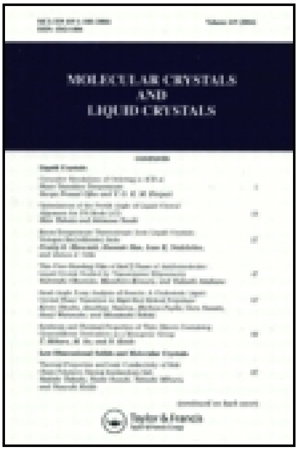

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Polymer / Ferroelectric Liquid Crystal Composite Device for Analog Gray Scale

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We have developed new polymer / Ferroelectric Liquid Crystal composite device having unique domain switching. The domains appear as a periodic stripe pattern and gently change by the applied field keeping its uniformity. This technique realizes the analog gray scale SSFLC without any modification of the device configuration and fabrication process. In this paper, we will report the correlation between the generation of stripe switching domain and the polymer material.

Keywords: polymer; ferroelectric liquid crystal; analog gray scale

INTRODUCTION

Since a first invention of Surface Stabilized Ferroelectric Liquid Crystal (SSFLC) device by N.A.Clark and S.T.Lagerwall, the techniques for the gray scale display have been investigated. The digital gray scale techniques such as spatial dither and temporal dither have been established for the practical display. However, the digital gray scale techniques have a restriction on its number of gray level. At least, it is necessary to achieve 256 gray levels on the multimedia display for next generation. Indeed, it will be possible to achieve 256 gray levels by the digital gray scale technique. For example, the combination of 2-bit spatial dither and 4-bit temporal dither realizes 256 gray levels. However, the digital gray scale technique has some serious problems. For example, the spatial dither technique using sub-pixels reduces the brightness by reducing the aperture ratio and increases the cost and the power consumption of the panel by increasing the number of the IC. Furthermore, very fast switching speed will be required for the FLC material to address the high resolution display with a temporal dither. The pseudo edge problem must be solved on the temporal dither technique.

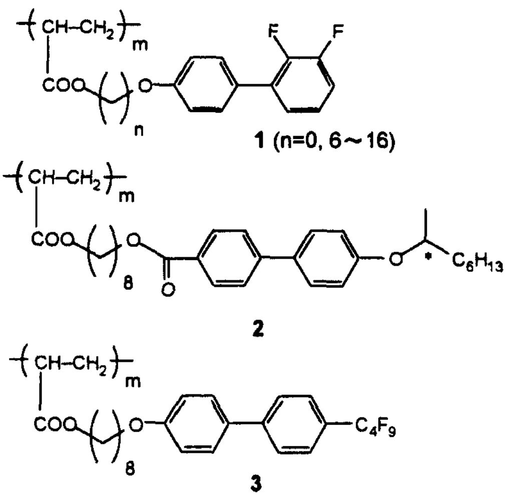
On the other hand, the analog gray scale FLC has also been investigated and some techniques had proposed. For example, fine particle dispersion[1], polymer network[2],[3],[4], etc. It must be achieved to obtain the small and even domain distribution on the analog gray scale device.

We have been reported new analog gray scale technique using the polymer / FLC composite device[5]. In this paper we will discuss the mechanism of this technique and the correlation between the appearance of stripe switching domain and the polymer material.

EXPERIMENTAL

1.Device Fabrication

The chemical structures of the typical polymers are collected in Figure 1.



1 (n=0, 6~16)

2

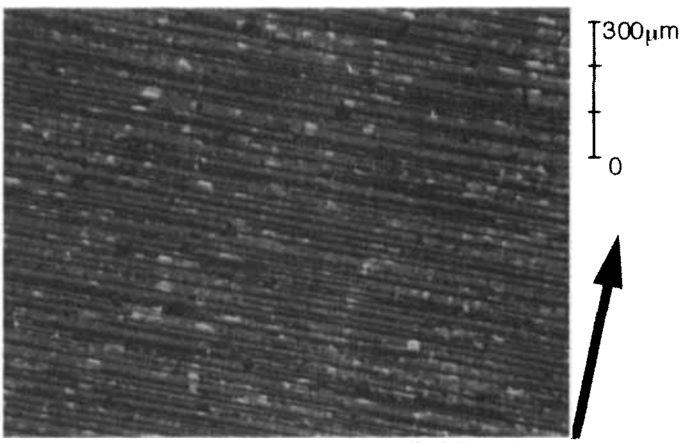
3

FIGURE 1 The Chemical structures of the polymers.

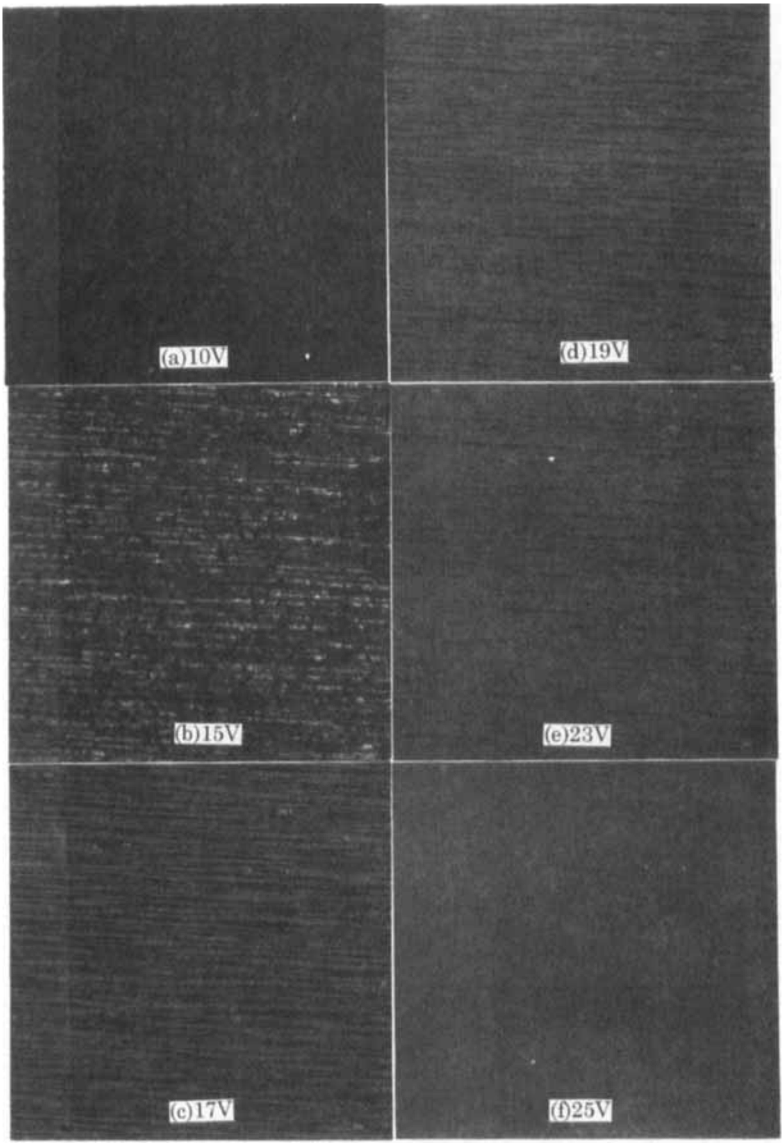
The polymer / FLC composite device was prepared by mixing a small amount (<3wt.%) of the polymer with the FLC material initially. The mixture was injected to the glass cell with ITO electrode, barrier layer and rubbed polyimide alignment layer. The cell thickness was around 1.5μm and C2U alignment was obtained by optimizing polyimide material and rubbing condition. At this moment, there is no change on its appearance compared to the FLC device without the polymer.

Photograph 1 shows a typical switching domain pattern of the polymer / FLC composite device under the intermediate pulse field. The hashed domains grow up as a periodic stripe pattern, which has about 10 - 15 μm width. The areas of the domains are easily controlled by the signal pulse height and/or width.

Photograph 2(a)-(f) shows an example of gray scale switching by changing a switching pulse voltage on the polymer / FLC composite device includes 0. 5wt.% of polymer. The short stripe pitch (less than 20μm in average), good uniformity and the gentle change of the domains enable to control the gray level analogously. Figure 2 shows the transmittance versus pulse voltage characteristics corresponding to Photograph 2.



PHOTOGRAPH 1 Typical stripe domain under the intermediate pulse. See color plate X at the back of this issue.



PHOTOGRAPH 2(a)-(f) Gray scale switching by changing the pulse voltage from 10V to 25V.(τ=15μsec.)

See color plate XI at the back of this issue.

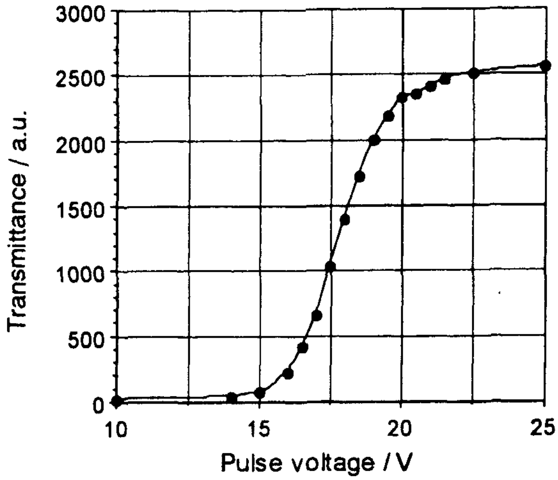
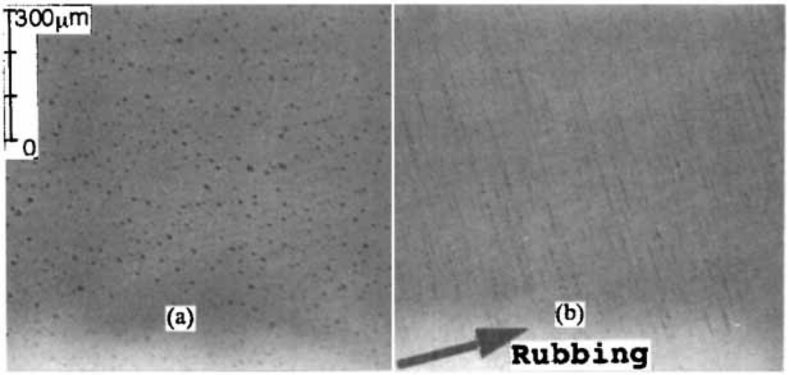


FIGURE 2 Transmittance vs. pulse voltage.

2.Mechanism of Stripe Switching Domain

We have investigated the combination of the FLC material and the polymer which provides the stripe domain distribution as described above. The most important feature is the phase separation of dispersed polymer from FLC mixture in the nematic phase and following realignment process at the smectic phase. Thus, the micro-scale phase separated polymer aligns along the smectic layer.

Photograph 3(a) shows an appearance of the polymer / FLC mixture in nematic phase when it was cooled from Isotropic phase. Small dots are the phase separated isotropic polymer. Photograph 3(b) shows nematic phase by heating up from smectic C phase and following smectic A phase. Small dots consist of phase separated isotropic polymer aligned along stripes perpendicular to the n-director (rubbing direction). The stripy aligned polymer in the nematic phase corresponds to the alignment in the smectic phase having a layer structure. Therefore, when the polymer is separated randomly from the nematic phase, it will be aligned along the smectic layer in the smectic A phase, by cooling from the nematic phase. Then, the alignment of the polymer is kept in the smectic C* phase and the local threshold variation is introduced around the polymer



PHOTOGRAPH 3 (a) N phase at the time of cooling from isotropic liquid. (b) N phase at the time of heating from smectic phase.
See color plate XII at the back of this issue.

In order to confirm the relationship between the phase separation in nematic phase and the generation of stripe domain, we tried to use the analogous compound as shown in Figure 3. The mixtures of SCE-8 and **4**, **5** or **6**, which are the monomer, the dimer or the trimer compounds with a similar chemical structure to **1**, showed no phase separation in the nematic phase and no stripe domain distribution in smectic C* phase under the intermediate field. The polymer **7**, which has a longer fluorinated carbon chain than **3**, showed excessive phase separation as a large size of droplet in the nematic phase (even in isotropic liquid) and consequently, no stripe domain was observed. In this case, the large size phase separation makes it difficult to align along the smectic layer.

On the other hand, the series of polymer **1**(n) were found to have a length dependence on their spacer alkyl chain between the core part and the polymer chain. The polymer **1**(n=0) which has no spacer chain showed excessive phase separation as a large size of droplet in the nematic phase as similar to the case of polymer **7**. The polymer **1**(n=6 - 12) which have longer spacer chain showed moderate phase separation in nematic phase and clear stripe domain switching in smectic C* phase.

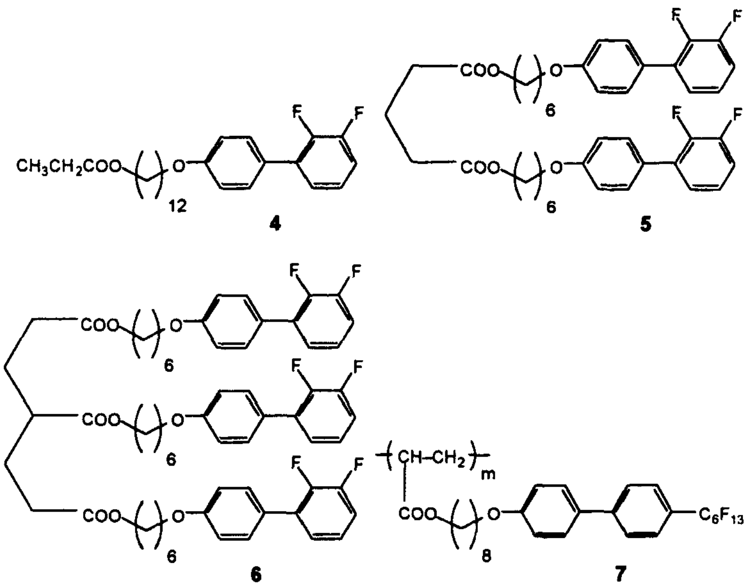


FIGURE 3 Chemical structures of investigated materials.

3.Molecular Weight of Polymer

In order to confirm the effect of molecular weight of polymer, we have prepared the polymers with different average molecular weight as shown in Table 1. These were fractionated from the radical polymerized polymer **1** (n=12) by the chromatographic method. The results are collected in Table 1. The higher molecular weight polymers showed clear phase separation in nematic phase and consequently generate the stripe switching domain in smectic C* phase. The highest molecular weight one (Mw=38106) showed phase separation in nematic phase as larger size compared to the others. Therefore, some phase separated polymers did not align along the smectic layer and remain as a grain in smectic phase. On the other hand, lowest molecular weight polymer (Mw=5646) showed no phase separation in nematic phase and no stripe switching domain in smectic C* phase at any concentration. The polymer No.3 (Mw=11614) showed clear stripe domain switching with only a very few polymer grains. The results indicate the generation of stripe domain based on the delicate solubility equilibrium of polymer in liquid crystal phase.

TABLE 1 Stripe domain switching vs. molecular weight of polymer **1** (n=12).

No.	Mw	Mn	Mw/Mn	Stripe domain switching in SmC*
1	38106	36003	1.06	yes (many polymer grains were observed)
2	21675	20436	1.06	yes (many polymer grains were observed)
3	11614	10776	1.08	yes (only a few polymer grains were observed)
4	5646	5202	1.09	no

CONCLUSION

We have investigated the mechanism of the stripe domain switching on the polymer / FLC composite device. It was found that the phase separation as the micro size of the polymer from the FLC material in the nematic phase and the following realignment along the smectic layer in the smectic A phase plays an important role for generating the stripe domain.

Acknowledgments
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