

Improved Low-Temperature Response in Polymer-Stabilized Vertically-Aligned Cell

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The longstanding weakness of liquid crystal displays (LCDs) is slow response at low temperature. We report that the in-cell polymer networks accelerate low-temperature response of vertically-aligned nematic cells. After refining the polymerization conditions of the LC and polymer, we succeed to improve from 143 ms to 31 ms in fall time at -20°C . © 2009 The Japan Society of Applied Physics

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1. Introduction

In recent years, demands for display devices are diversified. For example, the display with a broad operation-temperature range is requested for automobile-use, airborne-use, etc. However, at low temperature, many liquid crystal displays (LCDs) have problems of motion blur due to slowdown of response characteristics. The rise time of liquid crystal device is proportional to the applied electric field level and it can be improved to increase operation voltage. However, the fall time of LC devices depends on those nematic material constants and those cell gap. Other approaches for this fall time are needed.

One novel approach is to introduce polymer networks into nematic layers. However, it seems that no low-temperature studies of improvement response have been reported.¹⁻⁵⁾

We study polymerization conditions for precursor mixture and measure response of polymer-stabilized vertically-aligned (VA)-LC samples from this mixture at low temperature. This paper reports the characteristics of the polymer-stabilization in VA nematic layer.

2. Basic Operation of Polymer-Stabilized VA Cell

In this section we will explain about polymer-stabilized VA cell structure and its basic operation. Figure 1 shows schematic illustrations for the polymer-stabilized VA cell operation. The polymer-stabilized VA cell consists of ITO glass substrates, vertical alignment layer, LC with negative $\Delta\epsilon$, and dispersed polymer networks.

Figure 1(a) shows dark-state model under crossed-nicols at zero field. LC directors are aligned vertically and the cell does not transmit light.

Figure 1(b) shows bright-state model at electric field application. In this model, the LC layer is separated into multi-domains whose director directions are at random. The cell transmits light due to this multi-domain texture.

3. Sample Preparation and Typical Performance

We have prepared the polymer-stabilized VA cell which consists of a nematic material (Merck MLC-6608) and photo-initiator-doped reactive liquid crystalline monomer (DIC UCL-00-K1). The LC and the reactive liquid crystalline monomer were mixed at the ratio of 95 : 5 by weight, and this mixture also has nematic phase at room temperature. This mixture was injected into empty VA cells whose gaps were $3\mu\text{m}$, $10\mu\text{m}$ in isotropic state. The filled cells were then slowly cooled down to room temperature. Then,

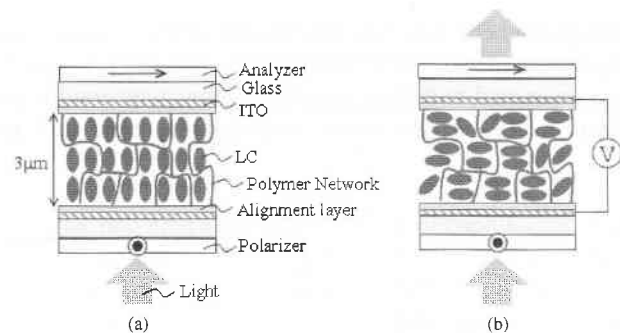


Fig. 1. (Color online) Schematic view-graphs of the polymer-stabilized VA-LC operation: (a) field-off (dark state model); (b) field-on (bright state model).

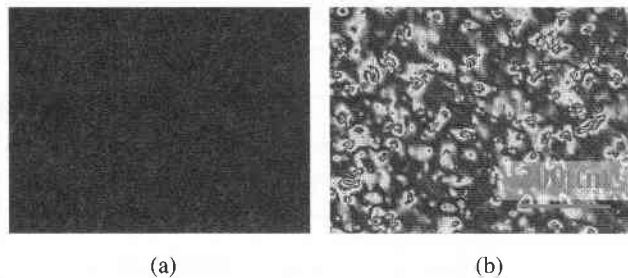


Fig. 2. (Color online) The micrographs of the typical polymer-stabilized VA-LC cell (cell gap: $3\mu\text{m}$) under crossed-nicols: (a) $V = 0\text{V}$ (dark state); (b) $V = 10\text{V}$ (bright state).

the mixture was polymerized at room temperature through UV light irradiation whose typical intensity is 8.52 mW/cm^2 . The typical UV curing time for the cells is 2 min. For comparison a non-polymer-introduced VA cell was fabricated.

Figure 2 shows the micrographs of the typical polymer-stabilized VA-LC cell. After UV curing, dark state between crossed-nicols can be maintained as shown in Fig. 2(a). Furthermore, after applying an electric field to it, multi-domain texture can be obtained as shown in Fig. 2(b). The transmittance in Fig. 2(b) is 40% of transmittance under parallel nicols.

Measured viewing angle characteristics of the typical polymer-stabilized VA-LC cell are shown in Fig. 3. The characteristic in Fig. 3(a) is similar to a typical VA viewing characteristic under crossed-nicols. Figure 3(b) shows a nearly-isotropic characteristic and it is caused by the multi domain texture. We could confirm the basic operation as shown in Fig. 1.

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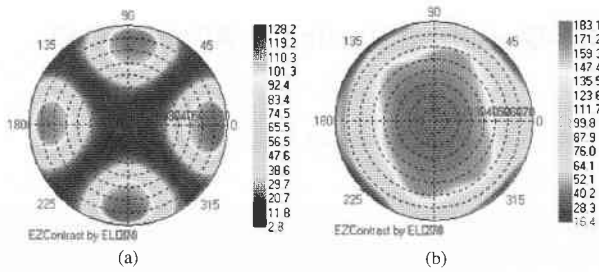


Fig. 3. (Color online) Viewing angle characteristics of a typical polymer-stabilized VA-LC cell (cell gap: 10 μm): (a) $V = 0$ V, (b) $V = 10$ V.

Response behaviors for conventional (100% nematic) and polymer-stabilized (95% nematic/5% polymer) VA cells were examined and these results at room temperature are shown in Fig. 4. At room temperature, there was no

remarkable difference between both samples. On the other hand, measurement results at -20°C are shown in Fig. 5, the polymer-network induces from 143 ms to 82 ms improvement in fall time. To clarify local response for each areas, high-speed camera observation has been carried out and it reveals that large LC droplets still degrade response time.

4. Polymerization Condition and Low Temperature Response

Based on the above camera observation, we tried to obtain smaller LC domain samples. The polymerization conditions of the LC/monomer-mixture were reexamined.

Figure 6 shows the micrographs of the polymer-stabilized VA-LC cell textures under crossed-nicols at 10 V. In the case of polymerization temperature of 41°C , we have large texture samples in any UV radiation conditions. In them, LC droplets over 50 μm can be found. On the other hand, in the

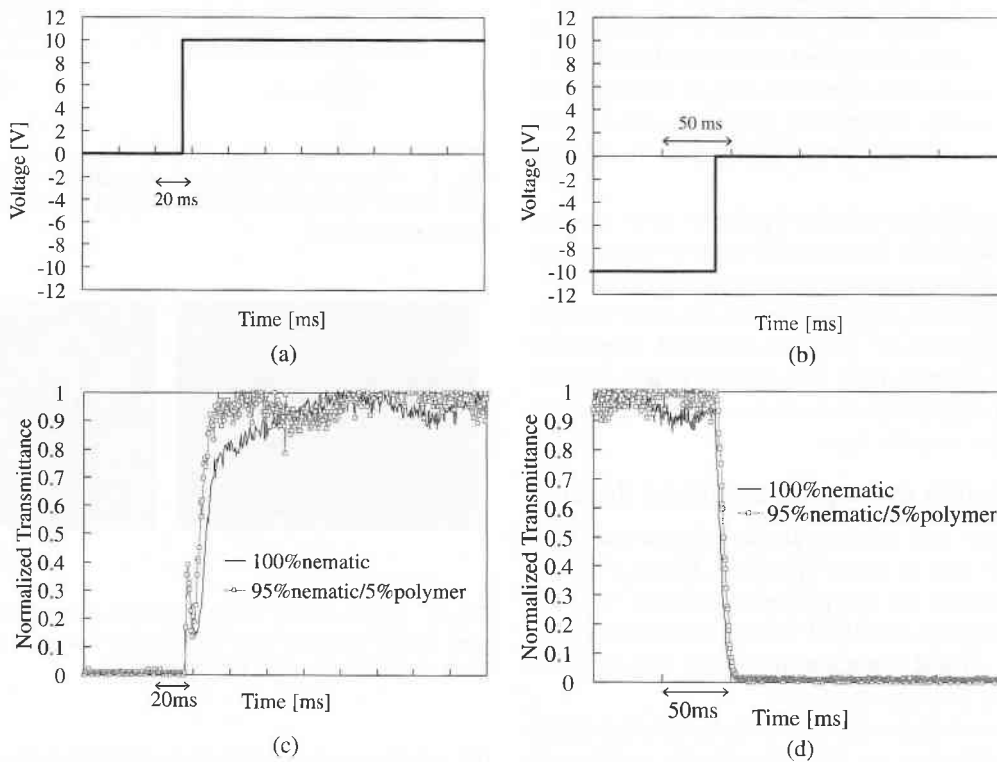


Fig. 4. (Color online) Response of the typical polymer-stabilized VA-LC cells (cell gap: 3 μm) at room temperature: (a) waveform of applied voltage in raise time, (b) waveform of applied voltage in fall time, (c) raise time, and (d) fall time.

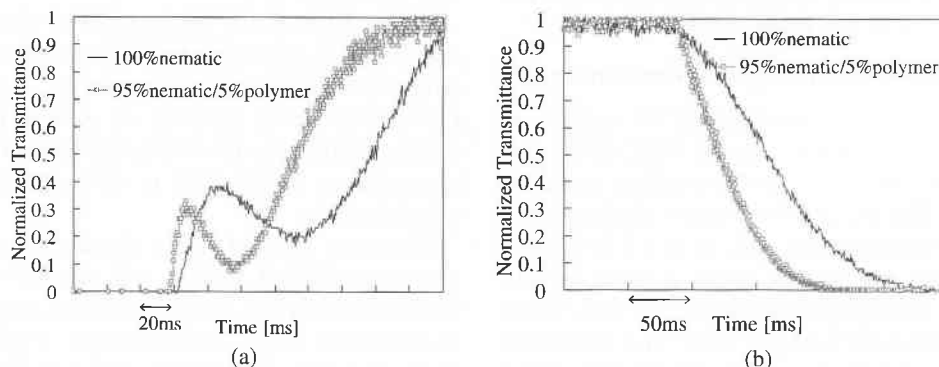


Fig. 5. (Color online) Response of the typical polymer-stabilized VA-LC cell (cell gap: 3 μm) at -20°C . Applied voltage waveforms are shown in Fig. 4.

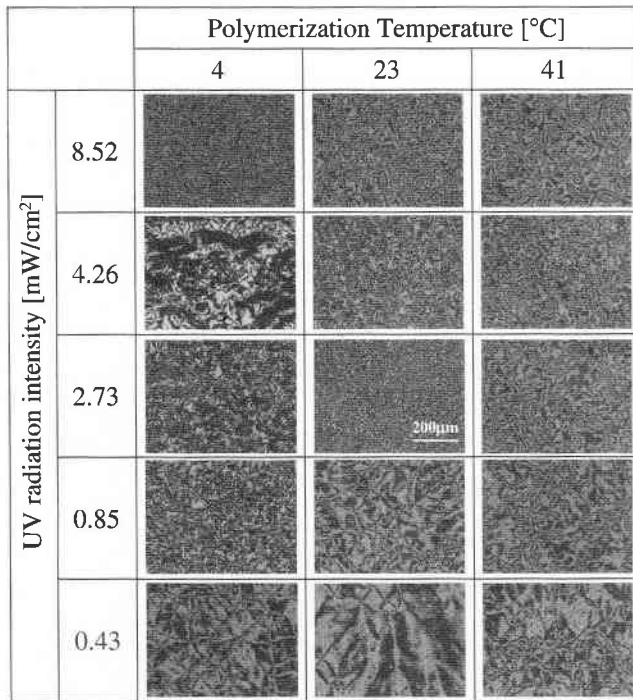


Fig. 6. The micrographs of the polymer-stabilized VA-LC cells between crossed-nicols (cell gap: 3 μm) at 10 V. Polymerization time has extended to 20 min.

condition of polymerization temperature of 23 $^{\circ}\text{C}$ and 4 $^{\circ}\text{C}$, the LC domain has the smallest size (below 25 μm) at 2.73 mW/cm^2 .

Figure 7 shows fall time at -20°C for the polymer-stabilized VA samples. Under conditions of UV radiation intensity of 2.73 mW/cm^2 , and polymerization temperature of 4 $^{\circ}\text{C}$ and 23 $^{\circ}\text{C}$, the polymer-network induces from 143 ms to 31 ms improvement and from 143 ms to 40 ms improvement in fall time, respectively. On the other hand, the fall time of the large LC domain size cells under polymerization temperature of 41 $^{\circ}\text{C}$ tended to slow down. The LC domain size really does affect the fall time at low temperature.

5. Discussion

Through the above experiments, we confirmed that the fine texture of the LC/polymer composition could improve fall time at low temperature. The LC phase is separated to fine sections by the fine polymer dispersion. It is believed that the fine texture makes polymer network force to the LC more effective and it makes the LC operation faster. Especially, this improvement of fall time is remarkable at low temperature.

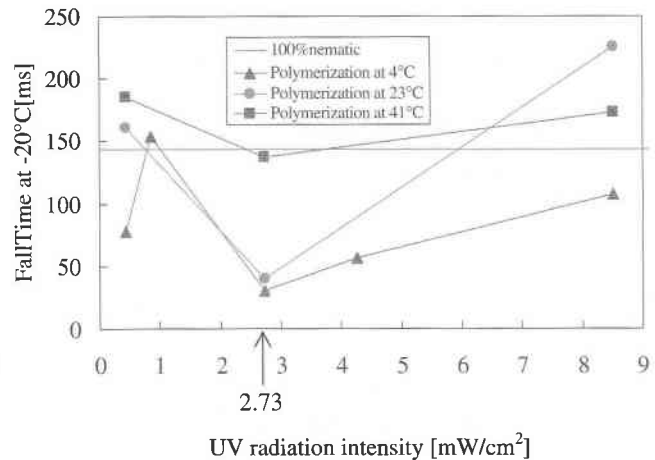


Fig. 7. (Color online) Fall time of the polymer-stabilized VA-LC cells (cell gap: 3 μm) at -20°C .

In the polymerization condition, it is important to make the polymerization progressed sufficiently, and to make it lead a liquid crystalline monomer to transform a polymer. As shown in Fig. 6, low intensity cured samples give coarse texture. However, it is believed that temperature accelerates phase separation action and LC droplet tends to grow. Naturally, additive amount of monomer is an important parameter for the polymerization of LC and monomer. However, an operation voltage of polymer-stabilized VA cell is increased with increasing the polymer content. Therefore, practical additive amount of monomer is a few percent.

6. Conclusions

We proposed polymer stabilized VA-LCD for improving fall time at low temperature. Polymerization conditions include polymerization time, UV radiation intensity and polymerization temperature. In this study, we found the favorable polymerization conditions of the LC and polymer and succeed fast response polymer-stabilized VA-LCD at -20°C . In this sample, the fall time is improved by from 143 ms to 31 ms.

- 1) M. J. Escuti, C. C. Bowley, G. P. Crawford, and S. Žumer: Appl. Phys. Lett. **75** (1999) 3264.
- 2) G. A. Held, S.-C. A. Lien, and D. Y. Yoon: U.S. Patent 6177972 (1999).
- 3) S. Kamata, H. Furue, H. Sato, H. Kikuchi, and H. Fujikake: 20th Japanese Liquid Crystal Society Round-Table Discussion, 2008, PA53 [in Japanese].
- 4) K.-H. Kim, J.-I. Baek, J. C. Kim, and T.-H. Yoon: Proc. IDW'08, 2008, p. 1555.
- 5) H. Ren, Y. H. Lin, C. H. Wen, and S. T. Wu: Appl. Phys. Lett. **87** (2005) 191106.