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Surface Control with Reactive Mesogen for Fast Switching Four-Domain Twisted Nematic mode

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We proposed a method to improve response time of the four-domain twisted nematic (TN) mode through surface modification using the mixture of diluted vertical alignment (VA) layer and UV curable reactive mesogen (RM). In our structure, the RMs enhance the surface anchoring energy and freeze the twist senses in each sub-pixels. As a result, we can obtain fast switching four-domain TN structure.

1. Introduction

In recent years, liquid crystal displays (LCDs) have been widely used in practical applications such as notebooks, tablet PCs, cellular phones and digital cameras. Many kinds of LCD modes have been reported such as the twisted nematic (TN) mode [1], in-plane switching (IPS) mode [2], optically compensated bend (OCB) mode [3], fringe field switching (FFS) mode [4] and Patterned vertical alignment (PVA) mode [5] to improve the properties of LCDs. However, up to now we still could not find a perfect LCD mode. There is bound to have a trade-off problem among different kinds of performance and choose the most appropriate one. To overcome these obstacles, many researchers have primarily focused on the typical problems of LCDs such as slow response time and narrow and non-uniform viewing angle characteristic and so on. Particularly, it is well known that TN mode is widely researched in order to find a solution. To overcome asymmetric viewing angle of TN mode, four-domain TN structure was suggested and the improvement of the viewing angle is explicitly visible [6-7]. However, it has a drawback such as slow response time which is not fast enough to realize high quality moving picture because this structure has different twist sense in one pixel without chiral dopant. Thus, the four-domain TN structure is not suitable for realizing applications to need a fast response although it has superior viewing angle characteristics.

In this paper, we proposed a method to improve response time of the four-domain TN mode through surface modification using the mixture of diluted VA layer and UV curable RM. From this method, we could improve the response time in comparison with conventional four-domain TN mode.

2. Experimental

Figure 1 shows the layer structure of the proposed four-domain TN mode base on the surface modification using RM. It needs to high pre-tilt angle to obtain stable four-domain structure [6] and we realized the high pre-tilt angle by using stacked alignment layer [8]. Also, we used RM monomers in the diluted vertical alignment layer to improve response time. We spin coated the planar alignment layer (SE7492 from Nissan) on the indium-tin-oxide (ITO) coated glass and then spin coated the diluted vertical alignment layer that consists of 3.17 wt% vertical alignment layer (AL-1H659 from JSR), 95.83 wt% solvent (n-methyl-pyrrolidone : buthyrolactone : butoxyethanol = 3:4:3), 1wt% RM monomers and 0.2wt% photo-initiator (IRGACURE 651, Ciba chemical) which can enhance the photo reactivity for a long time on the un-rubbed planar alignment layer. After polyimide (PI) coating step, soft baked at 100 ^{o}C for 10 min, followed by curing for imidization at 180 ^{o}C for 1 hrs. And then, we conducted reverse rubbing process to fabricate four-domain TN structure by using shadow rubbing mask (SUS, 150 μm spacing, 30 μm thickness). To fabricated four-domain TN structure, glasses assembled perpendicular to each other in the same way as a conventional single domain TN cell. For the electro-optical characteristic measurement, 5 μm test cell was prepared and filled with nematic LC (from Merck, $\Delta\varepsilon = 7.8$, $\Delta n = 0.1114$). It satisfies the first maximum condition given by the Gooch and Tarry's equation [9]. And then, we carried out UV curing process under critical applied voltage to polymerize the RM monomers [10].

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Figure 1. The schematic diagram of the proposed stacked alignment layer using RM.

3. Results and discussion

The four-domain TN structure needs to high pre-tilt angle to obtain stable structure. According to its mathematical model [6], the minimum pre-tilt angle of four-domain TN structure is 18.6^{o} in our cell parameters. The tested cell's pre-tilt angle in our stacked alignment system is 21^{o} and it is enough to obtain stable four-domain structure. To measure the pre-tilt angle, we used the polarizer rotation method [11]. This method can be used for the accurate and convenient measurement of pre-tilt angle without the restriction on measurable range. Thus, we can measure the pre-tilt angle of whole range.

Figure 2 shows micro-texture images of our four-domain TN cell using stacked alignment layer under polarized microscope. As you can see, the four-domain structure maintained even at the 0 V due to its high pre-tilt angle. Figure 2 (b) shows different twist senses in four-domain TN structure. In other words, the four-domain structure has two right handed sub-pixels and two left handed sub-pixels [6]. As a result, we can obtain good viewing angle characteristics.

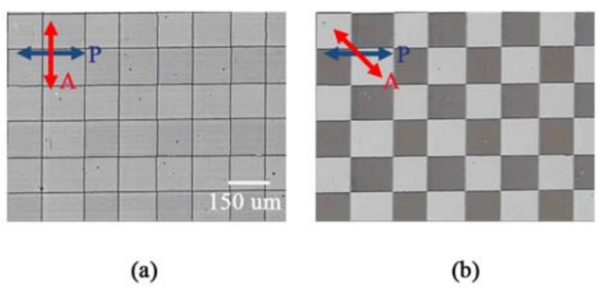

Figure 2. Textures of the produced four-domain TN structure using RM. (a) under 90^{o} crossed polarizer and analyzer condition, (b) 45^{o} crossed polarizer and analyzer condition.

In TN mode and electrically controlled birefringence (ECB) mode, the back-flow slows the relaxation of the liquid crystal director from the distorted state under an applied field to the undistorted at zero field. Conventional four-domain TN structure occurs the back-flow phenomenon severely compare with mono domain TN cell because it has two kind of twist senses in one pixel. However, our proposed four-domain TN structure improved back-flow phenomenon in comparison with conventional the four-domain TN structure because the polymerized RMs on the alignment surface memorize twist directions at each sub-pixels. As shown in figure 3, the back-flow phenomenon of RM adding four-domain TN cell improved compare with conventional four-domain TN cell.

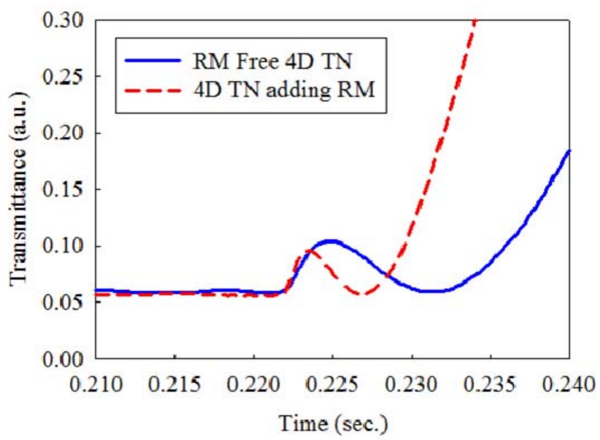

Figure 3. Back-flow phenomenon characteristics of the four-domain TN cell.

Figure 4 shows the relaxation time of the conventional and RM adding four-domain TN structure. The response time dramatically improved up to 50% in comparison with conventional four-domain TN cell. On relaxation time showing, the polymerized RM in the diluted vertical PI along the LC directors enhanced the surface anchoring energy. The falling times of the conventional and RM adding four-domain TN cells are measured to be about 50ms and 25ms at 10V, respectively.

4. Conclusion

We proposed a method to improve response time of the four-domain TN mode through surface modification using the mixture of diluted VA layer and UV curable RM. The polymerized RM network on the surface enhances the surface anchoring

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energy and freezes the twist directions in each sub-pixels of the four-domain TN cell. As a result, the response time characteristics improved dramatically up to 50% in comparison with conventional four-domain TN cell, especially in falling time.

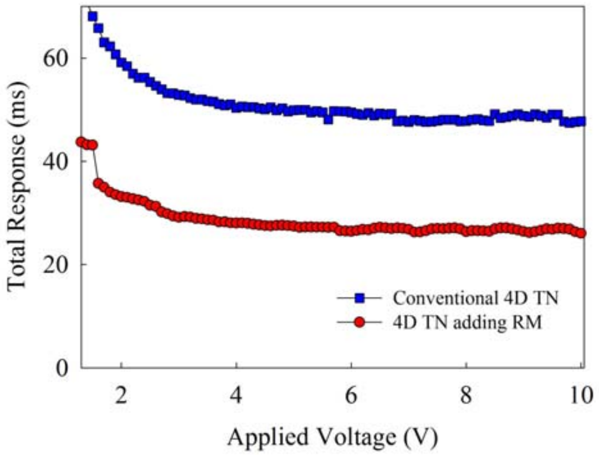

Figure 4. Response time characteristics of conventional four-domain TN cell and RM adding four-domain TN cell.

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