Plastic LCDs for 2D-3D Convertible Mobile Phone Application

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Abstract

We first report an application of plastic LCDs to 2D-3D convertible mobile phones. Plastic LCDs are proven to be most suitable solution for filter LCDs attached on main LCDs of 3D mobile phones in terms of quality and cost wises. The design and fabrication of plastic LCD filters are discussed in this paper.

1. Introduction

Recently, flexible displays have attracted much attention because they have remarkable advantages in comparison with conventional glass displays: thinner, lighter, non-breakable and conformable features. Flexible displays have a lot of potential applications utilizing the distinct features. Among flexible displays (LCD, OLED, Electrophoretic display, and so on), plastic LCD based on flexible plastic substrate becomes a front-runner in terms of variety of applications.

Plastic LCDs using STN mode were commercialized as sub-windows of mobile phones a couple of years ago, but the long-run of the products was not realized because the display quality and production cost were inferior to those of glass LCDs. In order to activate the market of plastic LCDs in spite of the presence of the quality and cost issue, it is essential to develop killer applications, which are definitely differentiated from glass LCDs.

New applications of plastic LCDs have been developed actively since last year. Nike, for instance, commercialized a fashionable digital watch equipped with a curved and round-shape plastic LCD. The development of stereoscopic 3D shutter glass with curved plastic LCDs was also reported. [1]

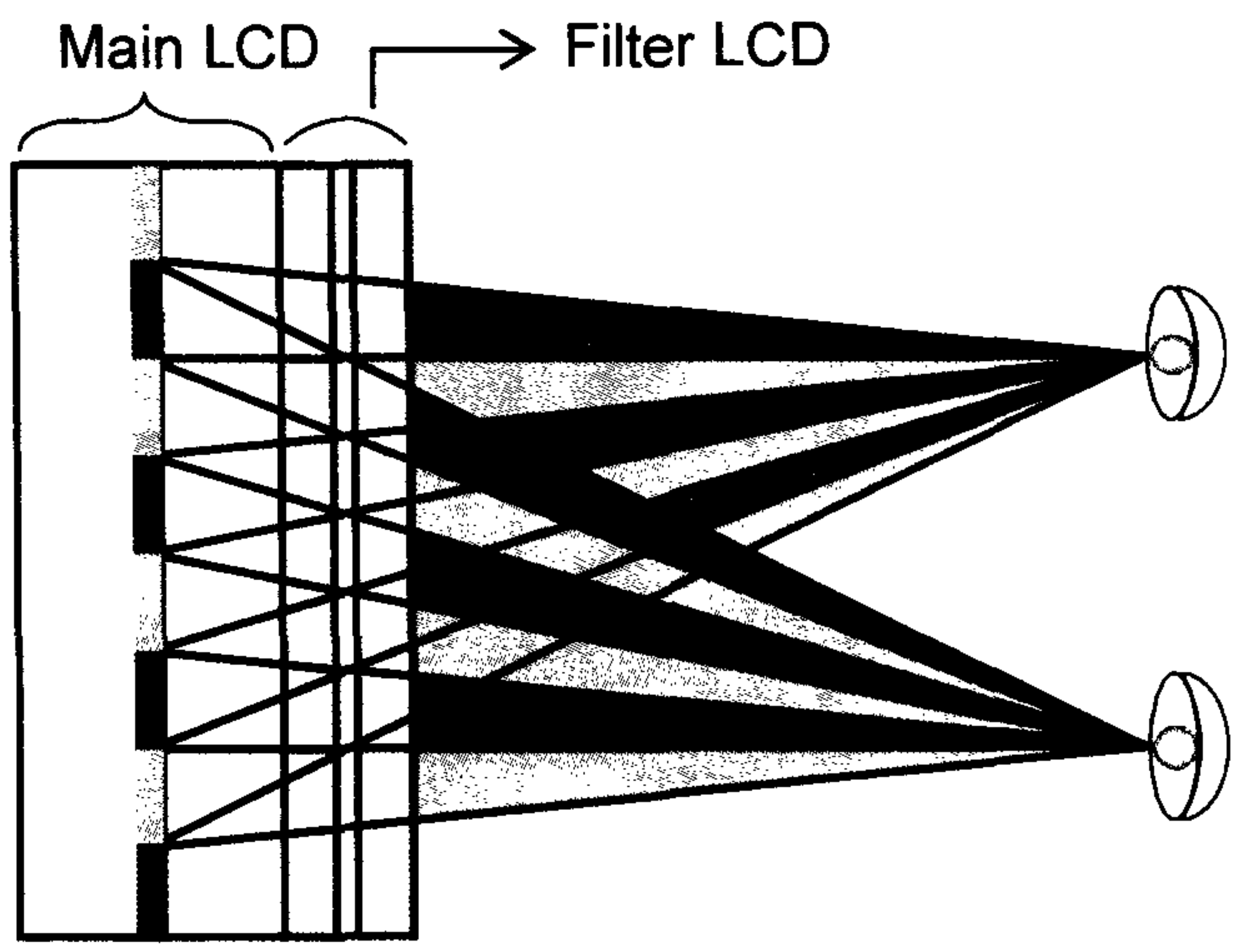
In this paper, we report a new application of plastic LCDs for 2D-3D convertible mobile phones. The key features of plastic LCD filter design for the application are discussed.

2. 2D-3D convertible LCD

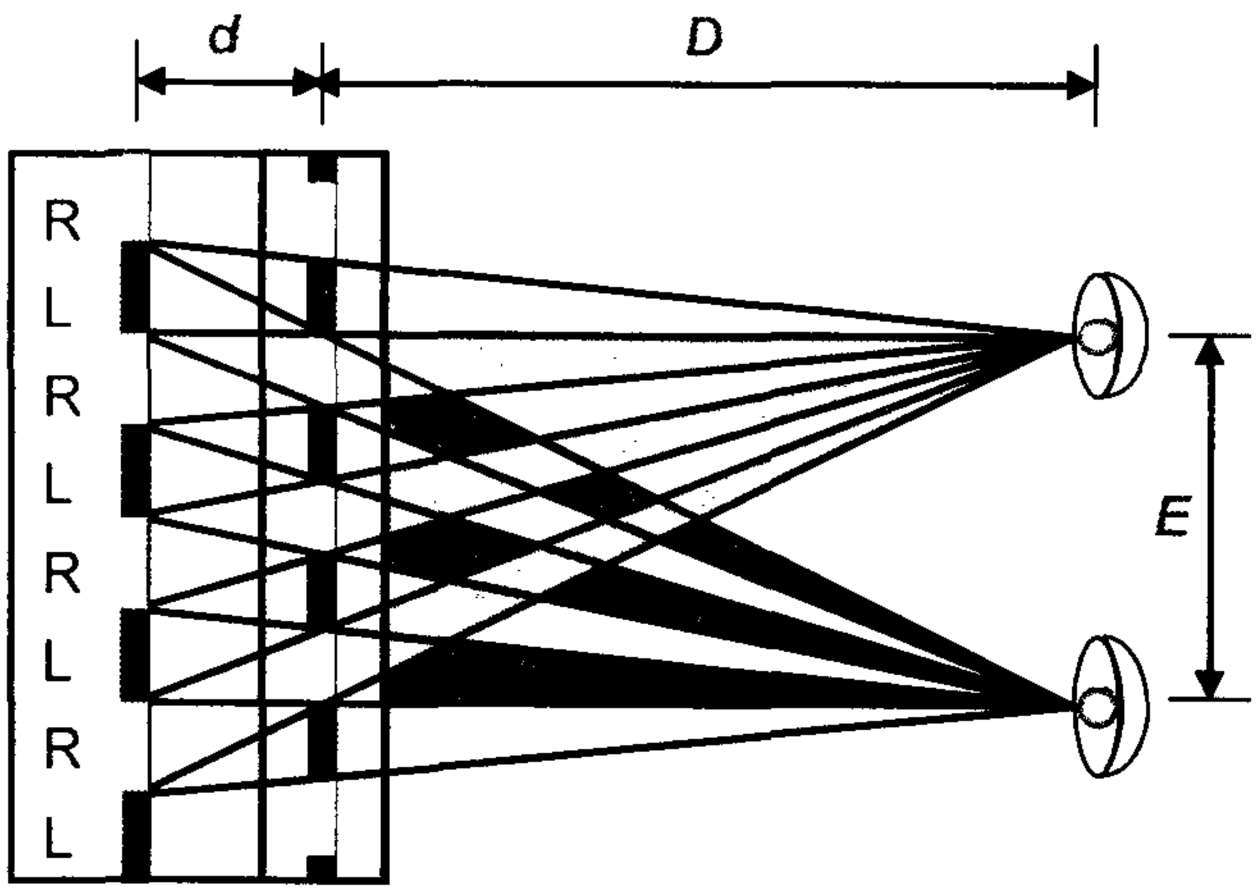
We designed and fabricated the plastic LCD filters for 2D-3D convertible mobile phones.

2.1 Configuration and Principle

Figure 1 shows the configuration of a 2D-3D convertible LCD. In this study, a conventional TFT-LCD was used as a main LCD and a plastic TN-LCD was used as a filter LCD attached on the main LCD. In order to realize a parallax barrier type 3D display, stripe-patterned electrodes were formed in filter LCD. When voltage is not applied to the filter LCD the filter LCD is transparent over whole area, so that the image of main LCD is shown as it is: 2D state as shown in Figure 1 (a). On the other hand, black stripe barriers appear when a voltage is applied to the filter LCD, so that left and right images displayed on the main LCD are visible as 3D image after passing through the filter LCD as shown in Figure 1 (b). Therefore, we can convert 2D to 3D state and 3D to 2D state in accordance with switch-on and switch-off of Filter LCD respectively.



(a) Filter LCD switch-off: 2D state



(b) Filter LCD switch-on: 3D state:

(R, L: pixels rendering the images for right eye and left eye respectively, E: distance between left and right eyes (typically 65mm), D: viewing distance between eyes and LCD, d: distance between LC layers of main LCD and filter LCD)

Figure 1 Configuration of 2D-3D convertible LCD

2.2 Design of Filter LCD

Figure 2 shows the schematic diagram of parallax barrier type 3D configuration. Given parameters d, D, E and p (pixel pitch of main LCD), black barriers were set to block lights propagating from left pixels to right eye and from right pixels to left eye: it must be required to render 3D image without cross-talk.

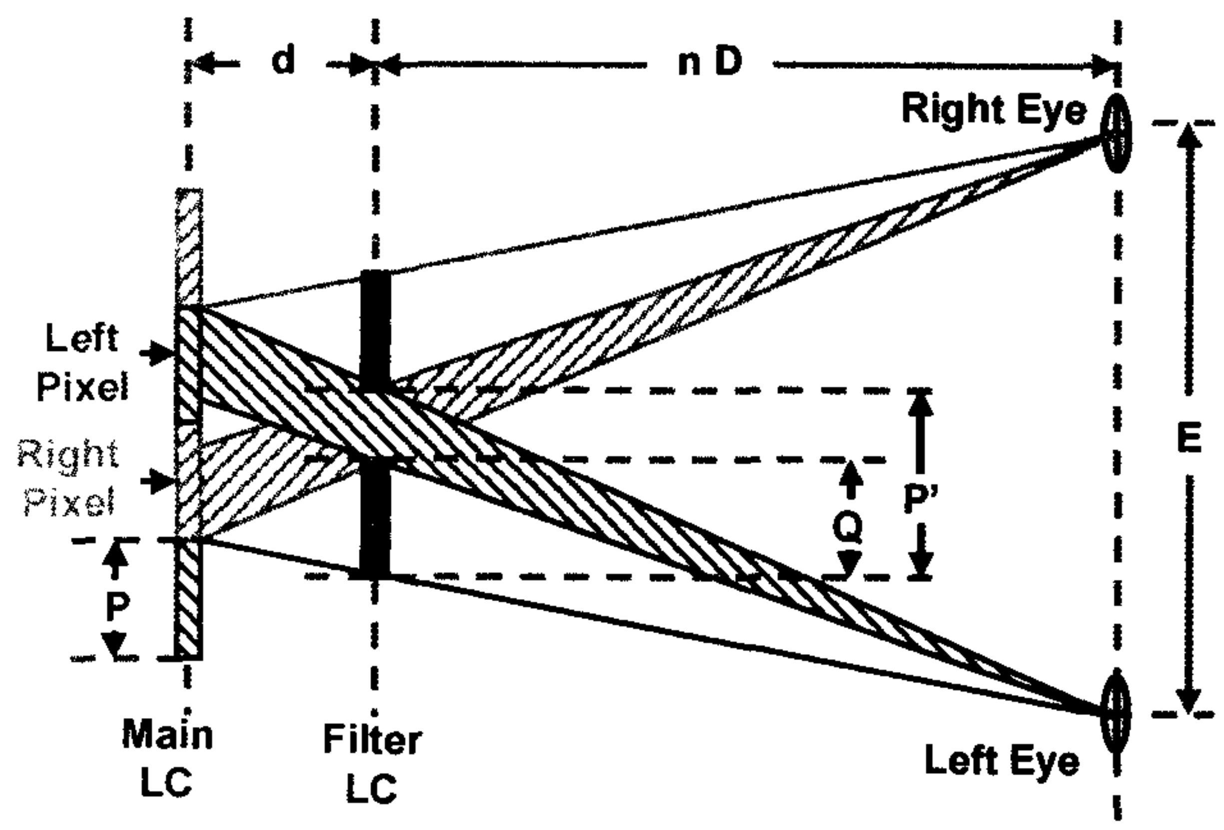


Figure 2 Parallax barrier type 3D configuration

Here, it should be noticed that D is replaced by nD, where n is a refractive index of the LC layer of main LCD, considering refraction of light.

From the geometry of Figure 2, we can derive the equations for the pitch, P' and the width of barrier, Q of the filter LCD as follows:

$$Q = \frac{Ed}{d + nD} \tag{1}$$

$$P' = \frac{2pnD}{d + nD} \tag{2}$$

From equations (1) and (2), the open ratio, x of filter LCD is given by

$$x = 1 - \frac{Q}{P'} = 1 - \frac{Ed}{2pnD} \tag{3}$$

, which is rewritten as

$$d = \frac{2(1-x)pnD}{E} \tag{4}$$

The d-x relations with parameter p for typical values D=300mm, E=65mm and n=1.5 are plotted in Figure 3.

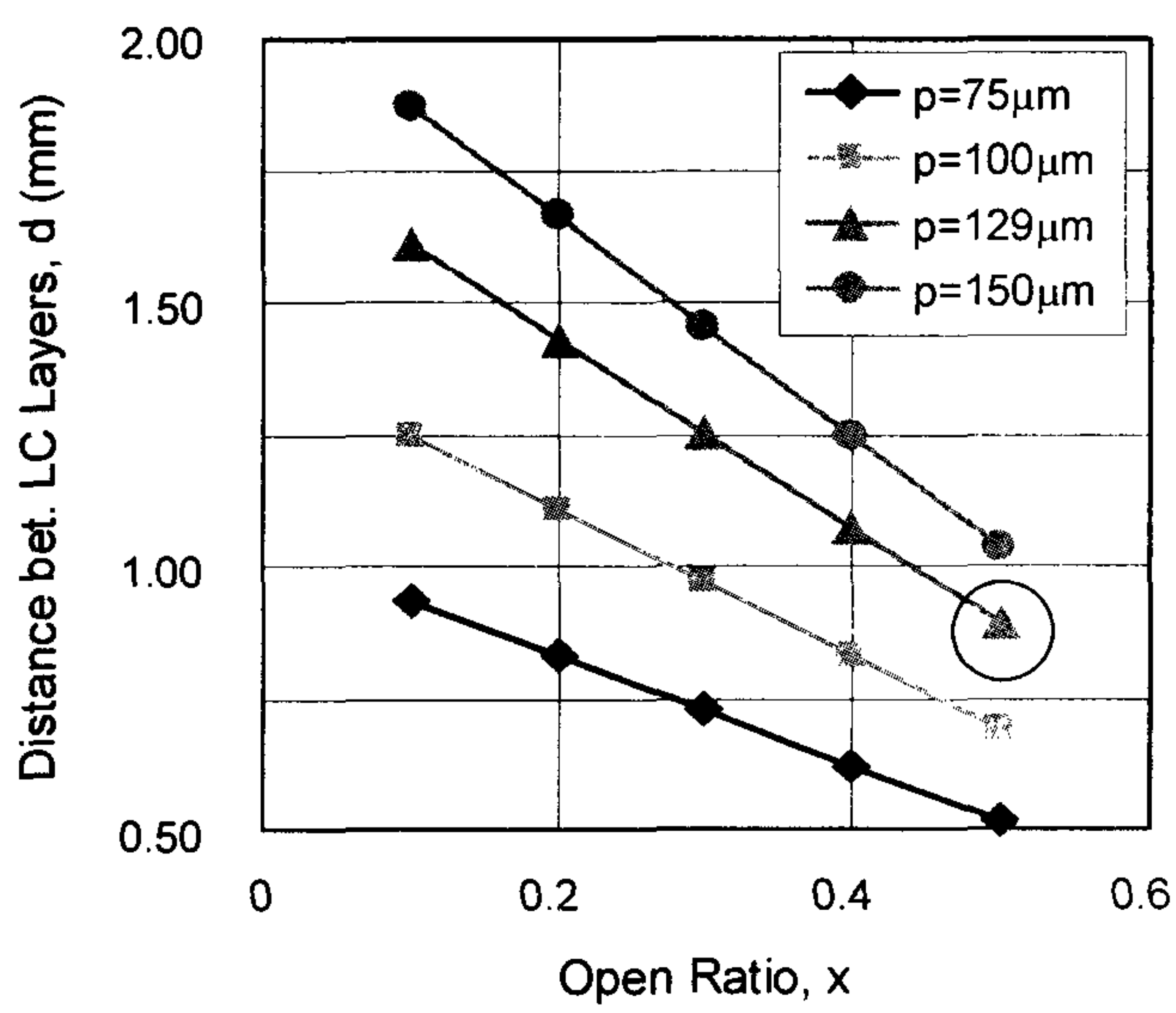


Figure 3 distance, d between LC layers of main LCD and filter LCD versus open ratio, x of filter LCD with parameter of pixel pitch, p for typical values D=300mm, E=65mm and n=1.5

From Figure 3, it is known that shorter p requires shorter d. For normal values of p (75μm ~ 150μm), d must be set as 0.52mm ~ 1.04mm to achieve maximum open ratio, which provides highest picture quality. For the main LCD and filter LCD with TN mode, d is the sum of the thickness of two substrates and one polarizer. If we consider conventional glass LCDs, d is about 1.2mm (0.5*2 for substrates + 0.2 for polarizer), so that maximum open ratio cannot be achieved. That is to say, the thickness of substrates must be reduced to achieve optimum 3D picture quality.

From the above description, it is obvious that thin plastic LCD is suitable for filter LCD providing high quality 3D image in most cases.

2.3 Fabrication of filter LCD and 2D-3D Convertible Mobile Phone

We designed and fabricated optimum plastic LCD filters corresponding to various main LCDs to achieve high performance 2D-3D convertible mobile phones.

Table 1 shows the specification of a main LCD used in our work.

Table 1 Specification of main TFT LCD

Item	Spec.
Resolution	240(RGB)×320
Pixel pitch, p(μm)	129 ×129
Panel size (mm)	35.56(H)×50.88(V)
Thickness of glass (mm)	0.5
Thickness of polarizer (mm)	0.23

From equation (4), optimum value of d corresponding to x=0.5 is calculated as 0.89mm. Considering the thickness adhesive layer between the main LCD and filter LCD, we used a plastic film with thickness of 0.12mm as a substrate of filter LCD.

Figure 4 shows the picture of a plastic LCD made for filter LCD.

Figure 5 shows an assembly process of attaching filter LCD on main LCD. Firstly, adhesive sheet was attached on filter LCD. Then, it was attached on main LCD. To assemble filter LCD and main LCD with high alignment accuracy, alignment marks formed on both main LCD and filter LCD were used.

Figure 6 shows a picture of 3D image rendered in 2D-3D convertible mobile phone sample made in this work.

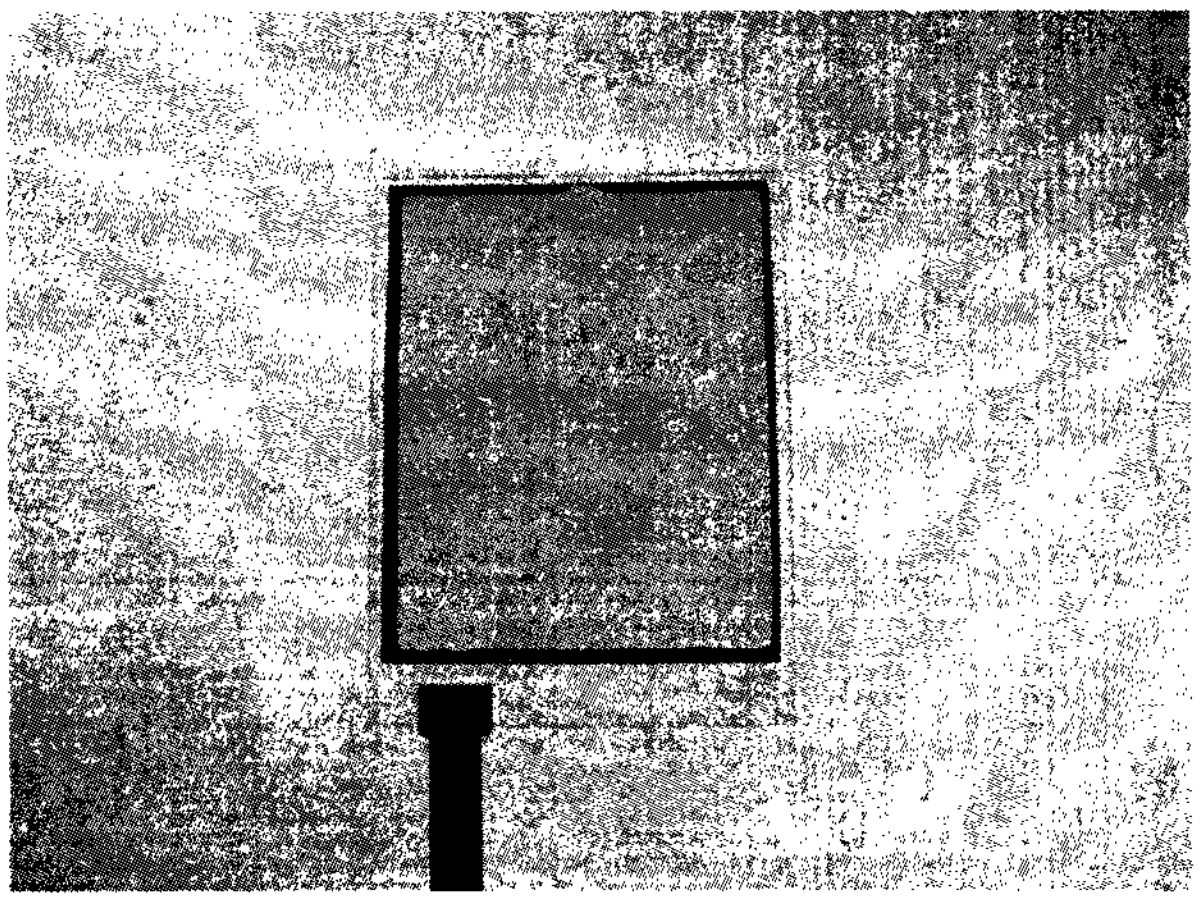


Figure 4 The sample of the 3D filter LCD

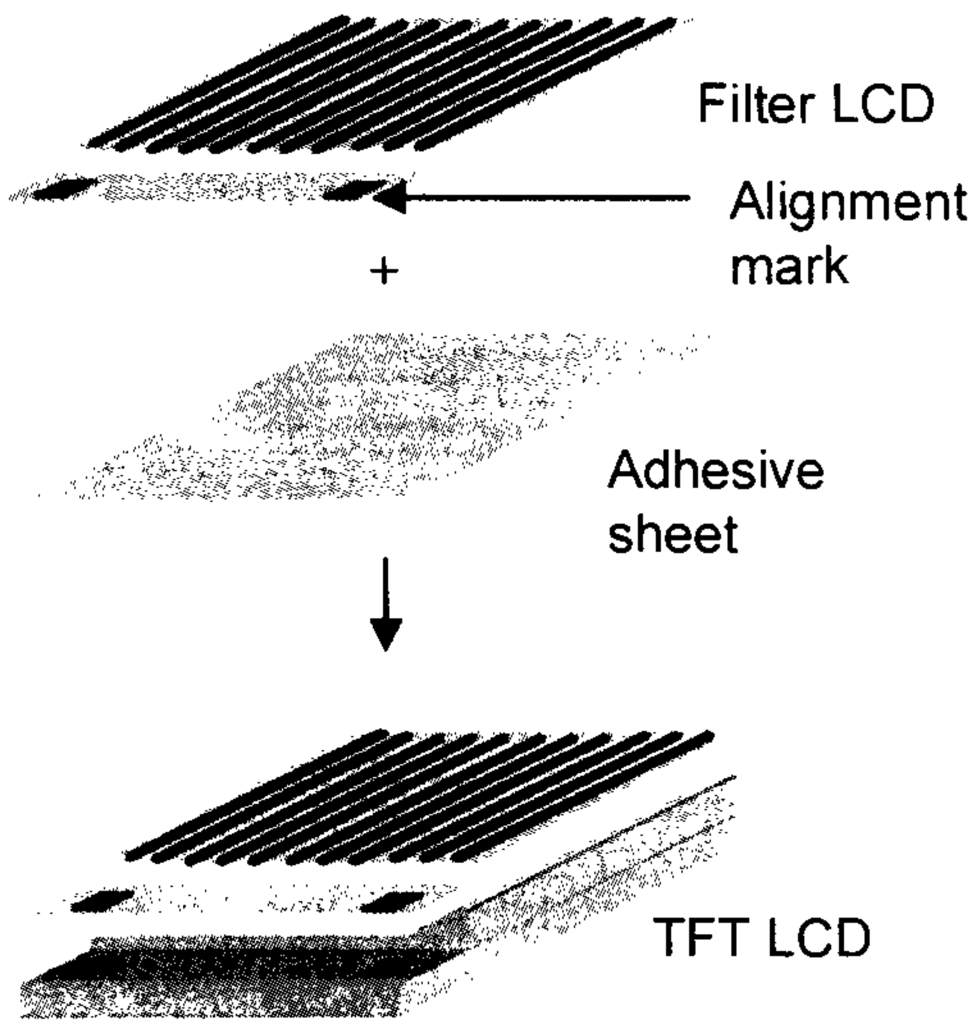


Figure 5 Assembly procedure of filter LCD and main LCD

Figure 6 2D-3D convertible mobile phone

3. Conclusion

We achieved high performance 2D-3D convertible mobile phones using plastic LCD as a filter LCD. It is believed that the new application of plastic LCDs to 2D-3D convertible mobile phones will greatly contribute to rapid expansion of emerging 3D mobile phone market because it enables to provide high quality and cost effective 3D mobile phone.

References

[1] S.-B. Kwon, S.-I. Woo, J.-S. Im, S.-K. Park, W.-M. Hwang, J.-H. Han and H.-S. Kim, *IMID,* 468 (2003).