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Fast response time Patternless Vertical Alignment Mode with Infinite Domains Using Reactive Mesogen

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We proposed patternless vertical alignment (VA) mode with infinite domains using delta shaped electrode structure. Alignment layer was obtained by UV curable reactive mesogen (RM) which is polymerized along the LC direction on surfaces for memorizing switching directions of LCs. Therefore, we can achieve infinite domains and fast response time and the transmittance are improved using optical modifications.

1. Introduction

The demand for small-sized flat panel display such as mobile phone has been increased as mobility of information play an important role in our society. Because of its portable characteristics, uniform image quality according to the viewing direction is important characteristics in mobile LCD. Various methods have been proposed to get wider viewing angle such as micro rubbing [1], photo-alignment [2] and using fringe field by changing the electrode structures. Among them, electrode patterning method is most popular method in commercial product by its high efficiency and alignment stability.

Various LC modes have been proposed such as in-plain switching (IPS), fringe-field switching (FFS), multi-domain vertical alignment (MVA), and patterned vertical alignment (PVA) [3-12]. Though modes have multi-domains of LC molecule for wide viewing angle, there are still some other problems. They have some difficulties such as etching processes for patterning the each substrates, accurate rubbing process, passivation layers and precise assembling between two substrates. And also, they cannot obtain the omni-directional LC alignment over all area because of limited numbers of LC domains. To overcome those problems, in our previous work, we proposed azimuthally continuous nematic domain (ACD) [13] for omni-directional LC alignment using slits and circular shaped electrodes. However, it needs additional fabrication process due to patterns on both top and bottom substrates and slow response time with reorientation process.

In this paper, we proposed patternless vertical alignment (VA) mode with infinite domains using delta shaped electrode patterns in pixel electrode. To enhance response time, we used polymerized reactive mesogen (RMs) on surfaces and enhanced transmittance by optical modifications.

2. Experiments

Figure 1 shows the electrode structures of the conventional and our proposed VA mode. In conventional structure, there are circular shaped slits in common electrode and square shaped electrodes in pixel electrode. Initially, both two modes, LC molecules are aligned in perpendicular direction to the substrate. At field on state, since the slits of the two substrates are arranged alternatively, the oblique fields are induced in conventional case. Therefore, it can define LC molecules' falling direction when the external field induced to the sample.

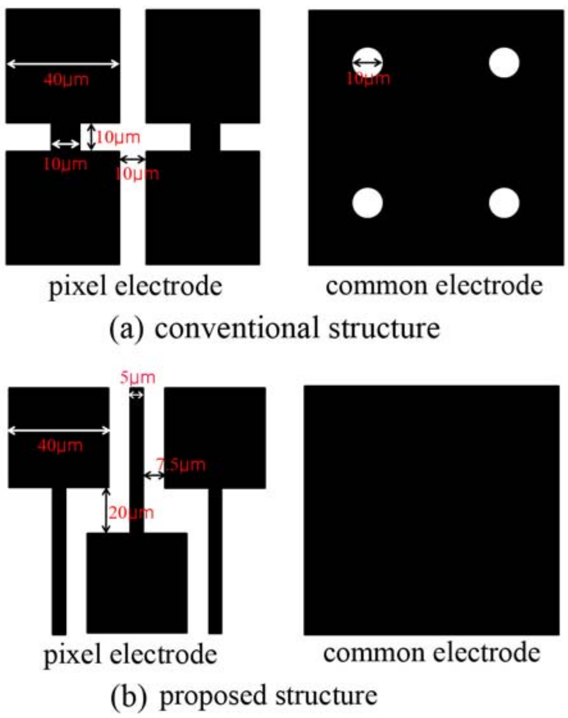

Figure 1. Electrode structures of (a) conventional and (b) proposed LCD modes.

Also, it makes spiral defect structures (m=±1) in each square shaped electrode of pixel electrode. So, three

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spiral defects are generated uniformly in one pixel. But conventional structure has complicated fabrication process because of circular shaped region in common electrode. If patterned regions in electrode are removed and ITO glass without pattern is used for substrate, fabrication process could be simple and lower the manufacturing cost. However, if circular shaped patterns in common electrode are removed, LC directors are propagated from edge of the pixel and collide at the center of the square and the reorientation process will occur unlike the conventional PVA mode.

Recently, Kim et al. reported the surface-controlled patterned vertical alignment mode to stabilize the LC directors with RMs for enhancing the response time [12]. Therefore, we proposed patternless VA mode with RMs for removing the reorientation process caused by the one side electrode pattern. In pixel electrode, there are square shaped electrodes which are designed like delta structures and connected at regular intervals. It can generate oblique field without slits.

For fabricating patternless VA mode sample, both substrates were spin coated with the mixtures of vertical alignment material AL1H659 (from JSR) and reactive mesogen (RM 257 from Merck) with proper weight ratio. The gap of the sandwiched cell was maintained with 3.0μm glass spacer and the cell was filled with LC (MLC-6608, Δε=-4.2, from Merck). With no voltage, LC molecules were aligned vertically by vertical material and RM monomers within vertical material were distributed randomly on the surface. When applied voltage was above threshold voltage, the LC molecules fell down omni-directionally and the RM monomers aligned along the LC molecules. After a few times later until the LC directors were stabilized enough, the cell was exposed to UV light and then the RM monomers were polymerized on the surface with certain polar and azimuthal direction along the LC molecules which were controlled by electric field.

3. Results and Conclusions

Figure 2 shows schematic diagram for optical modification and microscopic textures of proposed LC cell. As shown in the Fig. 2(b), spiral textures deteriorate the transmittance and we used the simple optical modifications. In experiment, we used the two crossed quarter wave plates (QWP) between the LC cell and two polarizers. The optic axes of the two QWPs are 45° and -45° with respect to the optic axes of polarizers as shown in Fig. 2(a), respectively. The spiral structures with QWPs, the spiral textures are disappeared and the transmittance is enhanced as shown in Fig. 2(c).

Through simple calculation was used by using Jones matrix to consider the increased transmittance due to adding two QWPs. It can also simply identify the polarization state of the light after passing the optical components using Poincare spheres. First, optical state of the incident light is change to the linearly polarized light after passing through the polarizer whose optic axis is parallel to the x-axis. And then, linearly polarized light is changed to circularly polarized light by QWP. Then, handedness of the circularly polarized light is changed due to the retardation of the LC cell. And finally, this light state are changed second QWP to the linearly polarized light and spiral defect structures are optically removed.

$$E_{out} = \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \cos\left(-\frac{\pi}{4}\right) & -\sin\left(-\frac{\pi}{4}\right) \\ \sin\left(-\frac{\pi}{4}\right) & \cos\left(-\frac{\pi}{4}\right) \end{pmatrix} \begin{pmatrix} e^{-\frac{\pi}{4}i} & 0 \\ 0 & e^{-\frac{\pi}{4}i} \end{pmatrix}$$

$$\begin{pmatrix} \cos\left(-\frac{\pi}{4}\right) & \sin\left(-\frac{\pi}{4}\right) \\ -\sin\left(-\frac{\pi}{4}\right) & \cos\left(-\frac{\pi}{4}\right) \end{pmatrix} \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} e^{-\frac{\pi}{2}i} & 0 \\ 0 & e^{\frac{\pi}{2}i} \end{pmatrix}$$

$$\begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} \cos\left(\frac{\pi}{4}\right) & -\sin\left(\frac{\pi}{4}\right) \\ \sin\left(\frac{\pi}{4}\right) & \cos\left(\frac{\pi}{4}\right) \end{pmatrix} \begin{pmatrix} e^{-\frac{\pi}{4}i} & 0 \\ 0 & e^{\frac{\pi}{4}i} \end{pmatrix}$$

$$\begin{pmatrix} \cos\left(\frac{\pi}{4}\right) & \sin\left(\frac{\pi}{4}\right) \\ -\sin\left(\frac{\pi}{4}\right) & \cos\left(\frac{\pi}{4}\right) \end{pmatrix} \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$T = \left(\frac{1}{\sqrt{2}}\right)^2 (\sin(2\theta) + i\cos(2\theta))(\sin(2\theta) - i\cos(2\theta))$$
$$= \frac{1}{2}$$

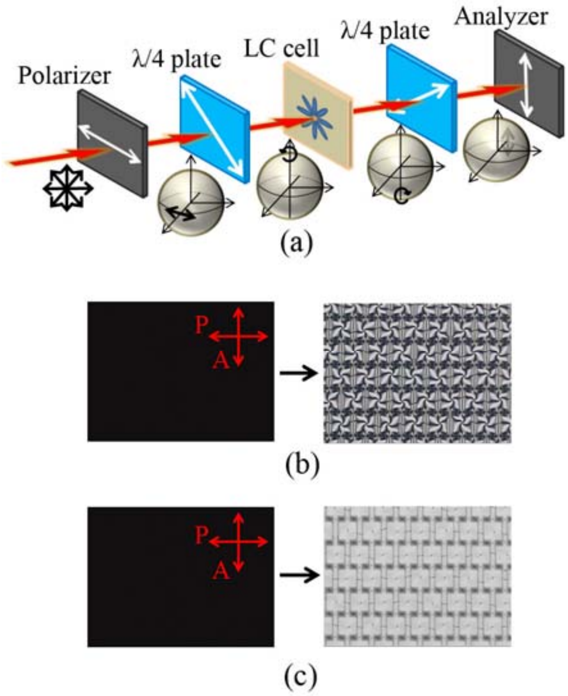

Figure 2. Schematic diagram of optical components for patternless VA mode cell with Poincare Spheres and textures of the cell under crossed polarizers (b) without λ/4 plates and (c) λ/4 plates.

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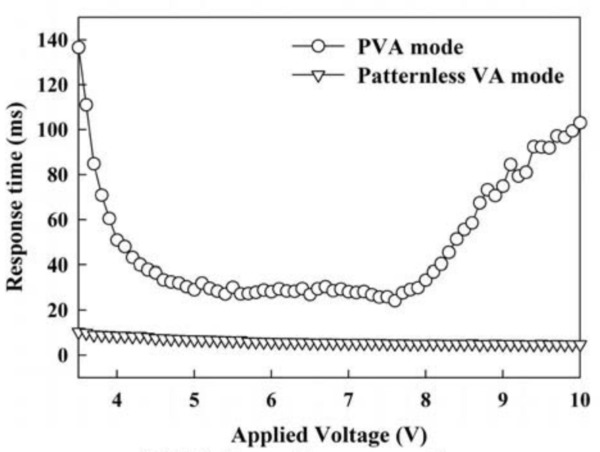
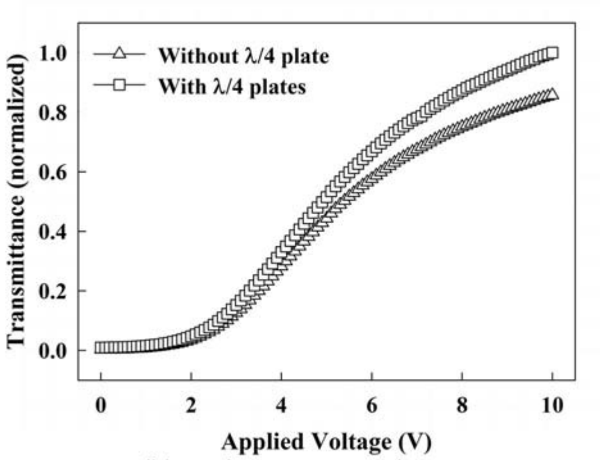


(a) Voltage-Response time



(b) Voltage-Transmittance

Figure 3. Electro-optical characteristics of (a) voltage-response time curve for PVA mode and patternless VA mode and (b) voltage-transmittance curve for patternless VA with and without λ/4 plates.

Figure 3 shows the response time characteristics of conventional PVA mode and proposed patternless VA mode as a function of the applied voltage. In conventional PVA mode cell, the response time was over 100 msec at low (4V) and high (10V) voltage because of the propagation of LC molecules and the slow reorientation process. However, in proposed patternless VA mode cell, the response time was about 5.4 msec with driving voltage (7V), similar to SC-PVA mode cell [12]. So, if RM monomers were polymerized at the UV curing process, we can get enhanced response time (about 10msec) due to memorizing the falling direction of LC molecules. And we can get increased transmittance (about 17%) using λ/4 plates due to removing the spiral defects.

4. Acknowledgements

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