Fast in-plane switching of an asymmetrically-anchored liquid crystal cell by vertical triggering.

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ABSTRACT

We demonstrate an asymmetrically-anchored liquid crystal (LC) cell by vertical triggering. We confirmed that the fabricated LC cell can achieve sub-millisecond turn-off time while maintaining the high transmittance of an asymmetrically-anchored cell.

1 INTRODUCTION

A liquid crystal display (LCD) has been widely used for TVs, monitors, and smartphones. Among the liquid crystal (LC) modes for display applications, fringe-field switching (FFS) mode has been one of the most influential LC modes because of its wide viewing angle and small color shift [1, 2]. However, it has relatively low transmittance and slow response time compared with other LC modes. For a high-performance LCD, several studies have been reported to increase the transmittance and to reduce the response time, but few kinds of research can be used to improve them at the same time.

We demonstrate an asymmetrically-anchored LC cell for high transmittance and fast switching at the same time. The LC cell's bottom substrate has anchoring energy different from that of the top substrate so that LC molecules can be twisted as in a twisted-nematic cell and exhibit a high transmittance. To achieve a fast response time, LC cell is driven with a vertical trigger pulse. We believe that the introduced method can be applied for a high-performance display in the future.

2 DEVICE FABRICATION

We also fabricated an asymmetrically-anchored LC cell. We used poly (methyl methacrylate) (PMMA, Sigma-Aldrich, USA) and commercial polyimide alignment material to realize an asymmetrical surface anchoring condition [3, 4]. For the three-terminal electrodes, which were introduced to apply a vertical trigger pulse as well as the in-plane field, we used an ITO-coated glass as the top substrate and interdigitated electrodes for the bottom substrate [5, 6]. The rubbing angle of LC molecules was chosen to be 10° with respect to the interdigitated electrodes, and the cell gap was 4.2 μm. We injected the positive LC mixture into an empty cell by capillary action at room temperature.

We also fabricated a symmetrically-anchored LC cell to compare its electro-optical characteristics with those of an asymmetrically-anchored cell. To fabricate a symmetrically anchored LC cell, we coated commercial polyimide alignment material used for an asymmetrically anchored LC cell on each substrate. The cell gap of the symmetrically anchored cell was 3.7 μm. The LC mixture which was used for an asymmetrically-anchored LC cell was injected into an empty cell by capillary action at room temperature.

3 EXPERIMENTAL RESULTS

We measured the transmittance–voltage curves of the fabricated cells. The results are shown in Fig. 1. At the dark state, the transmittance of an asymmetrically-anchored LC cell was 0.04%, almost the same as that of a symmetrically-anchored LC cell, which was 0.03%. At the bright state, the transmittance of an asymmetrically-anchored LC cell was 28.4%, 1.3 times higher than that of a symmetrically-anchored LC cell, which was 22.2%.

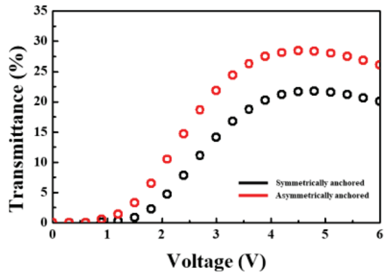


Fig. 1 Voltage-Transmittance curve of the fabricated LC cell

We also investigated the dynamic switching behavior of the fabricated LC cells. We measured the turn-on time of the fabricated LC cells without applying a vertical trigger pulse. As shown in Fig. 2, the measured turn-on time of an asymmetrically-anchored LC cell was 7.85 ms, slightly faster than that of a symmetrically-anchored LC cell, 8.71 ms. When the vertical trigger pulse was applied to the fabricated LC cell, the measured turn-on times of the asymmetrically and symmetrically-anchored LC cells were 8.78 and 7.85 ms, respectively.

The measured turn-off time is shown in Fig. 3. Differently from the turn-on time, the vertical trigger pulse brought abut a marked difference. When a vertical trigger pulse was not applied, the measured turn-off time of an asymmetrically-anchored LC cell was 28.46 ms, much slower than that of a symmetrically-anchored LC cell, 7.55 ms. On the other hand, when a vertical trigger pulse was applied to the fabricated LC cell, the measured turn-on time of the asymmetrically and symmetrically-anchored LC cell was 0.64 and 0.39 ms, respectively. It was confirmed that a vertical trigger pulse made it possible the sub-millisecond switching of an asymmetrically-anchored LC cell.

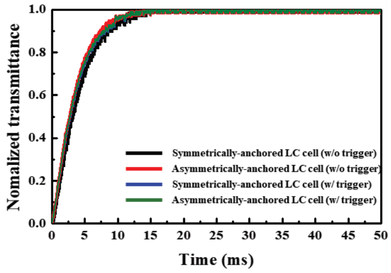


Fig. 2 Turn-on time of the fabricated LC cell

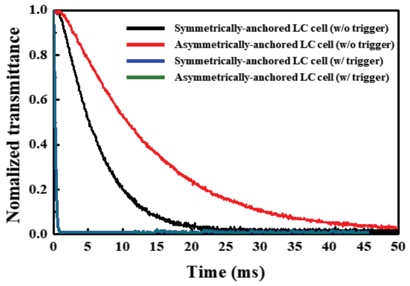
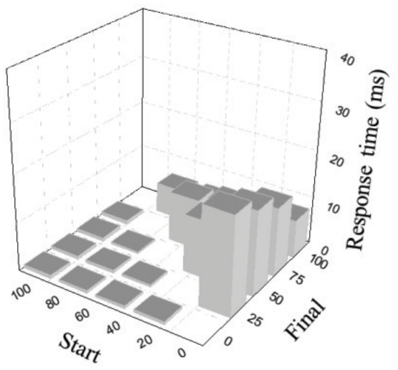


Fig. 3 Turn-off time of the fabricated LC cell



%		Final level				
		0	25	50	75	100
Start level	0		20.56	17.62	14.26	7.85
	25	0.57		12.12	11.87	7.21
	50	0.51	0.50		10.55	6.42
	75	0.52	0.48	0.47		6.35
	100	0.64	0.68	0.70	0.69	

Fig. 4 Grey-to-grey response time of the asymmetrically-anchored LC cell

Finally, we measured the grey-to-grey (GTG) response time of the asymmetrically-anchored LC cell. Figure 4 shows the GTG response time of the asymmetrically-anchored LC cell driven with a vertical trigger pulse. From a high to low grey level switching, the slowest GTG response time was 0.69 ms. However, from a low to a high level switching, the slowest GTG response time was 20.56 ms. To reduce the GTG response time from a low to a high level, further studies would be necessary to employ the driving technique, such as the overdrive technique [7, 8].

4 CONCLUSIONS

We introduced an asymmetrically-anchored LC cell with a vertical trigger pulse to achieve high transmittance and fast switching. The transmittance of the fabricated LC cell was 1.3 times higher than that of a symmetrically anchored cell. We also confirmed that the fabricated LC cell exhibits sub-millisecond turn-off time and GTG response time from a high to a low level. Further studies on driving techniques are necessary to improve the GTG response time from a low to a high level. We hope this method will be used for display applications in the future.

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