzerow, H. Molsen, et. al., Appl. Phys. Lett., **60**, 3093 (1992)
[6.] K. Lee, S.-W. Suh, S.-D. Lee, *Appl. Phys. Lett.*, **64**, 718 (1994)
[7.] H.S. Kitzerow, *Liquid Crystals*, **16**(1), 1 (1994)
[8.] R.A.M. Hikmet, H.M.J. Boots, *Liquid Crystals*, **19**(1), 65 (1995)
[9.] K. Nomura, et. al., *Jpn. J. Appl. Phys*,**34**, 5689 (1995)
[10.] Y.K. Fung, D.K. Yang, et. al., *Liquid Crystals*, **19**(6), 797 (1995)
[11.] A.B. Davey, W.A. Crossland, *Mol. Cryst. Liq. Cryst.*, **263**, 325 (1995)
[12.] L.Z. Ruan, J.R. Sambles, E.L. Wood, J. Seaver, *Liquid Crystals*, **18**(3), 401 (1995)