Novel Pixel Structure for the Improving Optical Performances of 8K LCD Panel

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ABSTRACT

We report on novel pixel architecture for improving the transmittance and reducing the gamma distortion to minimize the color shift in a 8K QUHD LCD panel with the hG-2D technology. In our LCD panel, each pixel has a unique electrode structure which is mixed with the micro-slits and reversed those. It is named "multi-domain reversed-slit VA mode (MRS-VA)". This MRSVA-LCD has the excellent transmittance by matching the LC distortions on the vertical electrode and two data lines which is asymmetrically positioned. Besides, by shielding the LC distortion line at the oblique viewing angle, the gamma distortion can be effectively suppressed. Through the QUHD panel with our structure, superior performances to normal LCD could be clearly demonstrated.

1 INTRODUCTION

In the recent market, displays size for the TV application reaches above 60 inches and becomes larger and larger. In this circumstance, several candidates such as OLEDs-TV have been developed in the recent years to compete with LCDs-TV. However, due to low cost, commercialized process, and the brilliant electro-optic performances, LCD still dominates the consumer market of large-screen TV over 50 inches [1, 2]. To firmly keep on the top of the candidates for large-sized LCD panel, high contrast ratio (with high luminance), wide viewing angle, and excellent color performance such as small color shift and good angular dependent color uniformity, all these have to be satisfied simultaneously. As is widely known, vertical alignment mode with multi-domain (MVA) has become the mainstream approach for LCD TVs owing to their high contrast ratio (CR) and wide viewing. Currently, with the help of compensation films, most of MVA-LCD panels have LC configurations practiced by the adaption of the patterned micro slit in the pixel electrode structure (be named SVA LC mode). However, owing to the evident gamut curve distortion at the large oblique viewing angles, SVA-LCD panel still has inferior performances in color shift and angular uniformity as compared to the multi-domain LC mode operated by the in-plane or fringe electric fields in addition to several OLED-TV panels [3].

Furthermore, reducing the aspect ratio becomes the other issue in a large-sized LCD panel. To overcome the weakness of motion image quality in a large panel, the SVA-LCD panel has been developed by adopting a half-gate two-data (hG-2D) which can induce further reduction of motion blur [4]. However, hG-2D technology essentially sacrifices the efficiency of the panel transmittance. Compared with a SVA mode with a 1G-1D, the transmittance is decreased of 20% due to the reduction of the aspect ratio by two data lines in a pixel. Finally, the significant issues of lower transmittance, gamma curve distortion and color shift still persist when employed in high resolution.

In this work, we propose on novel pixel structure for the higher transmittance and lower gamma distortion of a large-sized LCD panel with the hG-2D technology. Our LCD panel has a unique electrode structure which is mixed with conventional micro-slits and reversed those. It is named "multi-domain reversed-slit VA mode (MRS-VA)". This MRSVA-LCD has the excellent transmittance and suppressed gamma distortion by matching the LC distortions on the vertical electrode and two data lines which is asymmetrically positioned. We manufactured the QUHD LCD panel which is based on our pixel structure and evaluated its optical performance.

2 Structure & Superior Optical Properties

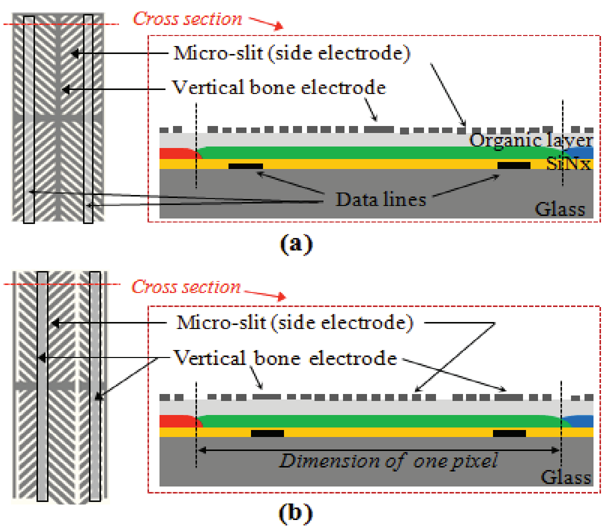

Fig. 1 Pixel electrode structures and plane views of (a) the SVA-LCD and (b) the MRSVA-LCD

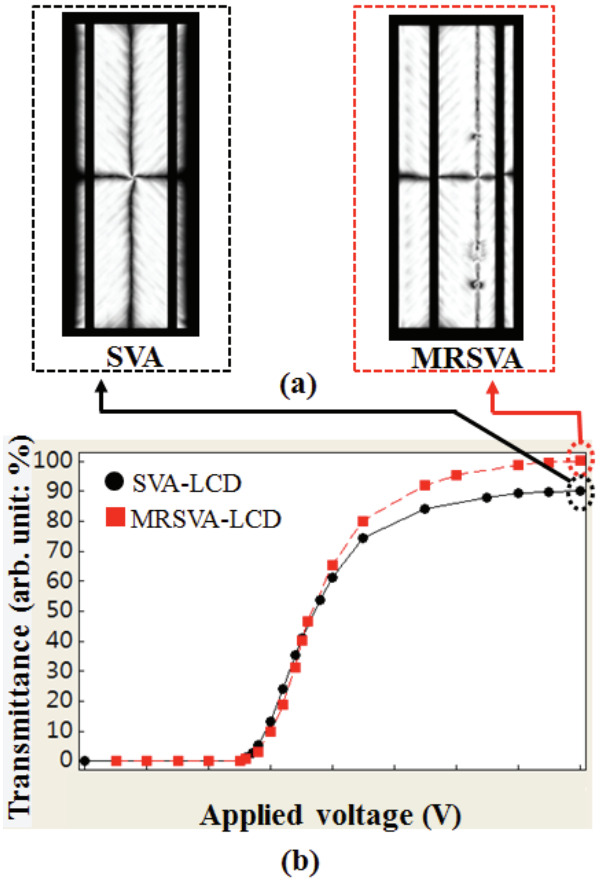

Fig. 2 (a) Transmittance images in on-state (8V), and (b) the voltage-dependent transmittance curves of a conventional SVA-LCD and a proposed MRSVA-LCD

Figure 1 shows the plane views and the schematic cross-sectional views along the line A-A' of the plane view of (a) the conventional SVA-LCD and (b) the MRSVA-LCD. In a SVA-LCD as shown in Fig. 1(a), the main-bone electrode is cross-shaped to connect side bone electrodes, which determine the azimuthal direction of the LC director under an applied electric field. The transmittance above the main bone electrode is ineffective because of no direction of the uniform LC azimuthal orientation for the good luminance. Beside, such as the gamma distortion and color shift, the optical efficiency which is dependent on the viewing angle is degraded by the non-uniform LC configuration on vertical main-bone electrode. In addition to this, there is inferior aperture ratio in a pixel owing to the two data lines, located to the edge area in a pixel under the pixel layer. In contrast, MRSVA-LCD has a unique electrode structure which is mixed with conventional micro-slits and reversed those. Two vertical main-bone electrodes are asymmetrically matched with two data lines under the organic layer. It was expected to the excellent transmittance and suppressed gamma distortion by shielding the LC distortions on the vertical main-bone electrode.

In Fig. 2, we present the pixel transmittance images and transmittance curves in a SVA-LCD and the proposed MRSVA-LCD under the 0° (90°) crossed polarizers. Figure 2(b) depicts the microscopic images under an applied voltage 7.5V. The significant difference in pixels is the widths of the exposed vertical disclination line between the domains. In figure 2(a), by this optical phenomenon, it is noted that proposed LCD shows approximately 10% higher luminance than a conventional it. The increased luminance is due to the effect, completely shielding the disclination line in vertical direction on the main-bone electrode in contrast with the conventional SVA-LCD. Naturally, there is an exposed extra disclination between the conventional slit electrodes and reverse those in a pixel of MRSVA-LCD. However, this extra disclination can be optimally suppressed because the side bone electrodes are not connected as shown in Fig. 1(b). Consequently, it is an advantage in terms of aperture ratio for the transmittance by comparison with the conventional it on the bone-electrode.

Fig. 3 compares the experimented and normalized gamma curves of a SVA-LCD and a MRSVA-LCD at different viewing angles. Here, the azimuthal angle is set at 0° and an 8 bit grayscale with 256 gray levels is evaluated. For the quantitative analysis of the off-axis image quality, an off-axis image distortion, expressed as D (θ, φ) is defined as

$$D(\theta,\varphi) = \left\langle \frac{\left|\Delta B_{i,j(\text{on axis})} - \Delta B_{i,j(\text{off axis},\theta,\varphi)}\right|}{\Delta B_{i,j(\text{on axis})}} \right\rangle_{i,j=0-255}$$

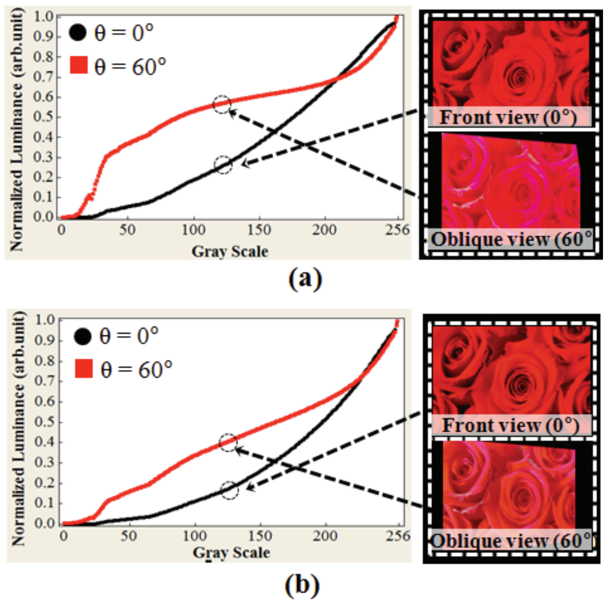

Fig. 3 Experimented gamma curves and panel luminance at different viewing angles (a) the conventional SVA-LCD, and (b) the proposed MRSVA-LCD

Here, ΔBi,j is the brightness difference between the ith and jth gray levels, and < > denotes the average for all cases of arbitrary gray levels. D (θ, φ) is within the range from 0 to 1. A smaller D (θ, φ) implies to a smaller image distortion as represented from the angular-dependent gamma curves, i.e., a better off-axis image quality. As calculated from Eq. (1) with the experimented luminance values at different viewing direction, the conventional SVA-LCD, as depicted in Fig. 3(a) has a D value of 0.450 at (θ, φ) = (60°, 0°) viewing direction. Figure 3 (b) shows the improved optical efficiency at different incident angles. Its D value is 0.345 at (θ, φ) = (60°, 0°) viewing direction which is 23.4% improved over the SVA-LCD. This indicates that a MRSVA-LCD with novel pixel structure indeed reduces the color shift at off-axis viewing directions in addition to minimization of the gamma distortion at different viewing angles. We could also demonstrate the superior optical performances through the manufactured QUHD MRSVA-LCD panel.

3 USEFUL PROPERTIES FOR MASS PRODUCTION

As described previously, by the experimental results, we demonstrated a novel hG-2D QUHD LCD panel with the improved transmittance and the reduced gamma distortion to minimize the color shift by the innovated pixel architecture. For actually applying to the commercial panel by the mass production, the crosstalk and bruising defect,

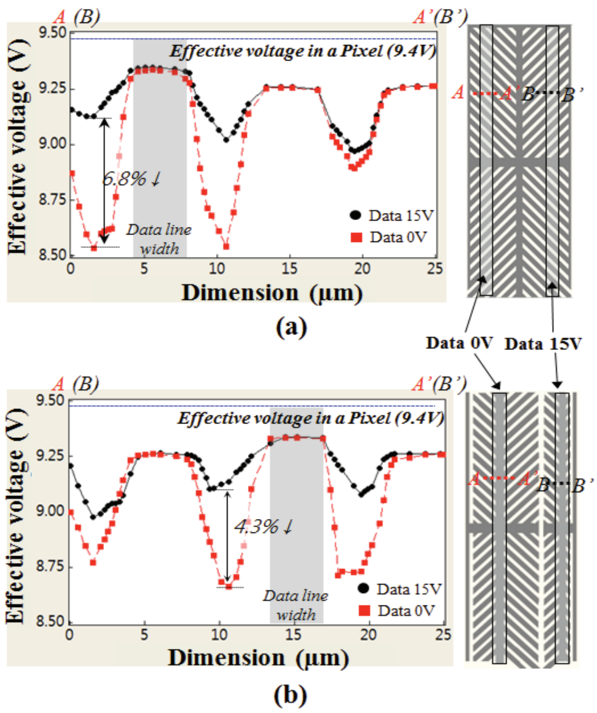

Fig. 4 Effective voltages of pixel layers near the data lines (in hG-2D backplane): (a) the conventional SVA-LCD panel (exposed to the data fields by two data-lines) and (b) the MRSVA-LCD panel (with the obstructed data-fields)

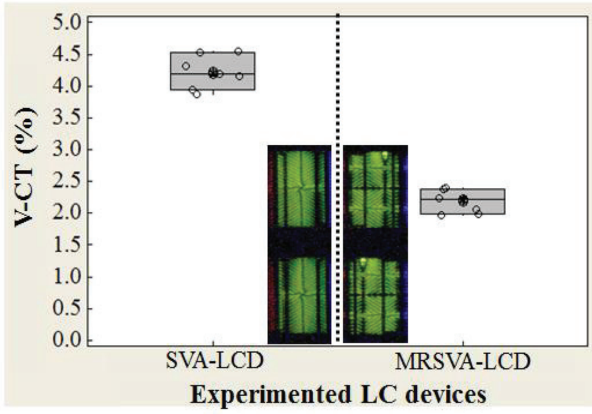

Fig. 5 Experimented vertical crosstalk (V-CT) levels of SVA-LCD panel and MRSVA-LCD panel. In addition, respective pixel images with local crosstalk by the different data-fields between the neighbouring data lines

one of the magnitude issues can be overcome in the panel with our pioneering pixel structure. Crosstalk is one of the main display related perceptual factors degrading image quality and causing the discomforts of the mass production. It causes visual artifacts such as blurring, ghosting effects, and lack of the color integrity which are considerably troublesome and can lead to hard to manufacture by the commercial mass production.

In a normal LCD panel with the hG-2D structure, the voltage difference of the local pixel area by unwanted interference between two neighbouring data lines can be a main factor among the various factors of the crosstalk defect. As mentioned above, the MRSVA-LCD mode has the unique pixel structure that is composed with side electrodes in six mono-domains and two vertical main-bone electrodes which are asymmetrically matched with two data lines under the organic layer. As illustrated in fig. 4, two vertical main-bone electrodes can block the heterogeneous voltage-level on two neighbouring data-lines and reduce the influence on LC layer between pixel and common electrodes.

Through the commonly test of crosstalk value, we demonstrated that MRSVA-LCD mode is superior to the normal SVA-LCD mode (Crosstalk level is reduced 48% in contrast with SVA-LCD panel) (as shown in Fig 5).

4 CONCLUSION

Here, we reported a novel hG-2D QUHD LCD panel with the improved transmittance and the reduced gamma distortion to minimize the color shift by the innovated pixel architecture. Our MRSVA-LCD with the unique pixel structure mixed with conventional micro-slits and reversed those has the excellent transmittance by matching the LC distortions on the vertical electrode and two data lines which is asymmetrically positioned. Besides, by shielding the LC distortion line at the oblique viewing angle, the gamma distortion can be suppressed effectively. It should be expected MRSVA-LCD can firmly keep on the top of the candidates in the large-sized and high resolution TV panels manufactured by the commercial mass-production.

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