Wide Viewing Angle Flexible Color Liquid Crystal Display

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Abstract

A novel wide viewing angle flexible liquid crystal display will be demonstrated. The crossed matrix-type micro-cell structure was adopted in this design. The LC domains were divided into four different tilted directions by the combination effect of pixel fringe field and crossed matrix type micro-cell. It can create four domains without rubbing process and form the cell gap without spacer. For flexible color fabrication, a novel inkjet printing technology is adopted. This cost effective wide viewing angle color flexible LCD technology can be a good solution for high performance flexible LCD.

Introduction

Nowadays, the applications on portable products gain much more attention. The relevant technologies aim at developing a flat panel display with light weight, thin size, high impact resistance and low power consumption. Therefore, the research trend of flat panel display is gradually switched from traditional glass substrate to plastic substrate[1-3].

ERSO/ITRI has spent a great amount of efforts on developing flexible LCDs[4-6]. Recently, we proposed a novel concept of micro-cell LCD which possessed a high contrast ratio with a fast response time, and it can be fabricated through a more reliable process[6]. However, this micro-cell technology is not good enough.

For the large size and flexible display applications, viewing angle problem becomes an important issue. As shown in Figure 1, the brightness of the upper and lower panel will be quite different because of the asymmetric LC molecule reorientation. In curved display, this viewing angle problem becomes more obvious. As shown in Figure 2, the asymmetric LC molecule reorientation will generate non-uniform brightness.

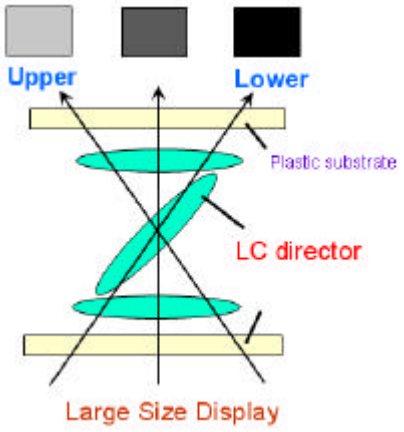

Fig.1 Viewing angle issue for a large display

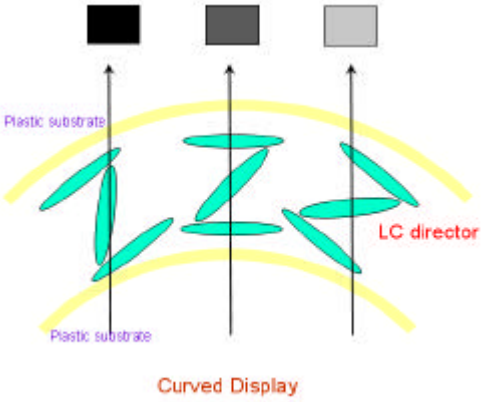

Fig.2 Viewing angle issue for a bent display

In this work, we proposed a new design to improve the viewing angle. The crossed matrix type micro-cell structure was adopted in this design. The LC domains were divided into four different tilted directions by the combination effect of pixel fringe field and crossed matrix type micro-cell. It can create four domains without the rubbing process and form the cell gap without spacer. This technology is also compatible to roll-to-roll fabrication process, so it is

extremely cost-effective for mass production of high performance flexible liquid crystal display.

For fabricating a flexible color LCD, we propose a novel inkjet printing technology to fabricate the color filter. By combining matrix-type micro-cell process, we neglect bank fabrication step which need one photolithography process. So our wide viewing angle flexible color LCD technology is cost effective.

Structure & Experiment

Figure 3 shows the cross-sectional view of our wide viewing angle flexible LCD structure. We make the matrix-type micro-cell both on upper and lower substrate. As the two substrates are assembled together, the cell gap can be formed automatically by the intersection of the two matrix-type micro-cell on the substrates. Then, the four domain-like effects and integrated spacer are formed in this design. As illustrated in Figure 3, the operating principle of this new display mode is a combination effect of pixel fringe field and crossed matrix type micro-cell. High pre-tilt angle around the pixel is introduced by the crossed matrix type micro-cell structure without utilizing rubbing process.

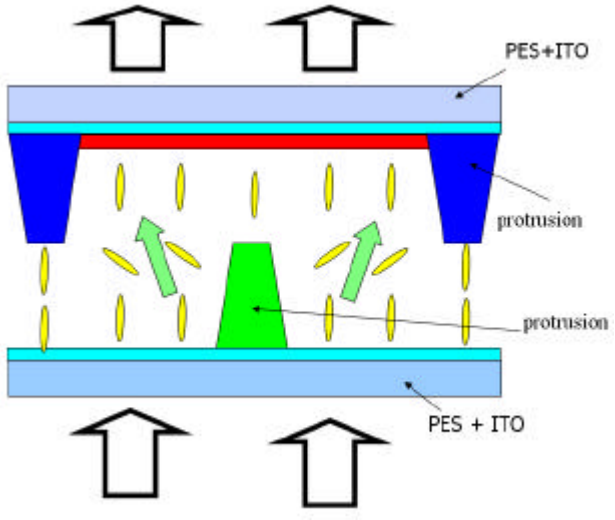

Fig.3 Wide viewing angle design

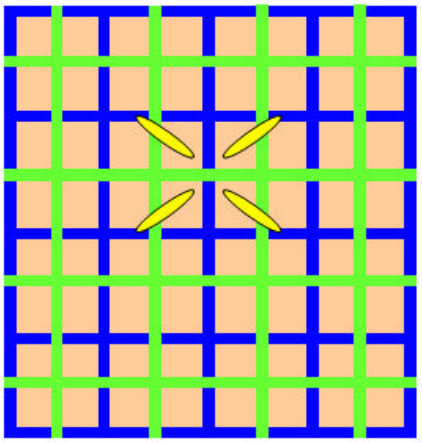

Fig.4 Top view for wide viewing angle structure

The manufacturing processes of the matrix-type micro-cell structure are as following. Firstly, a thick layer of PC series positive photo resist was formed on the substrate by spin-coating method. Secondly the specially designed matrix structures were patterned by using the g-line stepper. Then the matrix-type micro-cell were developed and baked as the usual process.

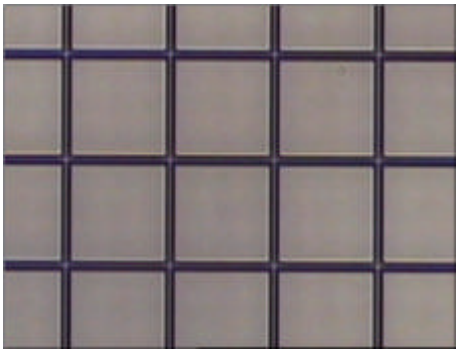

Fig.5 The micro graph of matrix type micro-cell

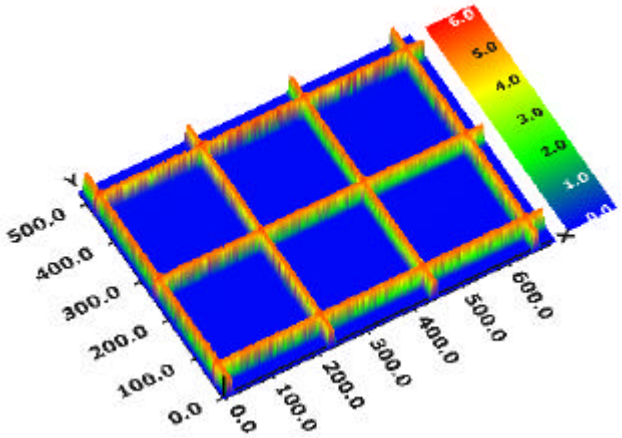

Fig.6 The 3D image of matrix type micro-cell

Figure 5 and figure 6 demonstrate the micro graph and the 3D image of the matrix-type micro cell structure on the plastic substrate. The width and height of the wall is 20μm and 2.2 μm, respectively. The spacing between two walls is 200um.

In addition to the traditional photolithography technology, we can also fabricate the micro-cell structures by a roll-to-roll compatible replication technologies such as embossing and UV photopolymer replication. This can reduce the fabrication cost and time.

After the matrix-type micro-cell structure process, we can inject the color ink into each matrix. The matrix-type micro-cell structure can also be served as the bank structure in inkjet printing process. Thus, the bank fabrication process is not required.

Finally, we use traditional LC cell assembly process to fabricate the wide viewing angle flexible LCD. The optical texture of the pixels at the ON State is shown in figure 7, most of the dark optical texture is limited around the wall of the matrix-type micro-cell. Figure 8 shows the iso-contrast contour for the test cell's result. With extra compensation films (a-plate and c-plate), the horizontal viewing angle can reach 150 degrees and the vertical viewing angle can reach 170 degrees. This novel design is quite suitable for wide viewing angle display application.

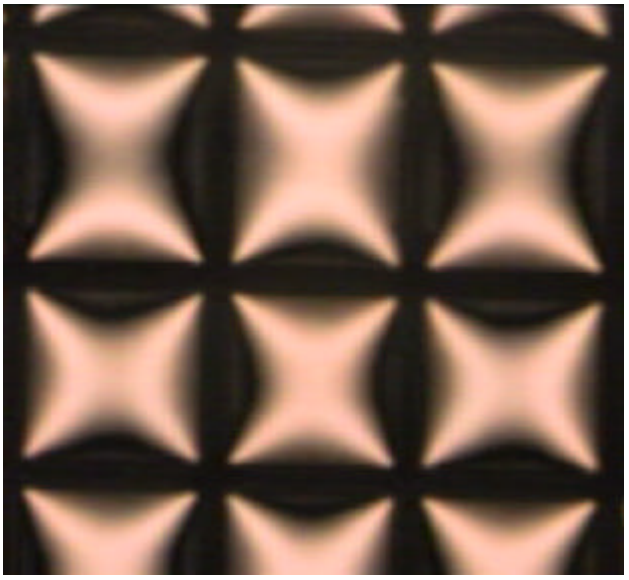

Fig.7 The optical texture of the pixel

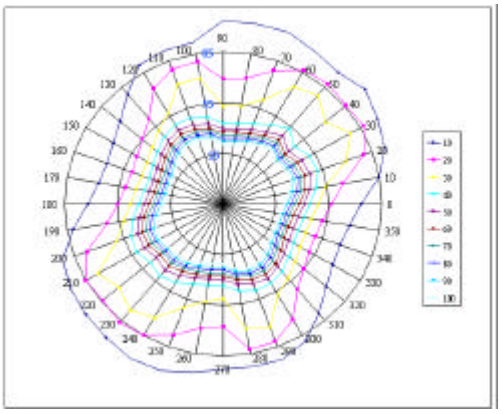

Fig.8 The contrast contour of the wide viewing angle LCD

Conclusions

We have proposed a wide viewing angle flexible color LCD technology, and the prototype panel is under developing. The LC domains were divided into four different tilted directions by the combination effect of pixel fringe field and crossed matrix type micro-cell. It can create four-domains without the rubbing process and form the cell gap without spacer. A novel inkjet printing technology is adopted to fabricate the color filter. The excellent optical performance reveals the possibility of making a high quality flexible display by the roll-to-roll process, which

means that the cost of flexible color LCD can be substantially reduced.

References

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