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Inverse twist nematic mode on stacked alignment layer method

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We propose the inverse twisted nematic mode on stacked alignment layer method. By using double layer structure, we can obtain not only initially vertical alignment state but also the enhanced azimuthal anchoring energy and represent twist structure when the field on state.

1. Introduction

Liquid crystal display (LCD) is the mostly received devices of the flat panel display market by high definition, applicability to the large sized area and reproducibility. Various LC modes such as twisted nematic (TN), vertical alignment (VA), in-plane switching (IPS) modes were introduced [1-3]. And among them, the (TN) mode is widely adopted in commercial LCD devices by its high transmittance and aperture ratio and the fast response time characteristics. However, TN mode has intrinsically low black level characteristics because the LC molecules near the surface are not fully arranged parallel to the field direction due to hard anchoring energy of the surface. Therefore, to overcome this problem, Patel reported the inverse twisted nematic (ITN) mode [4]. In ITN mode, LCs are aligned in vertical direction by using conventional vertical layer and the LCs are twisted when the external field induced to the sample. However, azimuthal anchoring energy of the vertical alignment layer is reported extremely too small to generate the TN structures, and therefore ITN mode uses chiral dopant due to the weak azimuthal anchoring energy of the vertical alignment layer [5]. If we can control the azimuthal anchoring energy of the vertical alignment layer, inverse TN structure will be obtained easily without chiral dopant. Recently, Kim et al. report that the pretilt angle is controlled by stacking of alignment material [6].

In this paper, we propose the inverse twisted nematic (ITN) mode on stacked alignment layer without chiral dopant. By strengthen the azimuthal anchoring energy, ITN structures are easily obtained and the response time was improved due to the defined azimuthal directions.

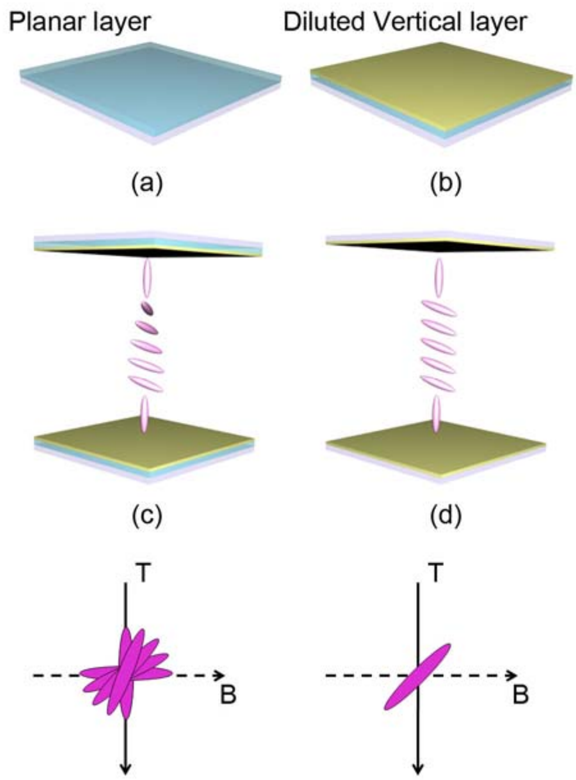

Fig. 1 The schematic diagrams of the fabrication processes of (a) planar alignment layer and (b) stacked alignment layer. And the configurations of the LC molecules of (c) conventional ITN with chiral dopant and proposed ITN mode and (d) conventional ITN mode without chiral dopant at field on state.

2. Experiments

For fabricating the LC sample, we cleaned the indium-tin oxide (ITO) glass using the mucasol mixed in di-ionized water. For comparision, we prepared the three samples for conventional ITN sample without chiral dopant, conventional ITN

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sample with dopant and proposed ITN. For conventional ITN sample, the vertical alignment layer was obtained and LCs with chiral dopant were injected selectively. The used chiral dopant was R-811 (E. Merck) for determining the twisting direction. For proposed ITN modes, the first layer was obtained with planar alignment material by using the spin-coating method and the cell was baked on the hot plate to fully imidize [Fig. 1(a)]. Then the diluted vertical alignment material was spin-coated onto the planar alignment layer as a second layer and the baking process was followed [Fig. 1(b)]. After stacking the double layer, two substrates were rubbed in perpendicular directions and assembled with glass spacers about 5 um. Then, the LCs (MLC-6608 from Merck) with negative dielectric constant was injected at isotropic phase without chiral dopant. Optical microscopic textures were obtained with the polarizing microscope (Eclipse E600 POL, Nikon).

3. Results

The arrangement of the LC molecules with the external field is described in fig. 1(c), (d). It was reported that the azimuthal anchoring energy is varying from 10-5 to 10-9 N/m by changing the pretilt angle from 1.6º to 87.2º [7]. And the elastic deformation energy of the LC molecules are about 10-6 N/m. Therefore, in case of the conventional ITN mode without chiral dopant as shown in fig. 1(d), LCs do not generate the TN structures when the external field is applied to the sample. That is because the azimuthal anchoring energy of the surface is not enough to generate the TN structures. Figure 2(c) shows the schematic diagrams of the ITN mode with chiral dopant and proposed ITN mode. In case of the conventional ITN mode, pitch was selected by using chiral dopant with d/p = 0.25. With chiral dopant, LCs can generate the twist structures in spite of the weak surface anchoring energy. However, by stacking the two alignment layer, twist structure can be generated without chiral dopant.

Figure 2 shows the microscopic textures of the various fabricated samples. At initial state, for all cases, LCs are aligned perfectly vertical to the surface and the optical retardation can be zero at normal directions.

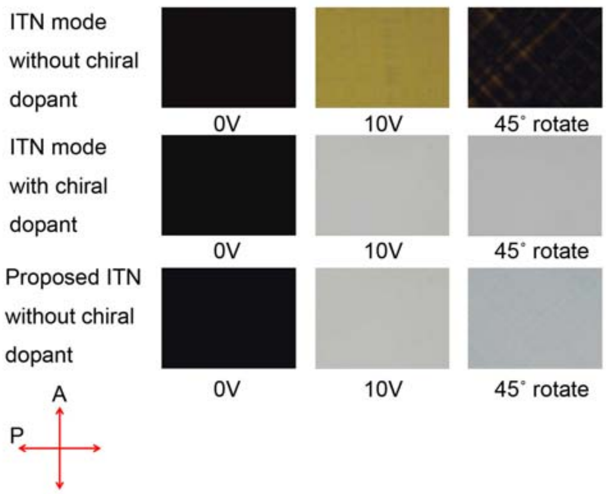

Fig. 2 The polarization optical microscopic textures of various fabricated sample conditions. The arrows inside the figure indicate the optical axis of the polarizers.

Therefore, light passing through the LC sample are not experienced the phase retardation and normally black state can be achieved under the crossed polarizers. However, when external field induced to the sample, the optical effect can be changed. In case of ITN mode without chiral dopant, LC molecules do not generate the TN structures as shown in fig. 2. The transmittance characteristics of the electrically controlled birefringence (ECB) mode under the crossed polarizers are expressed as a function of the angle between the polarizer and LCs molecule direction. If the optic axis of the LC molecule is parallel to that of polarizer, it represents black state as shown in fig. 2. However, in ITN mode with chiral dopant and proposed ITN modes which has the TN structures, transmittance are under the crossed polarizers are expressed as

$$T = con^2\beta + \frac{\alpha^2}{1+\alpha^2}\cos^2(2\theta)\sin^2\beta$$

where α is $\Gamma/2\Phi$ and β is $\Phi\sqrt{1+\alpha^2}$.

Therefore, the external field which is larger than the threshold voltage is applied to the sample, two cases at bottom show the white characteristic regardless to the rotation angle (45º). And also, proposed ITN sample represent the same effect compare to the ITN mode with chiral dopant.

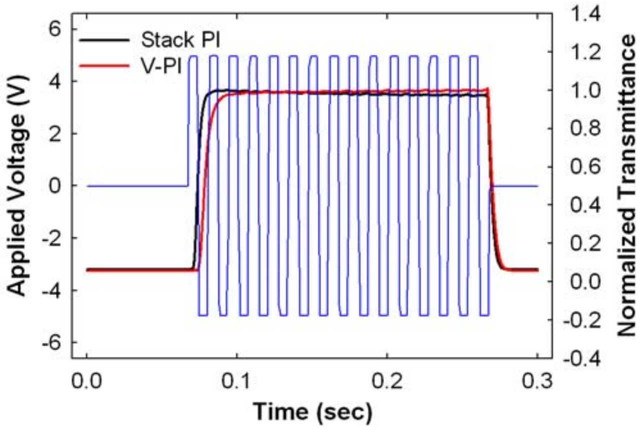

Fig. 3 Measured response time characteristics of the conventional ITN and proposed ITN mode.

Figure 3 shows the measured reponse time characteristics of the conventional ITN and proposed ITN mode. External field with 5V at 1 kHz square wave form was applied to each sample. The rising time of the conventional ITN sample was 16 msec and proposed ITN sample was 10 msec. The falling directions can defined by the increased azimuthal anchoring energy. It can make it possible to enhance the response time about 60 % in ITN structures. And also, this value is comparable to the conventional response time of the TN mode so called fast response device.

Figure 4 shows the measured voltage transmittance characteristics of the conventional ITN and proposed ITN mode. Proposed ITN modes has the low threshold voltage and it shows the low driving characteristics. In our thought, anchoring strength of the planar layer can devote to the shift of the threshold voltage. And the contrast ratio was about 700 : 1 and it is very high value compare to that of the normally white TN mode (500 : 1) in labatory level. In our proposed ITN mode, it has the high contrast ratio and fast response time characteristics without chiral dopant. Therefre, it can be applied to the four-domain TN devices which has the different twist direction [8].

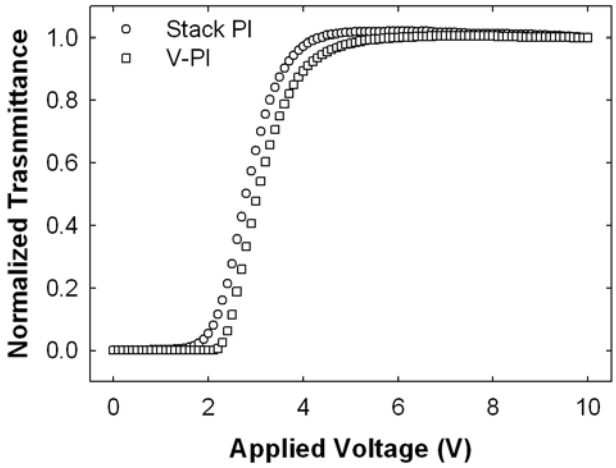

Fig 4. Measured voltage transmittance characteristics of the conventional ITN and proposed ITN mode.

4. CONCLUSION

We realize the ITN mode by stacking the two different alignment materials without chiral dopant in LC layer. By using stacking structures, we can achieve the excellent black state at initial state and the twist structures at on-state. And it also can be substitute the conventional TN LC modes by its fast response time characteristics. Furthermore, it can be applied to the photo alignment region by using the stacking alignment method and multi-domain structure can be realized to compensate the viewing angle.

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