Locked Super Homeotropic Liquid Crystal Mode with Wide Viewing Angle using patterned polymer

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Abstract

We have studied a liquid crystal (LC) mode, named locked super homeotropic (LSH), where the LCs aligned homeotropically are locked by surrounding walls such as cubic, hexagonal and cylinder. In the device, the vertically aligned LCs tilt down symmetrically around the center of the cell when a voltage is applied and thus it exhibits wide viewing angle. In addition, since the LCs is locked in micro domains the LCs do not flow to the bottom of the panel by gravity.

1. Objectives and Background

Recently, the replacement of Cathode Ray Tube (CRT) by Liquid Crystal Display (LCD) became a general tendency because research of many modes which have excellent characteristics has progressed briskly. One of the most useful LCD driving modes is twisted nematic (TN) mode[1, 2], because of simple driving mechanism, low operating voltage and high light efficiency. Also, LCD with TN mode has been dominant for an application of active matrix LCDs to notebooks and monitors which used under 17 inch. However, TN mode has demerits such as reversal gray scales, decreases of the contrast ratio, color shift, when it was seen from an oblique direction. So TN mode doesn't apply to adequate issue progressing large size nowadays. To overcome these problems, various techniques for improving TN mode has been proposed such as in-plane switching (IPS) mode[3,4], fringe field switching (FFS) mode[5-7], multi-domain vertical alignment (MVA) mode[8], axially symmetric aligned microcell (ASM)[9], advanced-super-view (ASV)[10] mode which have excellent viewing angle characteristics. Also, fast response time to realize perfectly moving screen have become major key point. However, various modes, introduced upper part, used to realize LCD panel of large size give rise to gravity mura because LCs flow to the bottom of the panel by gravity. ASM mode is driven by applying phase separation phenomenon from the mixture of liquid crystal and polymerizable resins and using the alignment strength of liquid crystal itself. In this method, the polymer walls are formed by UV irradiation in order to make the micro-cells of liquid crystal in each pixel. And the axially symmetric orientation of liquid crystal molecules is stabilized by the polymer wall. This mode has rubbing free, a wide viewing angle characteristic. However, ASM mode decreases voltage holding ratio (VHR) and causes to mura by existing LC droplet in polymer because the cell irradiates UV after injecting the mixture of liquid crystal and polymerizable resins. Conventional spacer process generated light leakage near spacers and impurities. So, nowadays, a post spacer is mainly used in a panel fabrication to keep a cell gap between top and bottom substrates.

So, in this paper, we will propose a new pixel structure using polymer wall and vertical alignment (VA) mode shown wide viewing angle characteristics, high contrast ratio. This LSH mode in which the polymer walls are patterned before the filling of the LC and the LCs are filling by one drop filling method. Therefore, LSH mode is possible to using panel of large size and overcome demerit of ASM mode. Also this LSH mode does not require ball or post types of the spacer, and rubbing process.

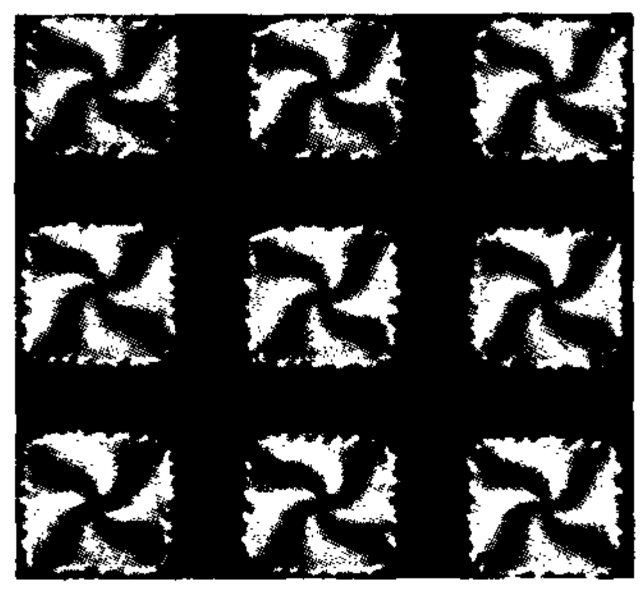
2. Results

For cell fabrications, firstly to form cell gap, polymer wall is patterned uniformly on bottom substrate by photo resist (PR) method using UV. PR method uses Negative PR (AZ CTP-100) and etches by developer (JSRPD523). Cell gap is 3.1 μm and the vertical alignment layer is coated on ITO-coated glass top and bottom substrates. The birefringence(Δn) of LC which has negative dielectric anisotropy is 0.11 and the cell retardation value is 0.34 μm.

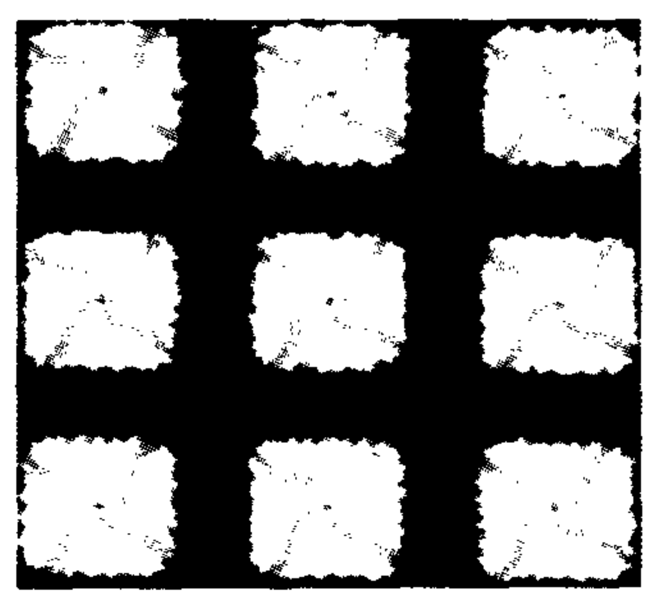
Fig. 1 shows optical microphotograph that polymer walls are patterned by UV irradiation on mask. The diameter of patterned area is 80 μm and distance between patterned area is 15 μm. In the absence of an electric field in this mode, the cell in LCs with negative dielectric anisotropy (-LC) are vertically aligned with a d/p ratio of about 0.19.

Fig. 1 The optical microphotograph that polymer walls are patterned by UV irradiation on mask.

We observed the cell under polarizing microscope by applying a square wave voltage of 60 Hz. Fig. 2 show optical microphotograph of the LSH cell when the transmittance is in (a) gray scale and (b) white state. Before applying a voltage, the cell shows a dark state but with bias voltage to grey level, the transmittance starts to occur. Interestingly, a pinwheel shape of dark texture appears, in which the transmittance in that area is lower than others and whose axes are coincident with the transmission axes of the crossed polarizers. The texture remains the same although the cell is rotated azimuthally by 360°. This indicates that the LC director orientation is not dependent on azimuthal angle, that is, it is axially symmetric aligned. With further increasing bias voltage, the darkness in a pinwheel-shaped texture weakens and the transmittance increases to white state, although the crossed textures still remain with increased transmittance. One noticeable thing is that a side of one pixel has irregularity because the plastic mask with low resolution is used. If changing the metal mask such as chrome mask, the LSH can have more regulated polymer wall. Further, this cell can have a pair of λ/4 retardation film on the front and the rear side of the cell to eliminate dark texture at gray-scale when applying voltage.



(a)



(b)

Fig. 2 Optical microphotograph of the LSH cell when transmittance is (a) 50%, (b) 100% in crossed polarizers.

Fig. 3 is mid-director profile of LSH mode. With bias voltage, the LCs tilts down likely 90° TN in a way that the mid-director directs in all azimuth directions. Consequently, the device exhibits wide viewing angle due to self-compensation effect.

Fig. 3 Mid-director profile of LSH mode.

Fig. 4 shows voltage-dependent transmittance (V-T) of the LSH cell. The LSH mode shows low operation voltage and high transmittance. The transmittance continuously increases as a voltage is applied. The reason is that the retardation value of the cell is not enough to generate maximal light efficiency such that it closes to optimal value with increasing a voltage.

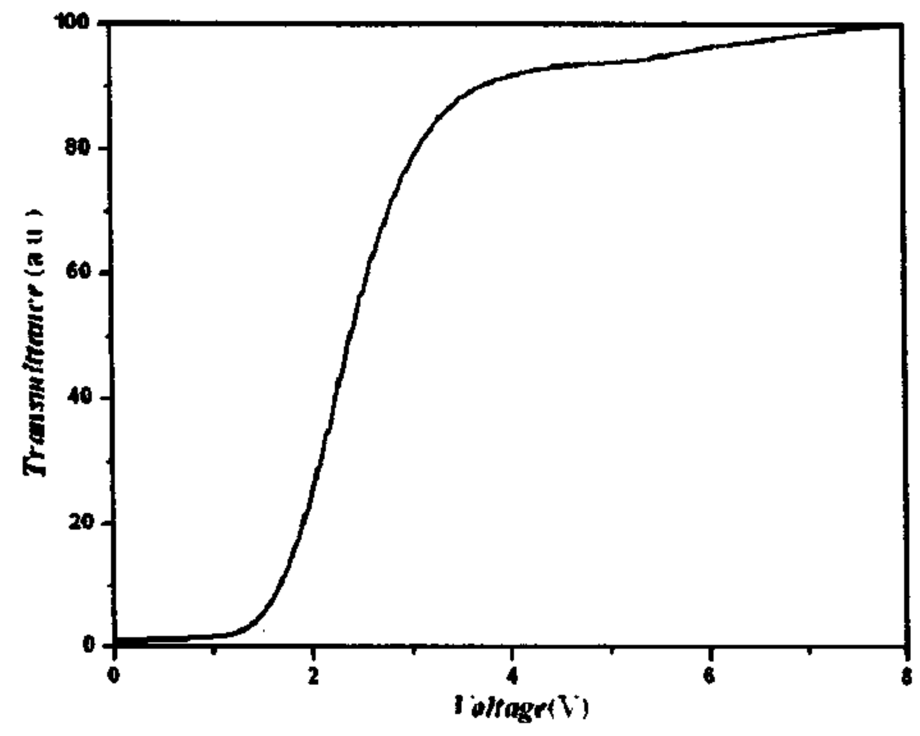


Fig. 4. Measured V-T curve of the LSH mode.

3. Impact

This LSH mode does not require ball or post types of the spacer, and rubbing process. Also, LCs of this LSH mode tilts down in a way that the mid-director directs in all azimuth directions. Consequently, the device exhibits wide viewing angle due to self-compensation effect. In addition, the device has advantages in applying to large size display since the LCs do not drop to bottom side of the display due to locking of the LC in confined domain. Further, this LSH mode has advantages such that the gate and data signal lines exist below the polymer walls and thus it does not disturb the LC orientation and some LCs which was stressed by gate DC does not exist anymore in the LSH cell.

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5. References

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