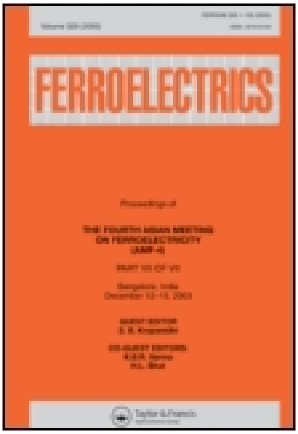

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Study of E-O properties of polymer network stabilized ferroelectric liquid crystal in smectic C* phase

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STUDY OF E-O PROPERTIES OF POLYMER NETWORK STABILIZED FERROELECTRIC LIQUID CRYSTAL IN SMECTIC C* PHASE

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A monomer with reactive diacrylate was mixed with a commercial ferroelectric liquid crystal(FLC)mixture and polymerized under UV irradiation to obtain polymer network stabilized ferroelectric liquid crystals(PNSFLC) . The polymer network formed in SmC* phase is anisotropic and fibrils-like. Optical and scanning electron microscopy(SEM) were used to study the polymer network. The electric-optic characteristics of PNSFLC cells were also measured. As the experimental results, it is found that presences of anisotropic polymer network have great effects on the FLC molecules alignment. The E-O curve of PNSFLC device is like "V" shape , so it's easier to get gray scales than SSFLC device.

Keywords: polymer network; ferroelectric liquid crystals; V shape

INTRODUCTION

Since the surface stabilized ferroelectric liquid crystals display(SSFLC) was discovered by N.A.Clark and S.T.Lagerwall[1]. It's characteristics caused many people's interesting. SSFLCs 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 uniform alignment as nematic liquid crystal display for zigzag defects, and difficult to realize gray scales for the bistability. But the most serious problem is that irreversible alignment destruction can be easily caused by a mechanical shock. Many experiments have been performed to solve the problem[2],[3]. Recently they got great improvements [4] by using plastic substrate. Following the polymer dispersed ferroelectric liquid crystal devices research's development[5],[6]. anisotropic gels of ferroelectric liquid crystal 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 this present research, we actually succeeded in fabricating a PNSFLC device with high contrast ratio and fast switching speed. It also exhibits a good uniform textures, an excellent EO performance with wide viewing angle and a low threshold voltage about 2-3v. Especially the EO curve is V-liked shape so that it is easier to get gray scales than SSFLC devices. Furthermore this device is more stable than SSFLC device.

EXPERIMENTS

The ferroelectric liquid crystals mixture (FLC) used in 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.

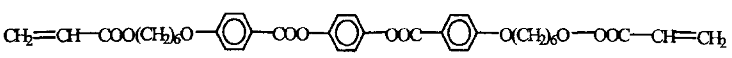


FIGURE 1. The chemical structure of the LC diacrylate

The fabrication process of the PNSFLC cells is as follows: the polymer and photoinitator IRG-184 (from Merck Ltd.) were dropped into the FLC at 2wt% concentration in a semi-dark room with minimum lighting conditions. The mixture was stirred for 30 minutes on magnetic stirrer and filled into cells with about 2μm thickness in the isotropic state. The experimental cells were constructed of two glass plates coated with ITO electrodes and PI aligning films which can cause a low pretilt angle about 5° in the TN cells, the thickness of PI films was 20nm. The rubbing direction on two glass 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 the an ultraviolet light source for 20 minutes for curing the monomer to form a polymer network while the FLC is in the Sc* phase. The UV power is about 5mw/cm^2 at 365nm ; finally, after PNSFLC panels were made ,the structure of the polymer networks was investigated by scanning electron microscope(SEM) measurement. The textures of PNSFLC cells were studied by the polarized microscope. Meantime the EO performance of the device was measured with our homemade LCD parameter tester in our laboratory.

RESULTS AND DISCUSSION

1.SEM measurement

Having polymerized under the 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 made, SEM photos were got from a 1000B SEM equipment to clarify the polymer network structure formed in PNSFLC cells.

the SEM photograph was shown in figure2. From Fig2. we can see that the size of most polymer network is less than 10 μ m. Meantime the polymer network formed is anisotropic and fibber-like. The fibrils of the polymer network are parallel to the rubbing direction. The polymer network appears more dense than 2.0 per cent(the concentration of monomer).The discrepancy is due to the fact that the polymer network collapsed in the direction perpendicular to the surface of the substrates .So the polymer networks can provide strong bulk anchoring strength to orient the alignment of the molecules. Under such condition, the free FLC molecular is dominated by the polymer network not the surface orientation film. Thus the FLC molecular alignment and layer structure were affected by the network greatly.

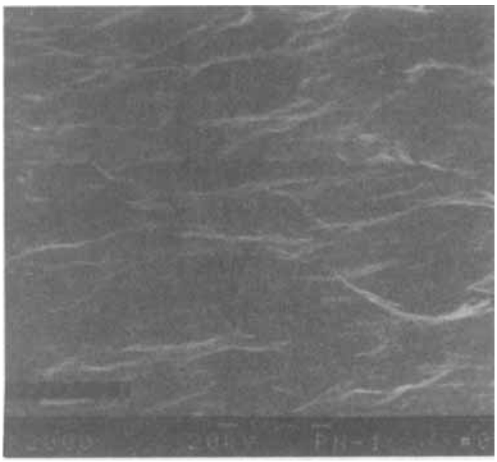


FIGURE 2. The SEM photograph of the polymer network structure formed in PNSFLC cells

2.Texture observation

The texture of PNSFLC were studied by polarized microscope and shown in figure3. When no field is on, only a stripped texture of the C1 uniform state was observed as figure 3. When an electric field about 2V was applied, The stripped texture became invisible and turn into bright state, but the course is a gradual change. In the conventional FLC cell almost only C2 uniform state preferably appears rather than C1 uniform state if the values of surface pretilt angle is small[9][10]. whereas the memory angle of the C2 state is smaller than C1 state[11]. In this experiment, we choose a low pretilt angle for attaining PNSFLC device. Beyond our assumption ,only C1 uniform state appears spontaneously. This predominant appearance of C1 state may be explained as follows: As the monomer was UV polarized in the S_A-Sc* phase sequence, the polymer network was formed in C1 uniform state. Because of the strong interaction between the polymer networks and FLC molecules[12], the transition from C1 state to C2 state[9] may be suppressed during the course of cooling within SmC* phase. Furthermore the polymer networks may play a role in suppressing the formation of the chevron layer structure and hence forming a quasi-bookshelf layer structure in accordance with the stripped texture[13]. This phenomena may be explained as follow: when the temperature approached to the S_A to Sc* transition from above, in order to maintain a constant volume in a finite sample, the smectic layers are locally inclined, which result in the deformation of the smectic layers in the form of undulations .While the polymer network was formed at the same time, because of the strong bulk anchoring strength of polymer network to the FLC molecules, the undulation of smectic C* layer was preserved into forming the stripped texture.

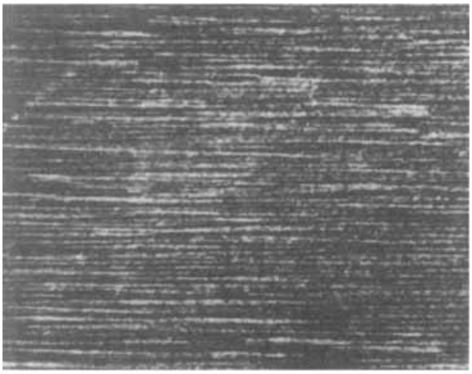
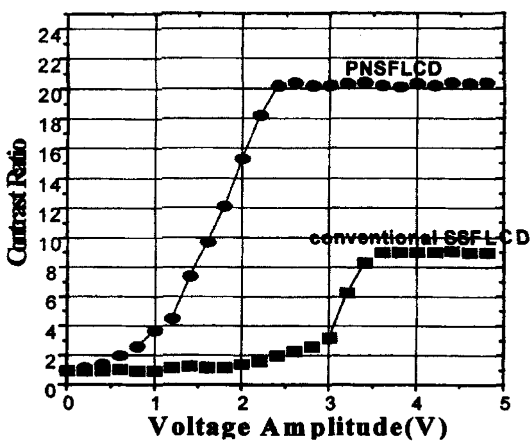


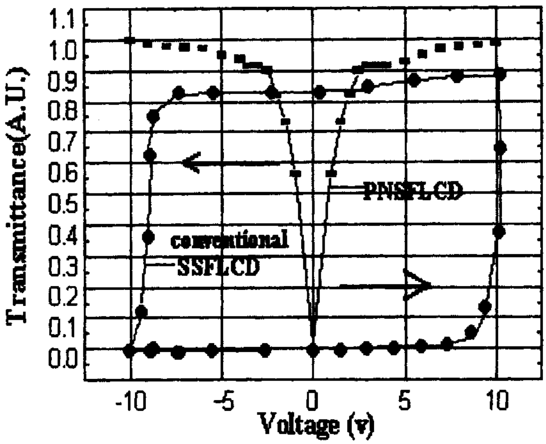
FIGURE 3. The microgragh of PNSFLC texture in Sc* phase

3.E-O characteristics of PNSFLC cells

The switching behavior of PNSFLC device was investigated by placing them between crossed polarizers and by following the change in the transmitted light intensity during the application of an electric field. The orientation of two polarizers were chosen so that the switching took place between the maximum dark state and transparent state. Figure 4(a) and 4(b) show the EO performance of the PNSFLC device in comparison with a conventional FLCD without polymer networks.



(a)



(b)

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

The existence of the polymer network in the device is shown to be effective to reduce threshold voltage and to improve the contrast ratio of FLC device. Figure 4(a) shows an excellent EO performance of the PNSFLC cells exhibiting a contrast ratio of 20:1. Whereas the contrast ratio of the conventional FLC device is only 9:1. This mainly due to only C1 uniform state existing in the PNSFLC cells. Furthermore, figure 4(b) shows a very interesting results that the curve of EO characteristics is V-like shape. So this PNSFLC device has no threshold voltage. Different transmission is dominated by the different values of the driving voltage. Therefore the PNSFLC device is much easier to get gray scales than

SSFLCD. This phenomena is explained as follow: As the polymer network exists in the PNSFLCD, the bulk anchoring strength is stronger than surface anchoring strength in the bulk[12], so the behavior of the free FLC molecular is dominated by the networks in the device. That changed the layer structure into quasi-bookshelf type which has been demonstrated by the striped texture observed in the cell. When the PNSFLC device is driven, the optic switching behavior is liked field induced electroclinic effect. More detailed research works on this new effect is now underway, and the results will be published elsewhere.

CONCLUSIONS

From the experimental results, it's shown that presences of anisotropic polymer networks have great effects on the FLC molecules alignment and forming a quasi-bookshelf layer structure of C1 uniform state in a PNSFLC device effectively. The E-O curve shape of PNSFLC device is like "V", so it's easier to get gray scales than SSFLC device. Furthermore the PNSFLC device exhibits a fast switching speed and high contrast ratio with a low threshold voltage.

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