Study on Electro-optic Characteristics in the Optically Compensated Splay Cell with UV-curable Reactive Mesogen

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Abstract

We have studied the optically compensated splay (OCS) mode using reactive mesogen monomer to reduce critical voltage, setting voltage and phase transition time from initial bend to splay state. The high pretilt angle from vertical alignment was formed through the polymerization of UV curable RM monomer at the surfaces. In this way, orientation of the LC with OCS can be achieved without setting voltage.

1. Introduction

Recently, liquid crystal displays show good performance such as high image quality, wide viewing angle and high brightness with multi-domain vertical alignment (MVA) [1], in-plane switching (IPS) [2], fringe-field switching (FFS) [3,4] and optically compensated bend (OCB) [5-6]. Especially, the OCB mode shows wide viewing angle and fast response time. But this device in order to realize good dark state needs some compensation films. Also new vertically aligned LC mode called by optically compensated splay (OCS) [7-9] shows wide viewing angle and fast response time, owing to mirror symmetry configuration along the mid-director. However, the device requires a generation voltage like in the OCB mode. Previously, we reported that the critical voltage from twist to splay decreases with decreasing tilt angle, and especially when the tilt angle is 45°, the LC has OCS structure from the beginning.

In this paper, we describe how the critical and setting voltage can be reduced by surface tilt angle change through the polymerization of UV curable reactive mesogen (RM) monomer at the surfaces.

2. Experiment

Figure 1 shows the process of forming new pretilt angle at the surface by polymerizing RM monomer in the cell. In the OCS mode, the LCs and RM monomer are almost homeotropically aligned with rubbed surface at parallel directions as shown in Fig. 1(a) and then a mid-director of LCs orients parallel to the substrate under a special voltage condition as shown in Fig. 1 (b) so that the device shows a wide-viewing-angle due to self-compensation effect. When the OCS cell has low pretilt angle close to 45°, the OCS state can be formed easily. The LC molecules were transformed into the splay state at certain electric field and then at this state, the cell was cured by UV light as shown in Fig. 1(c). Subsequently RM monomers in the middle of the cell were slowly moved to the both surfaces and react with those monomers close to the alignment layer. The low pretilt angle was formed through the polymerization of UV curable RM monomers at the surface. Fig. 1(d) shows initially splay state of OCS mode using UV-curable RM monomer.

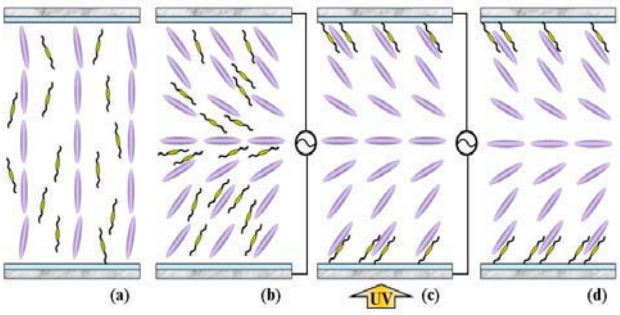

Fig. 1. The process of forming initial splay state using UV-curable RM monomer.

For this experiment, we used a UV-curable RM monomer and photo initiator (Irgacure 651) in LCs. The parameters of host LC are used: Δn=0.077 and Δε= -4 at 589.3nm, 20℃ and 1kHz. The LC was sandwiched between indium tin oxide (ITO) coated glass substrates separated by 4.8μm spacers. UV light irradiation progressed with a voltage applied across the cell, where the LC molecules and RM monomers kept splay state. The UV light intensity was fixed at 30mW/cm^2 and centered at a wavelength of 365nm. The sample cells were applied at 5V as a square wave of 60Hz when exposed to the UV light at room temperature. All sample cells were cured with UV light for 10min. After the photo-curing, RM monomers polymerized to a thin film and sustain the splay deformation of the LCs in the sample cells.

3. Results and discussion

The test cells were cured by UV light under maintaining splay state, but all polymeric thin films did not completely support splay state of LC. Concentration of RM monomer and UV curing voltage are main factors and needs to consider combination of these factors, carefully. In this experiment, curing voltage was fixed at 5V which does show OCS state and concentration of RM monomer was only considered. The thickness of polymeric thin film depended on ratio of RM monomer and sufficient thickness of film might well support splay state of LC. Figure 2 shows a result of forming low pretilt angle through the polymerization at the surface. As concentration of RM monomer increase, critical voltage is decreased. The special concentration of over 0.4% shows splay state initially without applying voltage.

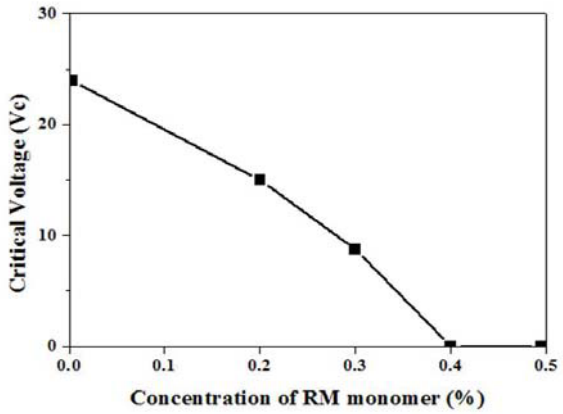

Fig. 2. The change of critical voltage according to concentration of RM monomer.

We also defined a setting voltage (Vs) as the voltage in which the OCS orientation is kept when decreasing a voltage after applying Vc. We evaluated the Vs as a function of surface pretilt angle through polymerization of RM monomer, as shown in Fig. 3. As concentration of RM monomer increase, setting voltage is decreased. The special concentration of over 0.4% is in the initially splay state without twisting of the LC, which is proved by rotating the cell under crossed polarizers.

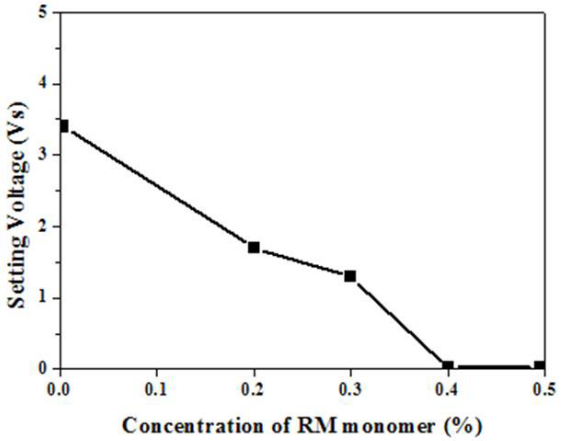

Fig. 3. The change of setting voltage according to concentration of RM monomer.

The pretilt variation has an effect on capacitance of LC cell. The capacitance values can be obtained by measured test cell as function of applied voltage. The definition is as follows in terms of the capacitance

$$C = \frac{\varepsilon \times A}{d}$$

where A, d and ε are the area and distance of electrode and dielectric constants of LC, respectively. Because A and d were fixed, a capacitance value only depends on tilt angle of LC. Negative LC has higher dielectric constant with perpendicular direction to electric field than with parallel direction to electric field. A measured result according to concentration of RM monomer is shown Fig. 4. To observe phase transition from splay to twist, voltage condition was set down form 10 V to 0 V. The LC is initially vertical aligned and then the LC tilts down to parallel substrate. The test cells with RM monomer have higher capacitance values with new low pretilt angle at no applied voltage. Phase transition of LC from splay to twist contributed the sudden change of capacitance values.

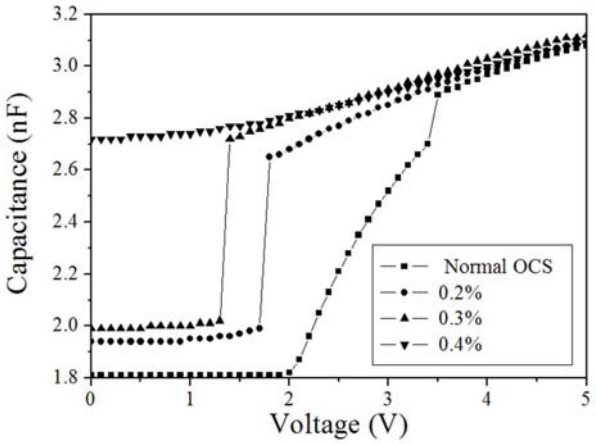

Fig. 4. Measured voltage-dependant capacitance curve according to concentration of RM monomer.

Fig. 5 shows voltage-dependent transmittance curve of test cell, where the splay state is achieved by 0.4% RM monomer. At 0 V, light leakage exists since $d\Delta n_{eff}$ of the cell at normal direction is larger than λ /2 so that the phase is not cancelled completely.

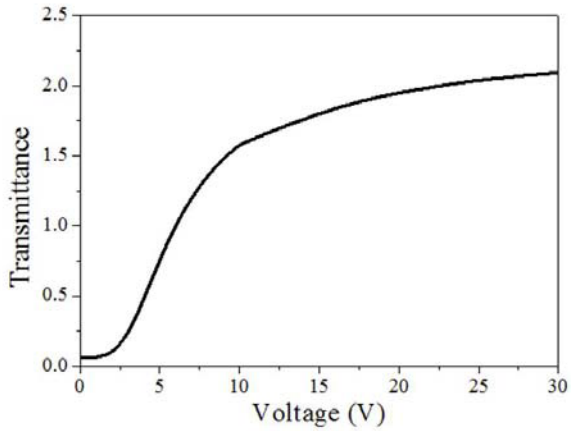

Fig. 5. Measured voltage-dependant transmittance curve of the film compensated normally black OCS cell.

4. Summary

In conclusion, for the first time, the optically compensated splay state was achieved by surface medication of the vertical alignment layer using UV-curable RM monomers. The weight percent of the RM monomer, UV condition and applied voltage play key role of surface medication. The new device can be applicable to LCDs or LC phase or amplitude modulator.

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6. Reference

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