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Wen-Jun Zheng [a], Janos Hajto [a] & Harry Milburn [a]
[a] Department of Applied Chemical and Physical Sciences, Napier University, 10 Colinton Road, Edinburgh, EH10 5DT, United Kingdom

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ALIGNED FERROELECTRIC LIQUID CRYSTAL/POLYMER NETWORK DEVICES

WEN-JUN ZHENG, JANOS HAJTO, HARRY MILBURN
Department of Applied Chemical and Physical Sciences, Napier University,
10 Colinton Road, Edinburgh EH10 5DT, United Kingdom

Abstract In this paper the preparation of fast switching ferroelectric liquid crystal/polymer network systems for display devices is reported. A composite mixture was prepared using a dye doped ferroelectric liquid crystal mixture mixed with a UV curable adhesive. The substrates of the cell do not need surface treatment and the alignment layer can be omitted. The alignment of the composite film was achieved using an external magnetic field. Liquid crystal molecules were forced to orient parallel to the direction of the external field. After UV curing of the material a planar aligned composite layer was obtained. The aligned composite films possess good electro-optic properties.

INTRODUCTION

Liquid crystal/polymer networks (LCPNs) are two phase systems in which a solid state polymer network is formed in a low molar mass liquid crystal continuum [1-7]. These materials have recently attracted considerable interest owing to their potential applications in display devices. Most currently studied LCPNs are nematic-based thin films which can be obtained by in situ polymerisation of a cross-linking monomer in a low molar mass nematic liquid crystal environment [1-5]. These films can strongly scatter light because of the differences of refractive index from one domain to another. Such materials are ideal for light shutters and projection devices due to their high contrast ratio. In LCPN devices the use of polarisers is omitted, thus increasing transmittance and brightness; the surface treatment of substrates is not necessary, so that the fabrication process becomes simpler and production costs are reduced. Unfortunately the usefulness of nematic-based network systems is limited by the relatively slow response.

Ferroelectric liquid crystals are known to be suitable for applications requiring fast switching. To produce new materials which combine the advantages of LCPNs with those of ferroelectric liquid crystals is of great interest [6,7]. The ferroelectric liquid crystal/polymer network (FLCPN) materials can be produced using techniques similar to those used for nematic LCPNs. However the operation of FLCPN displays is similar to that of surface stabilised ferroelectric liquid crystal displays (SSFLCDs) [8], so a particular alignment is required. In general, a planar alignment of FLCPN is desired. FLCPNs are so far scarcely studied because of the difficulties in obtaining a suitably aligned film. Recently, it has been reported that homogeneously aligned FLCPN layers were obtained by a photopolymerisation process using linearly polarised UV light [9].

In this paper, we report that a planar aligned FLCPN film can be obtained in a non-surface-treated cell. The alignment of FLCPN film was achieved using an external magnetic field. The initial electro-optical measurement results of the sample devices are also presented.

EXPERIMENT

In this work the liquid crystal used was a ferroelectric mixture SCE3 (Merck, UK) with a phase sequence of

K < 0°C SmC* 74.03°C SmA 107.15°C N* 138.54°C I.

The UV light curable adhesive, NOA65 (Norland,USA), was used as prepolymer. The dye used was Methyl Violet 6B (BDH). The mixtures were obtained by mixing the liquid crystal with NOA65 and Methyl Violet in different concentrations. Two typical materials were prepared with different concentrations of components:

- Material 1: 96.5 wt% of SCE3, 0.5 wt% of Methyl Violet, and 3 wt% of NOA65.
- Material 2: 99% wt% of SCE3, 0.05 wt% of Methyl Violet, and 0.95% of NOA65.

The components in each mixture were mixed by stirring at a high temperature (about 140°C) for about 20 minutes to get uniformity.

The cells were constructed using non-surface-treated ITO coated glass plates. The thickness of the cell was confined to 20μm by spherical glass spacers. The mixtures were easily introduced into the cells in their isotropic phase by a capillary action, and heated to an elevated temperature, usually well above the clear point of the liquid crystal. An external magnetic field of 4kGs was then applied. and the sample was slowly cooled down at a cooling rate in the order of 1°C/min. to room temperature in the presence of the magnetic field. The polymerisation was carried out by UV light curing the optical adhesive during the cooling process. Three sets of samples were made by UV light irradiation starting from 140°C, 110°C, and 60°C, where the liquid crystal was in isotropic, chiral nematic (N*), and chiral smectic C (SmC*) phases, respectively. A 100W high pressure mercury lamp was used as UV light source. The intensity of the UV light was 9~10mW/cm^2 (at the wavelength of 365nm) on the surface of the cell substrate.

The sample device was made by placing the cell between crossed polarisers with one polariser parallel to one of the two molecular orientational directions. Upon applying bipolar voltage pulses, two 'bright' and 'dark' states were observed. The intensity of the transmitted light across the cell between the two states can be written as

$$\Delta I = I_0(T_B - T_D)F(\theta) \qquad (1)$$

where F is a function of θ which is the angle between the two orientation positions of the liquid crystal molecular director, T_B and T_D are the light transmissions corresponding to the two positions.

The alignment and the electro-optic properties of the samples were studied on a general electro-optical measurement apparatus with a Nikon polarising microscope system. A 10MHz programmable function generator (Thurlby Thandar TG1010) coupled with a wide band voltage amplifier was used to provide voltages with different waveforms and frequencies. The light source used was a HeNe laser (632.8nm, 10mW). The transmittance of the cell under different electrical driving signals was determined by a photodiode attached to the microscope. The electro-optic properties of the cell were measured using a digital oscilloscope (Hewlett Packard 54602B). The temperature of the sample was controlled by a Linkam TMS90 temperature system.

RESULTS AND DISCUSSIONS

At high temperature, the liquid crystal became more easily oriented by an external field. In our case, the molecular director of the liquid crystal was aligned by an external magnetic field to orient in the direction parallel to that of the field. The orientational state of the liquid crystal can be maintained by carefully cooling down the material layer at a very slow cooling rate (0.1°C~1°C/min) so that the liquid crystal smoothly entered higher ordered mesophases from the isotropic phase. After UV light curing, an FLCPN film with planar alignment was obtained. We found that the alignment effect was different when the UV light curing of the mixture started from different mesophases. Figure 1 shows the microphotographs of films formed by starting the UV light curing of the mixture from different temperatures.

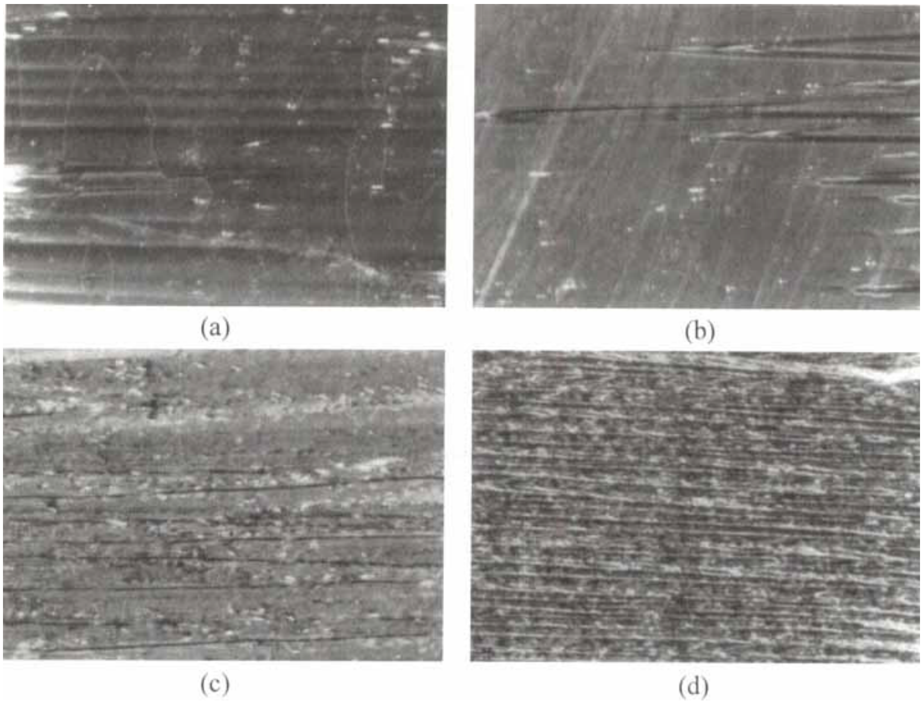

FIGURE 1. FLCPN films, containing mixture 2, formed by UV light curing the mixture starting from: (a) 140°C (isotropic phase), (b) 120°C (N* phase), (c) 90°C (SmA phase), and (d) 60°C (SmC* phase).

(See Color Plate VIII).

It can be seen that starting UV light irradiation of the mixture from a temperature above the SmA phase can produce films with very uniform alignment.

The electro-optic measurements were carried out on the film contained material 1. The ferroelectric liquid crystal molecules in the film can be easily switched by an external electrical pulse. Figure 2 shows an oscillogram of the electro-optic response of the film to a square wave voltage.

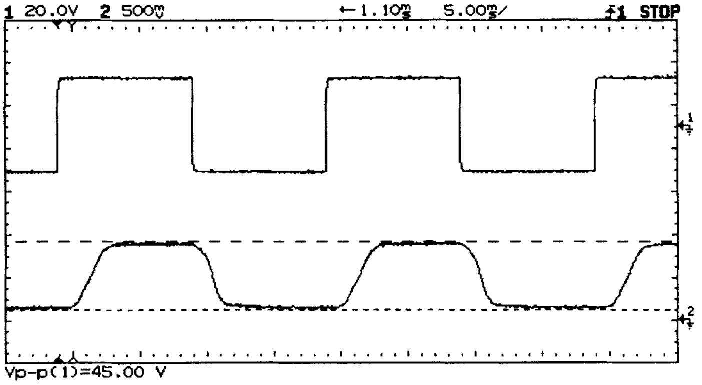

FIGURE 2. The electro-optical response of the FLCPN film to a 50Vpeak-peak 50Hz square waveform voltage.

The contrast ratio of the film is defined as

$$C.R.=\frac{I_B}{I_D} \qquad (2)$$

where I_B and I_D are light transmitting intensities in bright and dark states, respectively.

Figure 3 shows the measurement results of the contrast ratio as a function of applied field. The The film reaches its saturation at an applied field of about 1.25V/μm. At room temperature region, the contrast ratio of the film can reach 22 (c.f. Figure 3). The contrast ratio versus temperature is shown in Figure 4.

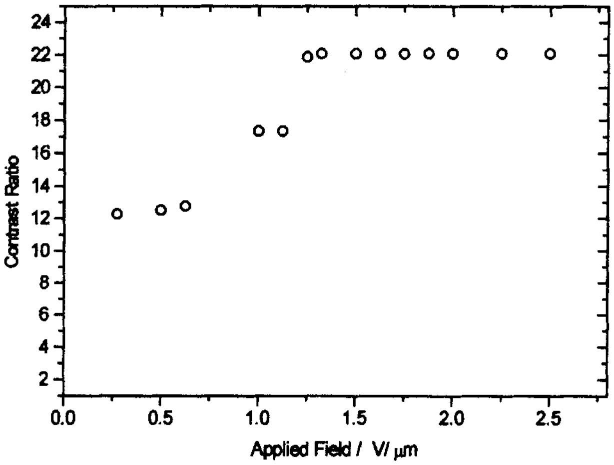

FIGURE 3. The contrast ratio of the FLCPN film against applied field. The measurement was carried out at room temperature.

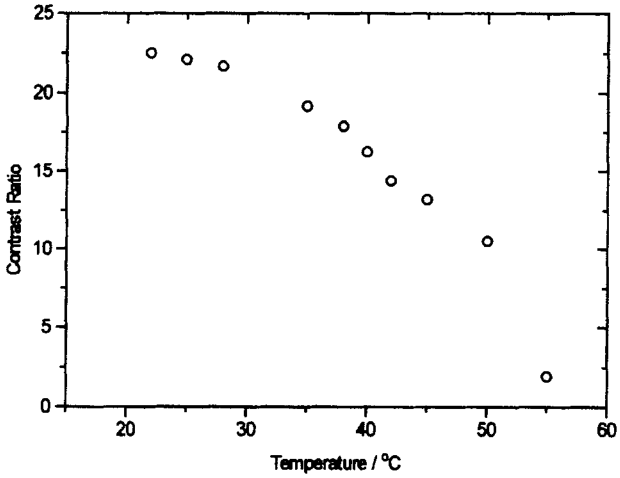

FIGURE 4. The contrast ration of the FLCPN film vs. temperature. The film was driven by a $100V_{peak-peak}$ 50Hz square wave voltage.

The response speed of the film was measured by the rise time during which the display reached 90% transmittance from the 10% level. The rise time is sensitive to both the drive voltage and the temperature. Figure 5 shows the curves of the rise time of the sample device against applied voltage at different temperatures. At room temperature region, the rise time of the sample device was about 700μs.

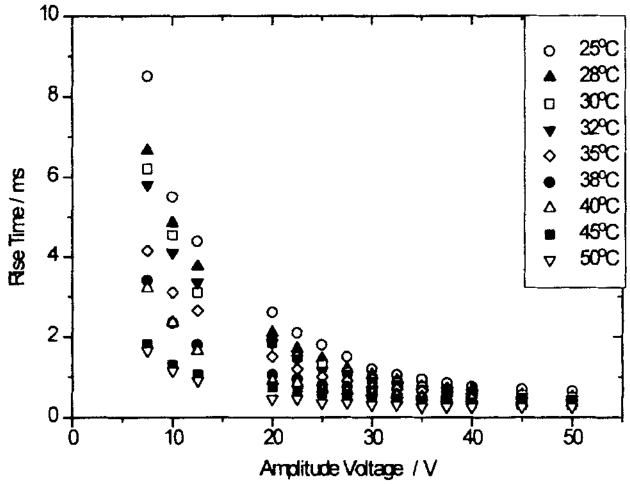

FIGURE 5. The response time of the FLCPN film against Applied voltage at different temperatures. The film was made using material 1. The thickness of the film was 20μm.

CONCLUSION

FLCPN layers with monodomain planar alignment have been produced using an external magnetic field. The alignment of the FLCPN films is strongly affected by the curing temperature. Our preliminary results show that curing the FLC/prepolymer mixture starting from isotropic phase or chiral nematic phase can produce uniformly aligned FLCPN films. This must be studied in more detail. FLCPN displays can be fabricated using cells without any surface treatment. Further investigations on these new materials are being carried out in order to understand the physical principles behind their operation phenomena, and improve their electro-optic properties.

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