Lowest-Cost Highest-Yield Superior Performance MVA LCDs by Amplified Intrinsic Fringe Field

Hiap L. Ong[1], Justin Liang[2], Jia Haw Guo[2], I Hao Chen[2], Chang Lin Wu[2], Wei-Chou Lan[2], and Tung-Liang Lin[2]

[1]Kyoritsu Optronics. NTUST BIC. 11 F. No. 1115. No 43. Section 4. Keelung Road. Taipei, Taiwan. ROC.

TEL: 886-2-8732-0850, e-mail: hiapong@taiflex.com.tw.

[2]Prime View International Co. Ltd. 3 Li Shin Rd. 1, Science-Based Industrial Park. Hsinchu, Taiwan. ROC.

Keywords: **MVA LCD, Fringe Field, Cost, Transmission, Yield**

Abstract

We successfully fabricated lowest-cost superior perform ance MVA LCDs with highest-yield, high transmission, high contrast-ratio, and wide viewing angle. Using the amplified intrinsic fringe field (AIFF) controlled MVA invented by Ong, we eliminated all protrusions and ITO slit geometries. We further achieved: (1) faster gray-gray response times without the over-drive technology, (2) faster tough mura, and (3) lower flicker and cross-talk in the row inversion driving schemes.

1. Introduction

High performance AMLCDs with wide viewing angle and high contrast ratio are widely used in both large size LCD TV and monitor, and also small-medium LCD applications, such as mobile phones, PDA, GPS, and mini-PC. Today even low-cost portable applications require high optical performance LCDs with symmetrical wide viewing angles for multi-media applications. These high performance, small-medium size LCD panels are now important products with high profit margins. With the new large price reduction on LC TVs, it is more important to improve the manufacturing cost, yield and performance for all LCDs. The MVA with protrusion geometry is the dominating LCD mode for the large size LC TV, but is difficult to use for the small-medium application because of the high-cost manufacturing process and low optical transmission, due mainly to the protrusion geometry.

In this paper, we report on important progress in the development of MVA LCDs to meet the low cost and high performance requirements for small-medium and large size LCD applications. We successfully developed the currently lowest-cost highest-yield high transmission wide viewing angle MVA panels with no protrusions and no ITO slits in both color filter and TFT substrates, using the amplified intrinsic fringe field (AIFF) controlled MVA that was invented recently by Ong.[1-4]

For our fabricated 3-in color WQVGA (320xRGB x400dots) MVA panels, the measured data showed super performance: on-axis contrast >600, viewing angle greater than 170° (CR>10) in all viewing zones, 5.3% transmittance, 10ms on and 6ms off response times. We further achieved: (1) faster gray-gray response times without the over-drive technology, (2) faster tough mura, and (3) lower flicker and cross-talk in the row inversion driving schemes.

2. Progress on Wide Viewing Angle LCDs

The limited viewing angle was a major LCD p erformance problem and much effort has been de voted to this important area. Table 1 summarizes the key progress on the invention and subsequent important improvement on LCD viewing angle im provements. From1980 to 2005, the major focus was on the development of a suitable wide viewing angle LCD technology that can be implementing in production with suitable yield. Since 2005, with the maturing of the WVA technology and emergence of many new LCD applications in the small-medium size LCDs, efforts were devoted to the improvement of cost, transmission, contrast ratio, and for portable LCD applications. For mobile phone and other portable applications, the pixel density is typically 150 to 300 pixel per inch (PPI). The conventional MVA and IPS that are suitable for standard LC TV and monitor with a PPI <120 are not suitable for many portable LCD applications because of high cost and low transmission for PPI >120.

In 2005, Ong had invented a new AIFF MVA that can be used for LC TV, monitor, and also for the higher density mobile and portable LCDs with low cost and high transmission. We successfully fabricated low cost high performance AIFF MVA panels for various applications using Ong designs.[1-4]

Table 1. Major progress on LCD viewing angle improvement.

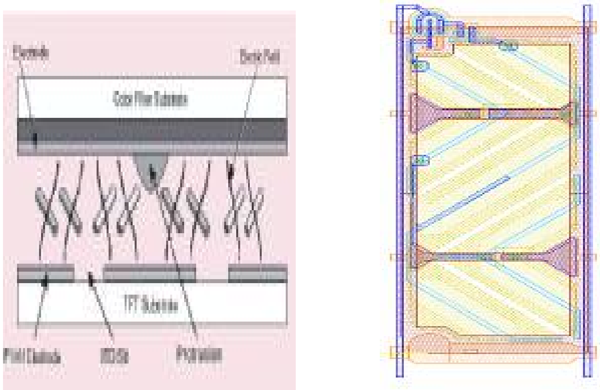
WVA LCD	Key Inventor	Key Improveme nt	Production Status
TN- Negative Birefringence Film	Ong(1992)[5]	Rockwell S cience, Nitto; FujiFilm	Yes, Widely used
MVA (PVA) – ITO Slit	Clerc (1989)[6]	Samsung, IBM, CMO	Yes, R&D
MVA – Protrusion	Ong(1992)[7]	Fujitsu (1997) Sharp	Yes, LC TV and Monitor
IPS	Baur (1992)[8]	Hitachi (1995) LGD	Yes
FFS	Lee(1998)[9]	Hydis	In progress
MVA – Microdisplay	Ong(2003)[10]	Kopin	Small Volume
AIFF MVA –No protrusion, no ITO slit	Ong(2005)[1]	Kyoritsu	Yes

3. Normal MVA vs. AIFF MVA LCDs

Figure 1 shows the TFT substrate design and p ixel layout for a typical MVA using protrusion ge ometry. The TFT substrate consists of many ITO slits and the color filter substrate consists of man y protrusions. Special process is needed to fabrica te the protrusion with appropriate shape using pho tosensitive material. High precision alignment eq uipment is needed for the alignment of TFT subst rate's protrusion with the color filter substrate's I TO slits. Thus it is a high cost process with yiel d lower than the TN/LCDs. In addition, because of protrusion and ITO slits, the aperture ratio and optical transmission are considerably lower than TN. These make the normal MVA suitable for ap plication with a pixel density <120 PPI; and diffi cult for portable LCDs applications with a pixel d ensity >160 PPI.

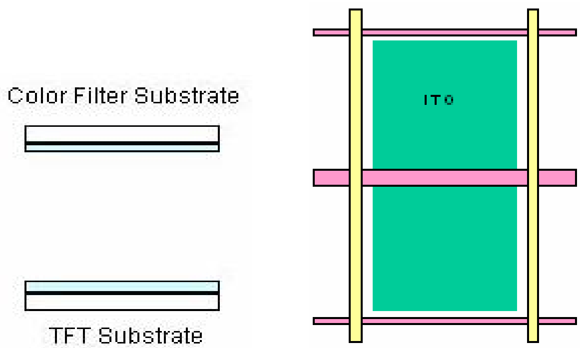
Figure 2 shows the TFT substrate design and p ixel layout for our AIFF MVA. The protrusion, I TO slit, PI rubbing and precision top to bottom s ubstrate alignment are all eliminated in AIFF MV A. Consequently, AIFF MVA offers the following major advantages as compared to normal MVA:

a. Lower cost.
b. Higher yield.
c. Higher aperture ratio and transmission.
d. Simpler fabrication process and design.



1(a). 1(b).

Fig. 1. Geometry for a MVA using protrusion d esign. 1(a). Substrate design. 1(b). Pixel l ayout.



2(a). 2(b).

Fig. 2. Geometry for AIFF MVA without protru sion and ITO slit. 2(a). Substrate design. 2(b). Pixel layout.

Indeed, AIFF MVA yield is even higher than T N, which needs the rubbing process. The aperture ratio is also higher than TN because there is no edge reverse tiled disclination, and practically no black matrix is needed around the edge of the p ixel. AIFF can be used for applications with low pixel density of ~100 PPI and also high pixel de nsity of 160 PPI to even >300 PPI. Since a perfe ct vertical LC alignment is used, a complete optic al black state is obtained. Because of the multi-domain LC structure, wide symmetrical viewing a ngle is obtained and the viewing angle could be f urther improved by a vertical oriented negative bi refringence optical compensation film.

4. AIFF MVA LCDs Fabrication
4-1. AIFF MVA Designs

The intrinsic fringe field is weak in the direct view LCDs and strongly depends on the display driving scheme and applied voltage. In the AIFF MVA, we need to amplify the fringe field in its own sub-pixel, and eliminate the fringe field form the soundings sub-pixels, and also control the fringe field effects. AIFF MVA pixel designs thus depend on the driving scheme. In the typical design, we subdivide a pixel into RGB color components, which are further subdivided into color dots. To amplify and control the intrinsic fringe field, we have introduced a few special pixel designs and layouts, including the following layouts:

a. Checkerboard pattern of dot polarities;
b. Polarized associated dots;
c. Additional polarized associated dots;
d. Implement dot inversion driving scheme using row inversion or column inversion driving scheme ICs; and
e. Polarity extension portions.

For general applications, we use the regular LCD driving ICs to reduce the design cost and complicity. Since special IC, protrusion and ITO slits are not required, we can greatly reduce the cost and time cycle in both the R&D and manufacturing phases.

4-2. AIFF MVA Panels with Row Inversion

Mobile phones are now a major portable LCD application. It continually requires better performances but at a lower price. Multi-media applications need higher resolution (QVGA in 2003, VGA in 2007 and WVGA in 2009) TFT panel and also wide viewing angle performance (4%, 24% and 40% in 2006, 2008 and 2010 respectively). The pixel density is 155 PPI for 3-in WQVGA to 327 for 3.2-in WVGA.

The fringe field is much weaker in the row inversion as compared to the dot inversion, thus more complex designs are needed for the mobile phone applications. We had successfully fabricated color AIFF MVA for mobile phone application with super performance, including a 2.2-in QVGA, 3-in WQVGA and 3.5-in HVGA. The measured data showed much better performance than the normal MVA: typical aperture ratio 55-60%, transmission 5.2-5.5%, CR > 600 and NTSC 60%. With the normal LC and a cell gap of 3.5um, we had achieved a fast response of 10ms on and 6ms off. The viewing angle is larger than 160° in left-right and up-down using normal polarizer and larger than 160° in all viewing zones using MVA wide-viewing angle polarizer. Figure 3 shows the typical viewing angle contour plot.

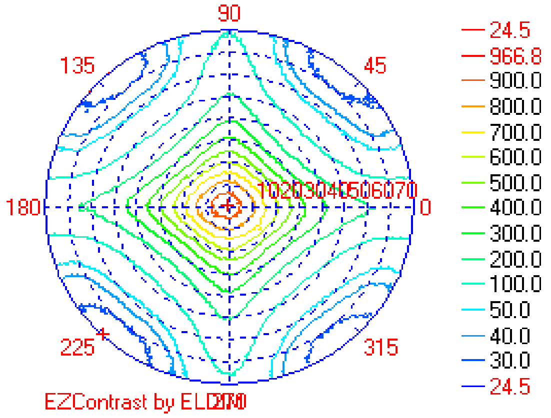


Fig. 3. Typical measured contrast ratio contour plot for a fabricated 3-in WQVGA AIFF MVA.

4-3. AIFF MVA Panels with Dot Inversion

The high-end LCD for car GPS, LC TV and monitor used dot inversion driving scheme to reduce the flicker and cross-talk effects. In general, AIFF MVA using the dot inversion driving scheme is easier than the row inversion because larger intrinsic fringe field effects are present in the dot inversion LCDs. In 1996, we reported 7-in WVGA (800RGBx480) AIFF MVA for car GPS, UMPC, DPF, DVD applications, with 63.5x190.5um color dot and 133 PPI.[2] The measured data is as follows: contrast ratio 900, transmission 5.3%, NTSC 60%, wide viewing angle >170° (CR>10) for all viewing angle zones, on and off response times are 15 and 10ms. We have improved pixel designs to further improve the performances.

5. AIFF MVA Meeting New Challengers
5-1. AIFF MVA vs. ASV for PPI >250

Currently very high-end mobile phone and portable LCDs are fabricated using ASV[11] with LTPS TFT technology. The pixel densities for 2.8-in VGA and WVGA LCD panels are 286 and 350 PPI respectively. Normal MVA is not suitable for these high-end applications where ASV MVA using circular protrusion is used. Our AIFF MVA offer even more significantly competitive advantages over all existing MVA for very high end application, as demonstrated in the comparison Table 2.

Table 2. Comparison between AIFF vs. ASV MVA for 3-in VGA LCD applications.

LC Mode	ASV MVA	AIFF MVA
Protrusion Area	~18%	0
Aperture Ratio	~40%	~60%
Brightness	Lower	>150% Higher
Black State	Gray	Perfect Black
CR	300-400	600-1000

5-2. Tough Mura

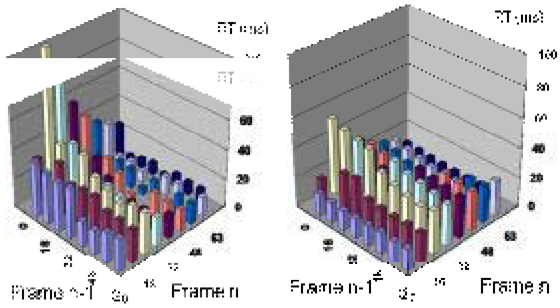
In general, MVA LCDs have an intrinsic slower tough mura performance than the TN/LCDs by their LC spatial structures. We have fabricated improved AIFF MVA with faster tough mura operation by special pixel designs with enlargement on the horizontal fringe field components with the regular IC and no extra mask. Currently the fabricated AIFF MVA reduced the tough mura from more than 5-sec to 2-sec with a 3.5um cell gap and regular LC. We could improve the tough mura effects to less than 1-sec with better pixel designs, faster LC and thinner cell gap.

5-3. Faster Gray-Gray Response Times

Very fast gray-gray response times are obtained in LC TV and monitor by the use of over-drive technology that needs special adjustments with extra cost and power. There is a need for the portable LCD applications with a faster gray-gray response times but no extra cost and power. We have fabricated improved AIFF MVA with faster gray-gray response times by special pixel designs with the regular IC, no extra cost, no extra power and no extra mask. Currently the fabricated AIFF MVA reduced the longest gray-gray response times from more than 170-ms to less than 70-ms. The normal and improved gray-gray response time measured data are shown in Figs 4(a) and (b).

5-4. Row-Inversion with Reduced Flicker

Compared to dot inversion driving, row inversion has lower driving voltage, lower power consumption and cost, but a larger flicker and cross-talk. We invented a modified row inversion driving scheme with appropriate pixel layout to retain advantages on low cost, driving voltage, and power consumption and also reduce the flicker and cross-talk to comparable with dot inversion.



4(a). 4(b).

Fig 4. Typical measured gray-gray response time for a 3-in WQVGA panels. (a). Normal design. (b). Special design for faster gray-gray response time

6. Summary

We successfully fabricated low-cost, high-transmission AIFF MVA LCDs with high yield, high contrast-ratio, and super wide viewing angle, without protrusions and ITO slit geometries in both ITO and TFT substrates. The AIFF MVA offers competitive LCDs for small-medium LCD mobile phone, GPS, PDA, UMPC, and large size LC monitor and TV applications.

Ong gratefully acknowledges: J.S. Chou, C.C. Chiu, C. Chen and V. Yeh for their technical supports during various phases of this program; Dr M Verrall and Dr R. Yan of Merck Display Technologies Ltd., T. Nagatsuka, H. Yoshimi and G. Lin of Nitto Denko, for their good supports.

7. References

1. H.L. Ong and J. Chou, *EuroDisplay'05*, p. 564 (2005).
2. H. L. Ong, J.S. Chou, W.C. Lan, J.H. Guo and I.H. Chen, *IDW'06*, p. 205-206 (2006).
3. H.L. Ong, C.C. Chiu, C.M. Huang, C.C. Lee, C.F. Hsu, and F.C. Wu, IDW'07, p.1569 (2007).
4. H.L. Ong (unpublished).
5. H.L. Ong, *Japan Display'92*, p. 247 (1992).
6. J.F. Clerc, *SID'91*, p. 758 (1991).
7. H.L. Ong, *SID'92*, p. 405 (1992); Y. Koike, et al., IDW'97, p. 97 (1997).
8. R.Kiefer, et. al., *Japan Display '92*, p. 547 (1992); M. Ohta, et. al., Asia Display'95, p. 68 (1995).
9. S.H. Lee, et. al., *Asia Display'98*, p. 371 (1998).
10. H.L. Ong, et. al., *SID'03*, p. 680 (2003).
11. M. Kubo and K. Ogishima, Sharp, US Patent Pub no. 2004/0041770A1 (2004).