A reflective color TFT-LCD with high aperture ratio

Su-Seok CHOI, Wonseok Kang, Hyun-Suk Jin, Woo-Nam Jeong
Anyang R&D center, LG. Philips LCD, Anyang, 431-080, Korea
Phone : +82-31-450-7761 , E-mail : aiconess@lgphilips-lcd.com

Abstract

We have developed a reflective 3.5" QVGA color TFT-LCD with high reflection within viewing angle .For this, We have introduced new pixel design and asymmetric reflector. Based on these technical concepts , we get a high aperture ratio of 93.5% and much higher reflection up to 64% with a 3.5" prototype panel.

1. Introduction

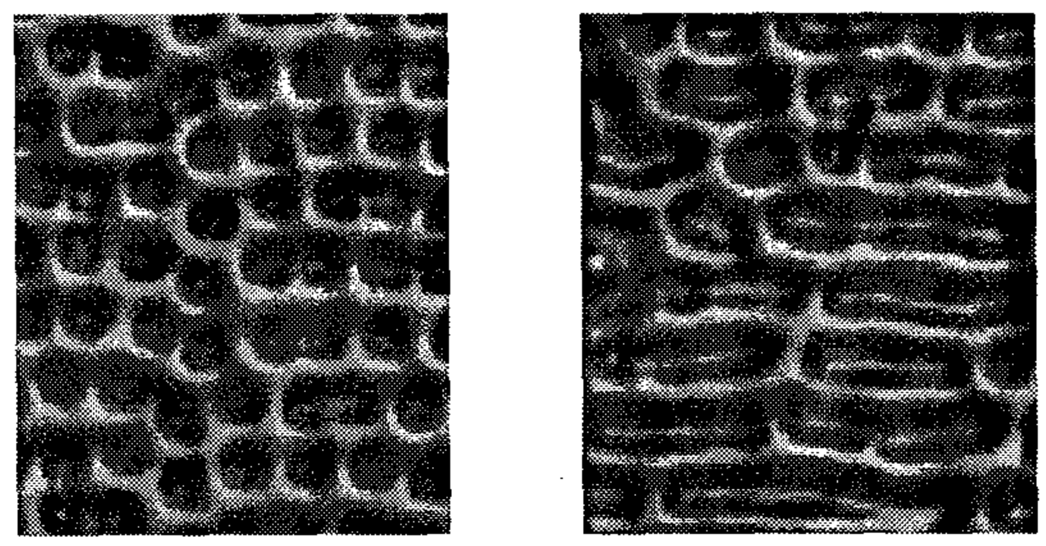
As the development of information technologies and social infra for this, the needs for mobile display is also rapidly increasing now. This mobile display is generally used in outdoor frequently. So mobile displays essentially need legibility under sunlight, lightweight and low power consumption. Because of this needs, reflective and transflective LCDs are thought as leading candidates for this mobile displays and have been studied by many researchers. To get a good display image in reflective LCDs, high reflection under ambient light is important. This high reflection is related with a reflecting area and the efficiency of reflector within viewing angle. To get a high efficiency of reflector the concept of uneven reflector, which is placed inside of cell, was suggested and has been widely studied [1]-[6]. But this is limited in increasing of reflection and efficiency as viewing direction.

In this work, we have introduced two differential technologies to get a high reflection and the efficiency of reflector in a certain viewing direction. One is maximizing of reflecting pixel area by using a new pixel structure and the other one is controlling the arrangement of reflecting unit bumps asymmetrically.

2. Reflector design for higher reflection to main direction.

In general, reflective LCDs have a diffusive reflector inside of cell to haze reflecting light within viewing angle. For this, reflector has certain uneven shape to control haze level of reflection. Therefore, design and control of reflecting bumpy unit's surface profile is very important. In addition, density of reflecting units as reflecting direction is more deeply related with reflecting level of reflective LCDs. To get a higher reflection within wanted reflecting direction, much more reflection along this direction is needed.

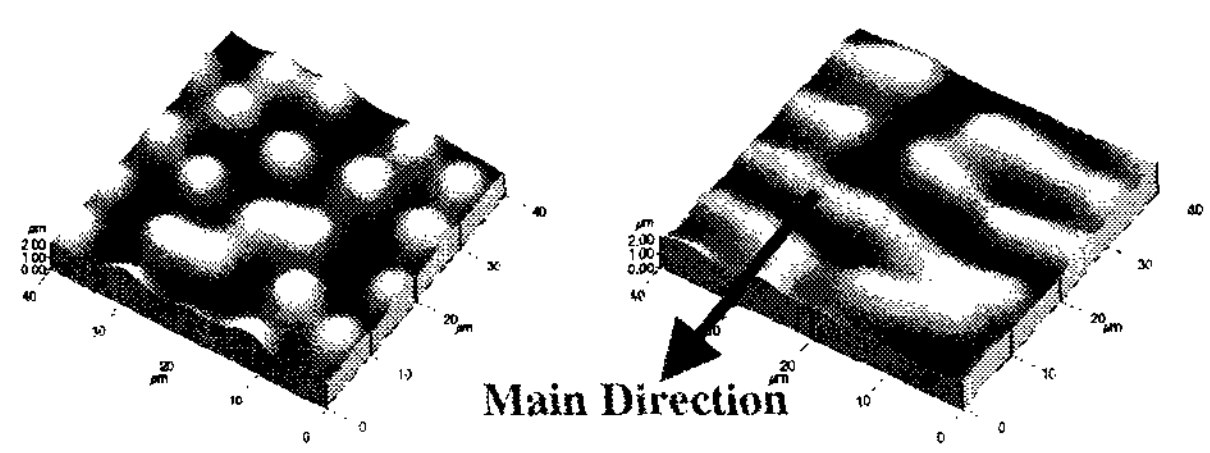
For this, we designed a reflector with certain surface profile to control haze level of reflection and allocation of reflecting light as reflecting angle. Additionally we introduced the concept of controlling of reflecting bumpy units as reflecting direction.



(A) Pattern A (Symmetrical) **(B) Pattern B(Asymmetrical)**

Figure 1. Reflector patterns considering viewing directions

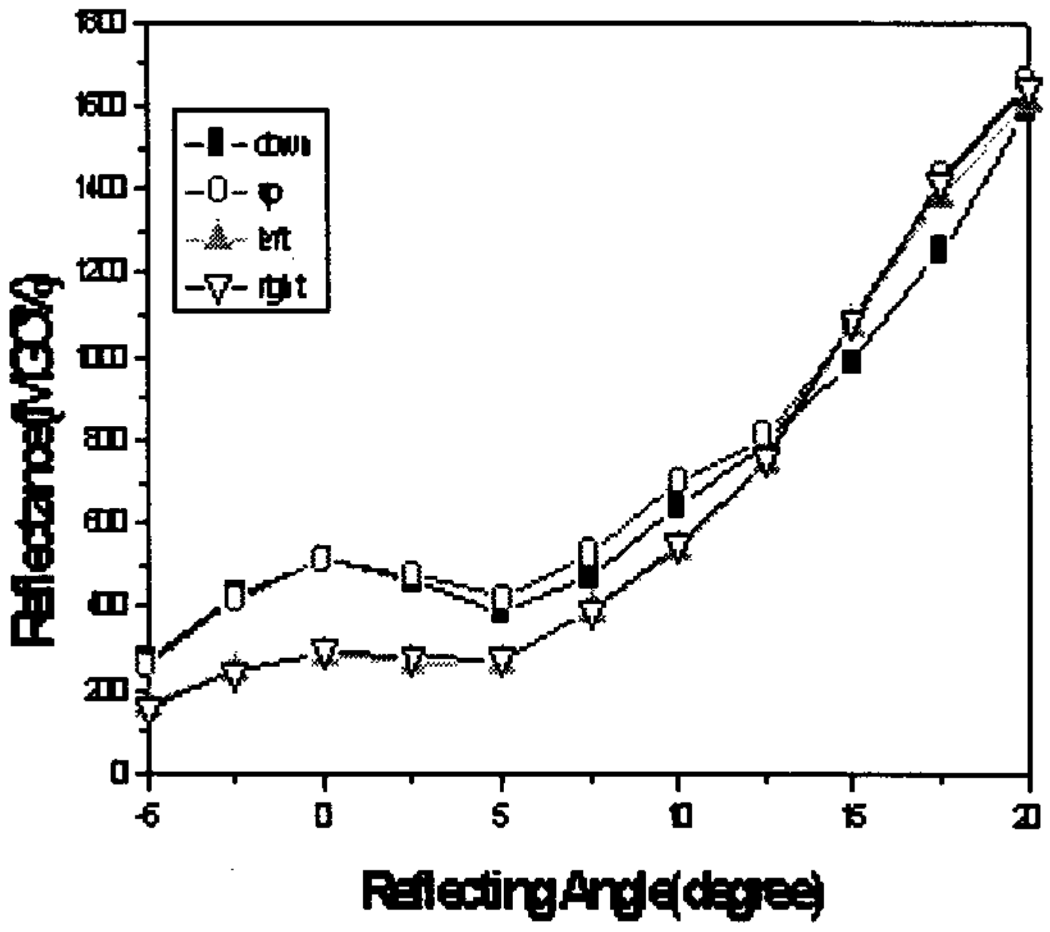
We tried two type reflectors, which are different in arrangement as directions. Reflector 'A' has symmetrical density and randomization of bumps so this has almost symmetrical reflection as viewing directions. On the contrary, reflector 'B' has asymmetrical bumps density and arrangements as directions. This pattern is intended to increase reflecting profile area along up-down main viewing direction by sacrificing reflection along left-right viewing direction.



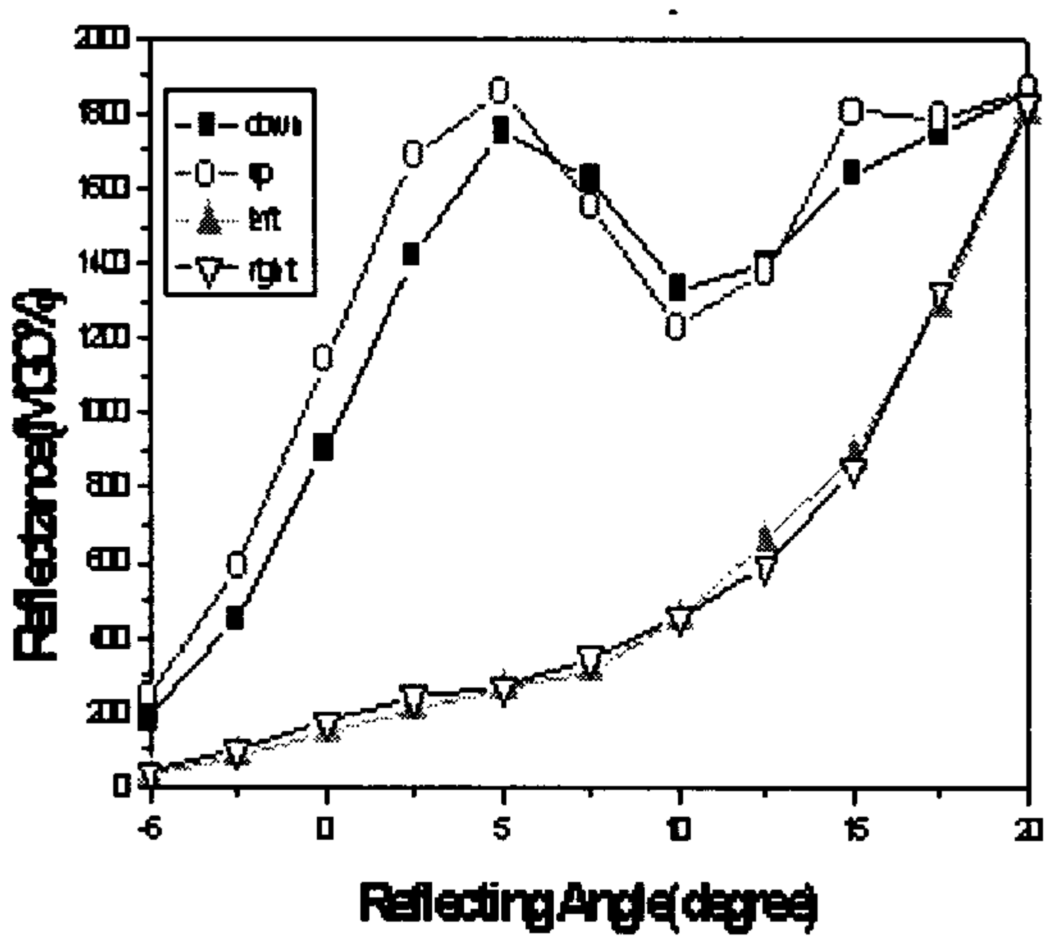
(A) Pattern A **(B) Pattern B**

Figure 2. Surface morphology of two different reflector (AFM image)

As result of this, the reflection of reflector adopting this patterns is asymmetrical. and this asymmetry of reflection as directions can be controlled with unit bumps' arrangement and distance optimization.



(A) Pattern A (Symmetrical)



(B) Pattern B(Asymmetrical)

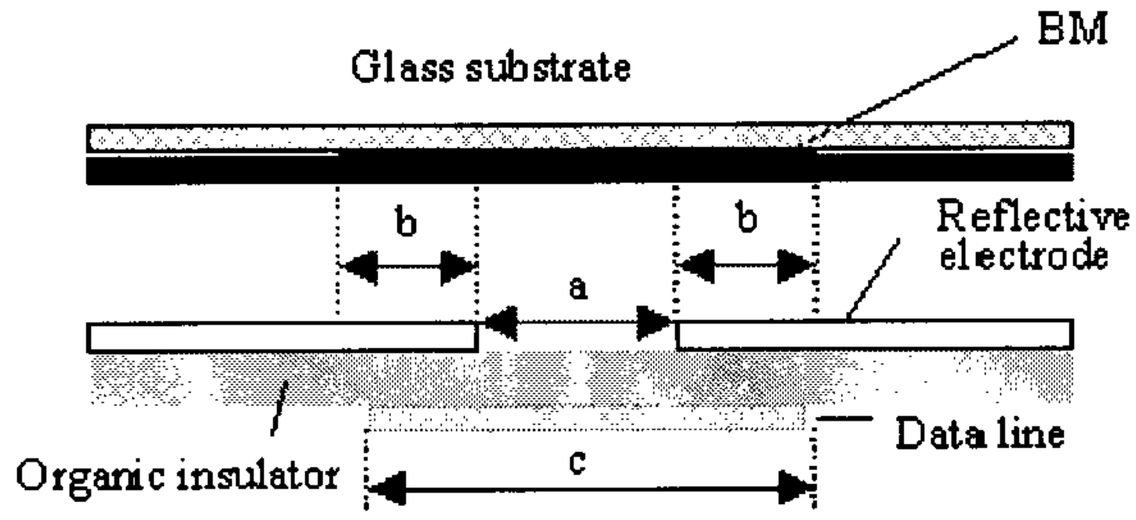
Figure 3. Reflecting properties of reflectors as adopting patterns(Under –20° incident spot light source)

3. Pixel concept for high aperture structure

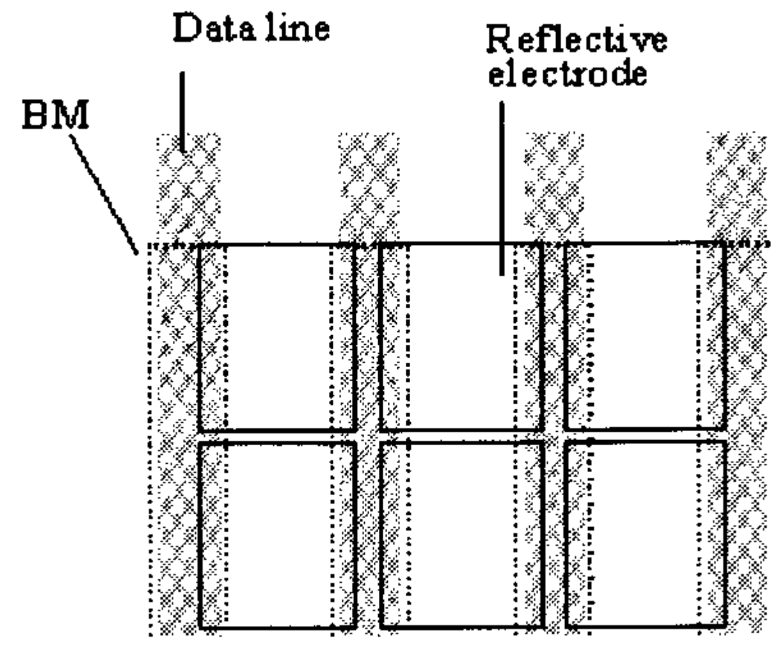
<1> High Aperture Structure

In addition to efficient reflector, a larger area of reflecting electrode within pixel area is needed for higher reflection.

To get a larger pixel electrode, conventional high aperture structure, which use organic insulator with low dielectric constant as passivation layer as shown in Figure 4, can be used.



(A) Vertical pixel concept



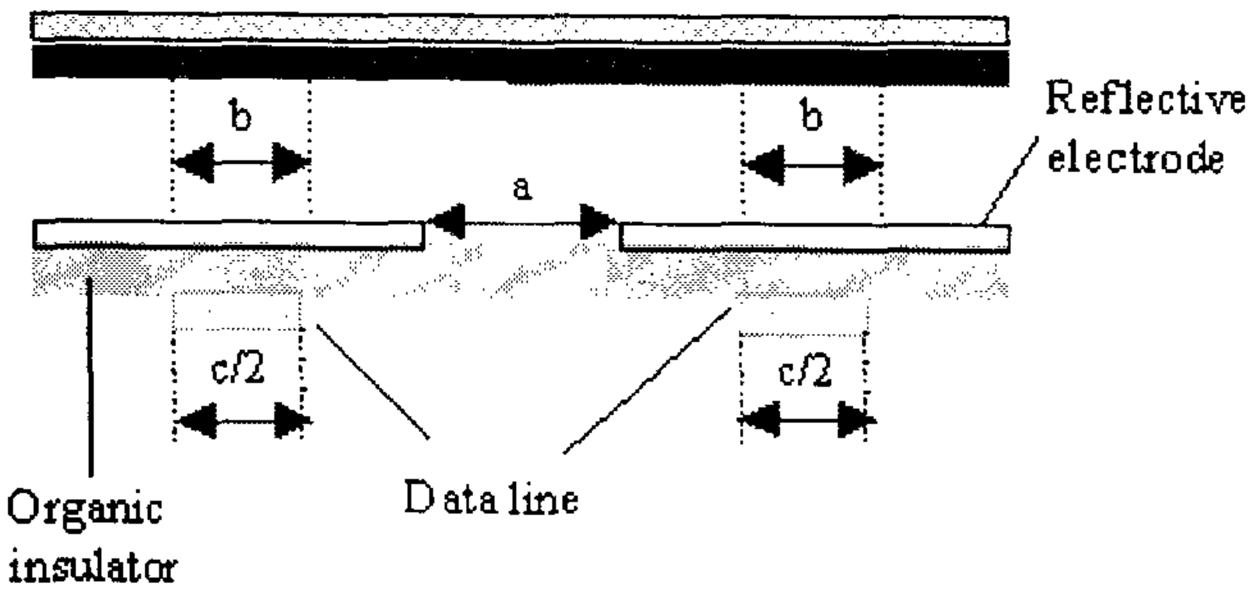
(B) Horizontal Pixel Layout concept

Figure 4. The pixel layout of conventional reflective LCD with high aperture ratio

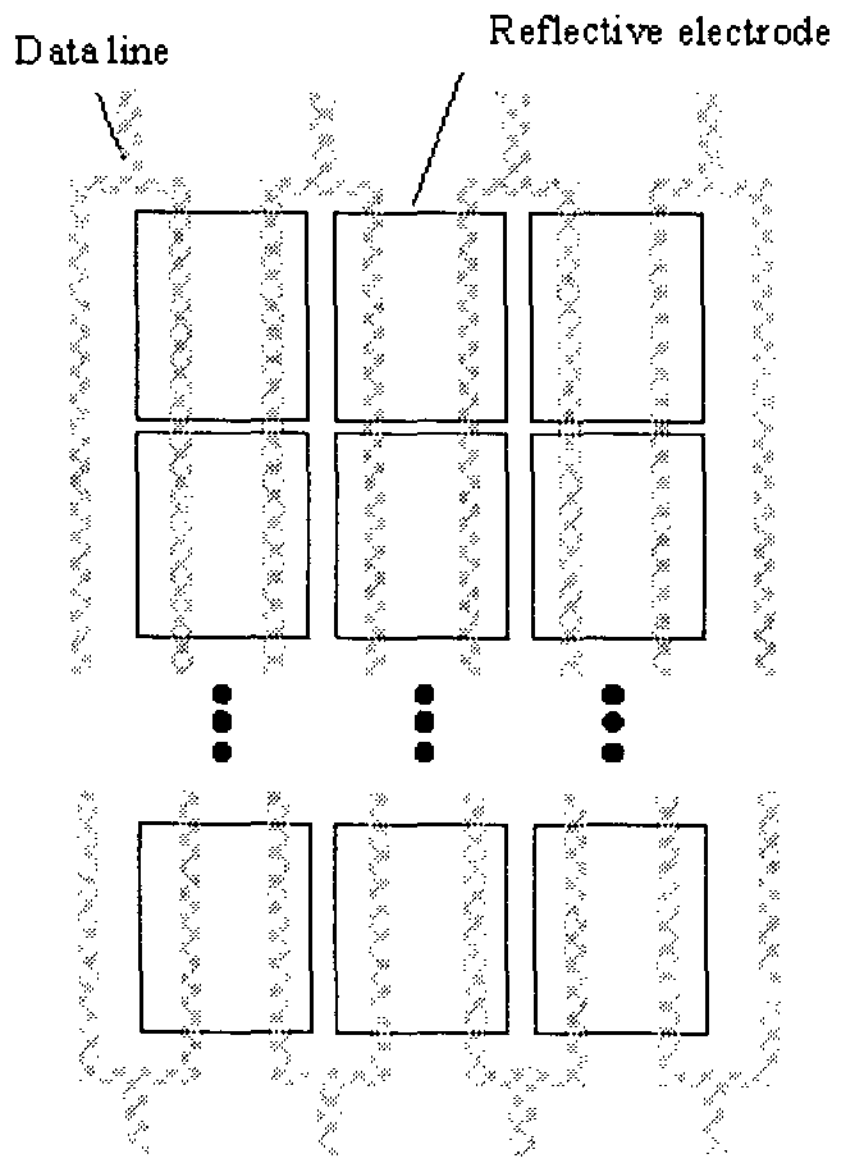
In this structure reflective pixel electrode area can be enlarged by overlapping ('b' regions) with data line metal. But, this structure necessarily needs black matrix to shield light leakage at "a" region due to uncontrolled LCs' alignment and data metal's reflection. So this black matrix limits pixel aperture ratio and reflection efficiency

<2> A new concept for higher aperture structure

To overcome this limit in high aperture structure, we suggest a new data line layout, which divides single data metal line into dual lines structure as Figure 5.



(A) Vertical pixel concept



(B) Horizontal Pixel Layout concept

Figure 5. The suggested pixel structure and data line layout for reflective LCD with high aperture ratio

As shown in figure 5, single data signal line is divided into 2 physically splitted lines and these splitted data metal lines are buried beneath reflective metal electrode. Organic material and layer thickness are optimized considering the overlap-capacity. Divided data lines overlap neighboring pixels and polarity is balanced by driving inversion. Dually divided data lines are put together at gate lines periodically. So these data lines are splitted physically but act electrically same as single line structure and electrical pixel properties do not be deteriorated.

With this pixel layout, unwanted reflection at data line metal's surface is removed by reflecting electrode metal's shielding effect. As result from this, black matrix to shield unwanted reflection is not necessary any more. So reflecting area efficiency increase (as much as 2b) and more incident light is reflected. So relatively higher reflection can be expected.

4. 3.5"QVGA Proto Type

We prepared a 3.5" QVGA (320x3(RGB)x240) fully reflective prototype adopting technologies mentioned above, 1) dual data line splitting, 2) bumpy reflector arrangements. Table 1.shows brief information of this prototype panel.

Panel Size	3.5" Diagonal
Resolution	320 X R,G,B X 240
Pixel Pitch	74umx222um
Aperture raio	93.5%
Reflectance	Up to 64% (at front angle) (-30° incident source light)
LC	LC A (Δn=0.065)
LC-mode	Low TN
Contrast Ratio	About 20:1
Driving method	Dot inversion
Driving voltage	3.3V

Table 1. Specifications of 3.5" reflective LCD prototype

This prototype has no BM and no uncontrolled light leakage at data-line metal surface. So this has super high aperture ratio (93.5%). In addition to this, the reflector is designed to have asymmetrical reflecting properties.

Based on these two main technological concepts,

we get a higher reflection up to 64% at normal reflecting angle in main direction. Figure 6. shows displaying image of prototype panel.

5. Conclusions

We could control reflection direction and reflection level asymmetrically as needed. A much higher aperture ratio and BM-less pixel layout was suggested for reflective-LCDs. Based on these approaches we get a much higher reflection in main direction and optimized displaying image as mobile and outdoor display.

Figure 6. Photograph of prototype panel

6. Acknowledgements

We would like to thank Mrs. M.S Nam, Mr.S.M. Jang, Mr.K.S.Ha, Mr.H.I.Baek, Mr. D.G. Kim, I.D. Lee, H.K. Lee and Dr. H.K. Hong kind of advice and useful discussion

7. References

[1] T.Tadokoro, T.Uchida , Proc. SID 1988, p157

[2] S.Mitsui et al , SID 1992' Digest , p437

[3] N.Sugiura et al AMLCD 94' Digest p.92(1994)

[4] N.Sugiura and T.Uchida, AM-LCD'95 digest, p.153(1995)

[5] N.Sugiura and T. Uchida SID 97, Digest, p.1011 (1997)

[6] Y.Itoh et al ,SID 98 Digest, p221 (1998)

[7] K.Tsuda et al , AM-LCD'98 digest, p.105

[8] Y.Itoh et al AM-LCD 2000, p243

[9] N.Kimura AM-LCD 01' , p 55 (2001)