Plastic Film Liquid Crystal Shutter and Its Application to 3D Stereoscopic Display

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Abstract

We firstly report liquid crystal shutter based on plastic film and its application to 3D shutter for stereoscopic displays. Plastic liquid crystal shutters have remarkable advantages compared to conventional glass liquid crystal shutters. They are thin, light and non-breakable so that very comfortable 3D shutter eye-wear can be realized using them. The concepts, optical performances and reliability test results of plastic film liquid crystal shutters are presented.

1. Introduction

One of the suitable stereoscopic display is liquid crystal shutter glasses adapted one. Liquid crystal devices are frequently used for displays because of their ability to selectively transmit or block light, which depends on polarization. This electro-optic effect allows them to be used in non-mechanical light shuttering application including viewing systems. In the LC shutter glass 3D display, the left and right images are displayed on the monitor alternately[1]. When the viewer looks at the monitor screen through the shutter glasses, each shutter is synchronized to sequentially transmit and block image.

Conventional LCSs(Liquid Crystal Shutters) for 3D stereoscopic displays are based on glass substrate, so that they are bulky and inconvenient for long time use. We propose plastic substrate based 3D LC shutters. The whole processes are based on our plastic LCD manufacturing process. And we achieved good optical performances and reliability. Our plastic LCSs have high transmission and fast response time which can reduce the cross-talk in the 3D display. Plastic LC shutters are in principal thinner, lighter and non-breakable as compared to glass LCSs. In addition, we can form round shapes.

Our ability to see stereo-vision comes from each of our eyes seeing a slightly different view of object. The key element in producing the stereoscopic effect is parallax-horizontal distance between corresponding left and right image point. In the LCD shutter glass 3D display, the left and right images are alternated on the monitor screen. The viewer looks at the screen through the shutter glass which is synchronized to block the unwanted image and to transmit the wanted image. Thus each eye sees only its appropriate perspective view. The left eye sees only the left image and the right eye sees the right image. This technique is often called field-sequential since sequential or alternative images contain the left and right image. The field-sequential technique applies to interlaced video systems and frame-sequential technique applies to progressive mode video displays. But the drawback of these types of stereoscopic displays is the presence of image ghosting or crosstalk. This could be minimized by achieving fast response time and high contrast ratio of liquid crystal shutter.

In this paper, we introduce plastic film liquid crystal shutter glasses for 3D stereoscopic system. And we showed the possibility of comfortable shutter glasses with good electro-optical performances.

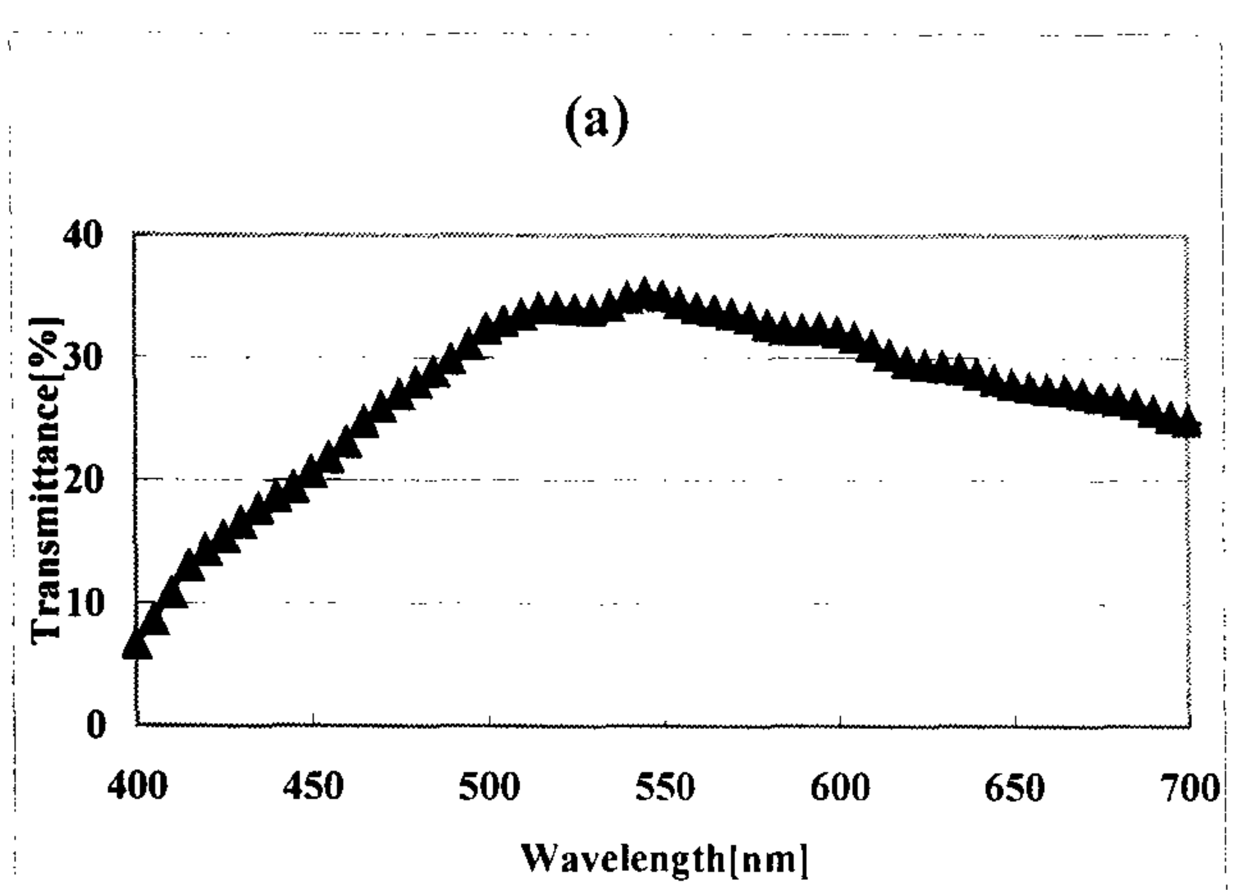
2. LC Shutter Characteristics

2.1 Dynamic range and switching speed

LCS requires fast response time and high contrast ratio for 3D stereoscopic displays. A common drawback of time-sequential stereoscopic display is the presence of image ghosting or cross-talk between two eyes. The origin of cross-talk can be classified into two factors, one is the incomplete shuttering and the other is the afterglow of the phosphors of the

CRT[2],[3]. But many NTSC and computer monitors use display tube with phosphors which have short decay time. So we concern about the dynamic range of shutter and switching time in this report. To achieve a fast switching time and high dynamic range, we designed the liquid crystal shutter with STN mode.

We achieved high transmission as shown in Figure 1. Transmittance at open shutter is 34% over visual spectrum and closed shutter transmission is less than 0.25%. The contrast ratio (open shutter transmission / closed shutter transmission) of our fabricated shutter is about 140:1. There is a concerning point in designing plastic liquid crystal devices such as shutter application and LCDs(Liquid Crystal Displays). Most of the mother plastic substrate have retardation to some degree. This factor may degrade the contrast ratio of the shutter result in ghosting in 3D stereoscopic displays. So it is needed to compensate the retardation of the plastic substrate with proper optical design. We made the rubbing direction of lower and upper substrate coincide with the optic axis of plastic substrate. Also the transmission axis of the polarizer needs to be parallel or perpendicular with regard to the optic axis of the substrate film. If the angle between the transmission axis of the polarizer and the optic axis of the film substrate is 45° in case of crossed-polarizer cell structure, the birefringent effect of the substrate film itself is maximum and light leakage is not negligible anymore. With this structure, the contrast ratio was less than 60:1 in case of PES film with thickness of 120μm. This caused ghosting image even at the low parallax value. So it is very important to compensate the birefringence of the substrate film.



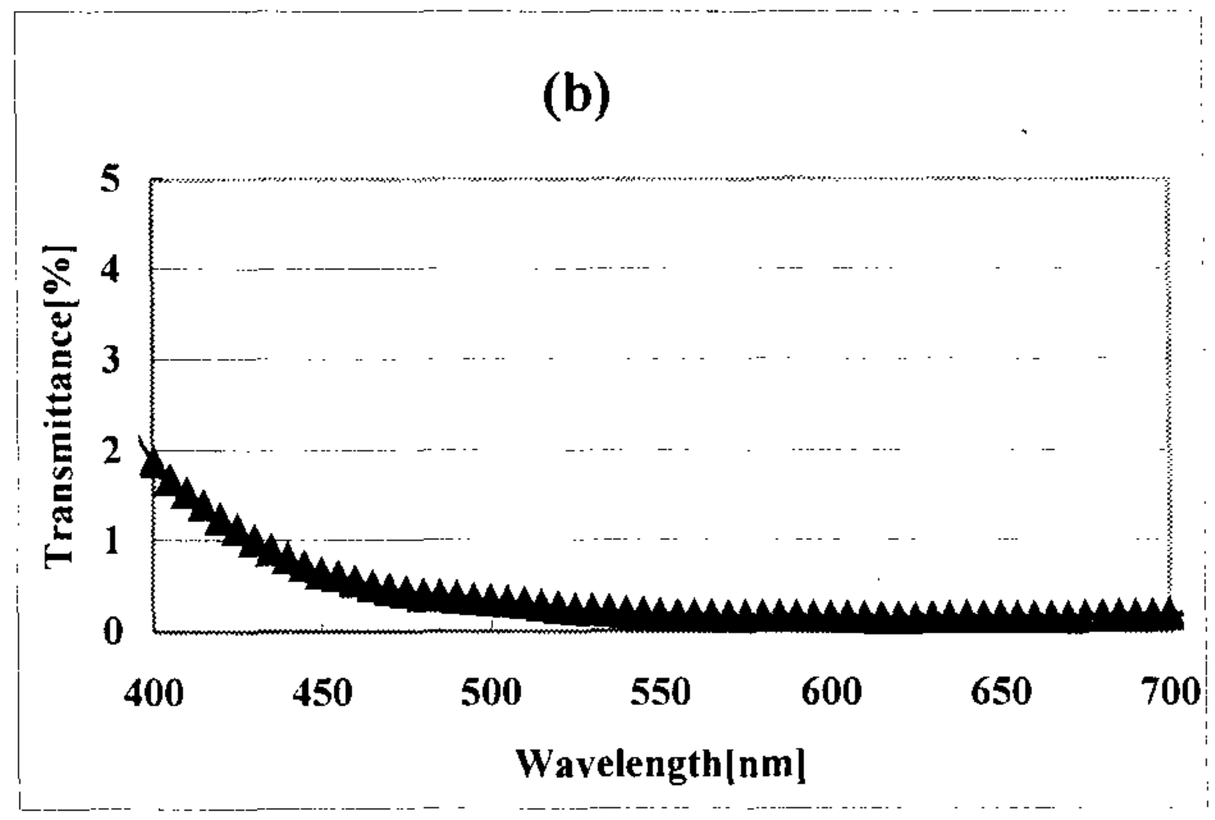


Figure 1. Optical transmission of plastic liquid crystal shutter of open shutter(a) and closed shutter(b).

Another important factor influencing the image quality is the switching time of liquid crystal shutter. The on transition time (open to close : 90% to 10%) of our cell is about 0.3msec and the off transition time(close to open : 10% to 90%) is 1.9msec(Figure 2). The lower graph is the zoomed one of upper graph. For a flickerless stereoscopic display, it is needed to write the image at twice 60fields/sec refresh rate, because each eye needs to see 60 fields/sec. The waveform to measure the response time of the shutter is square wave. The frequency is 120Hz with a carrier frequency of 1kHz, and the voltage is 10volts. As shown in Figure 2, delay time is negligible at the off transition (close to open). With the result of fast response time, it is possible to increase the average brightness of the image as expected.

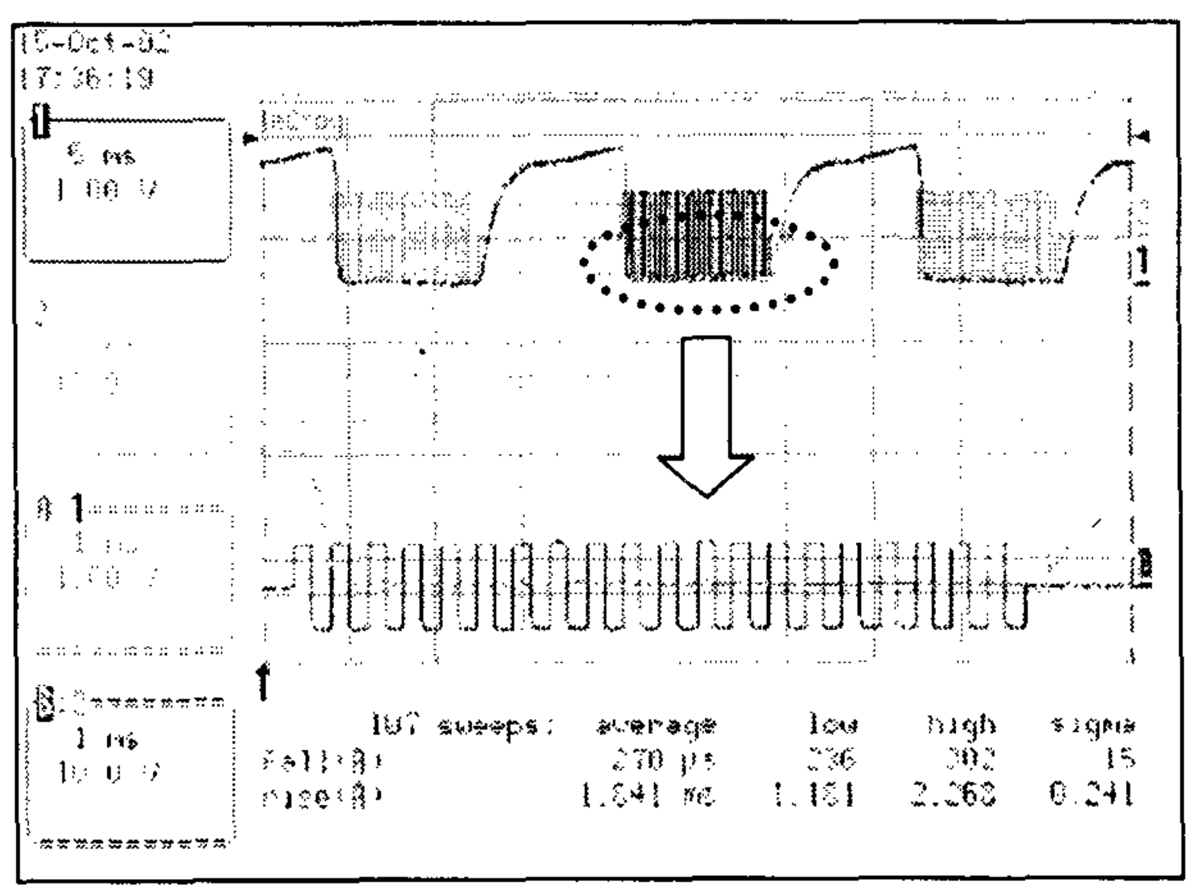


Figure 2 : Switching time of liquid crystal shutter

2.2 Reliability Test

We measured the temperature dependence of contrast ratio. To investigate the temperature dependence, we tested the plastic liquid crystal shutter at room temperature to around 70°C as shown in Figure 3. Contrast ratio is over 100:1 in all temperature range (25°C ~ 70°C). As the temperature increases, the contrast ratio decreases. So the ghosting at 70°C condition is worse than that at room temperature but the contrast of over 100 is acceptable value. The point where the change rate reaches at 10% both transmittance and contrast ratio (relative to room temperature) is 65°C.

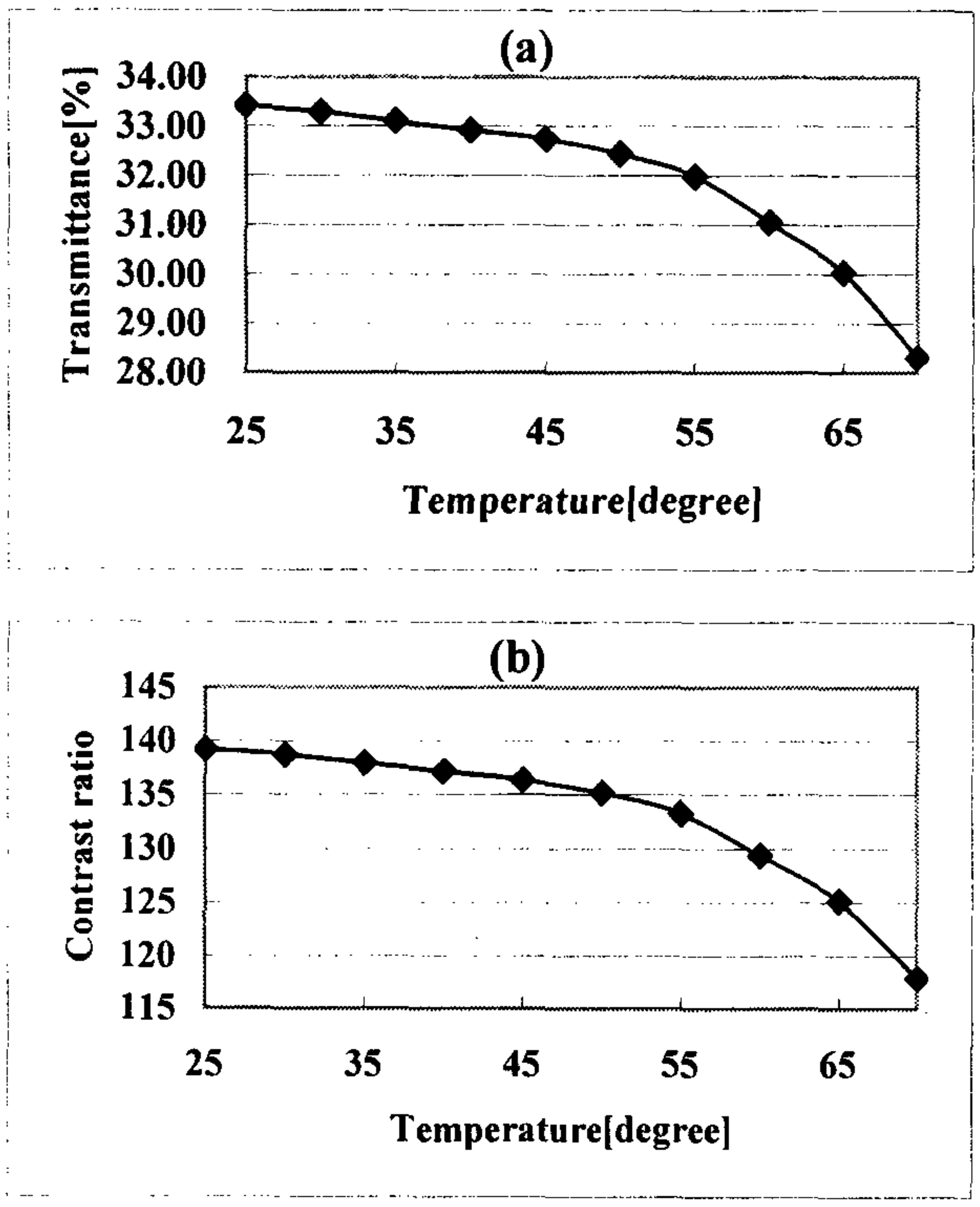


Figure 3: Temperature dependence of transmittance(a) and contrast ratio(b)

3. Prototype : *Virtual-i*

We firstly fabricated plastic film LCS for the application to 3D stereoscopic display system. So that we could realize thin, light and more robust 3D shutter glasses.

Total thickness is 0.5mm including rear and front polarizer and weight is about 0.6g for one shutter. In addition, we could achieve high transmission, high dynamic range and fast switching time. As shown in Figure 4, plastic LC shutter is very thin, so that it is very flexible in designing eye-wear. We prototyped 3D shutter goggle, *Virtual-i*™, using plastic LC shutter fabricated with our core process.(Figure 5)

It is believed that our plastic LCSs are the lightest and most comfortable, which enable to expand 3D stereoscopic market.

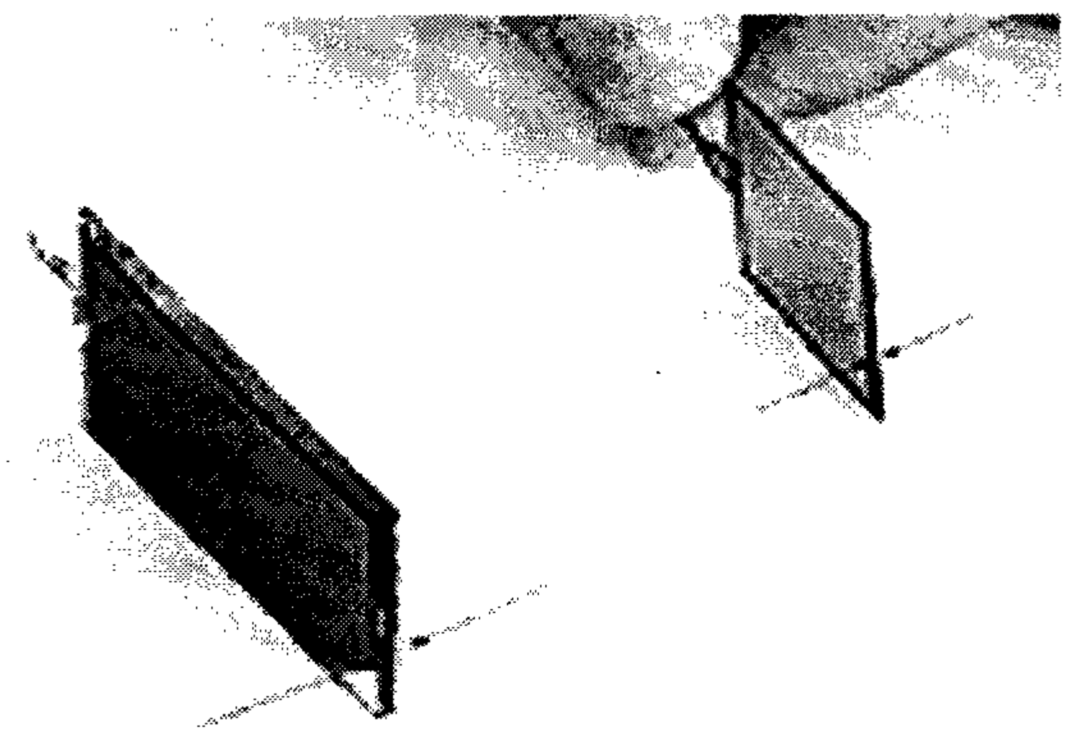


Figure 4: Comparison between conventional glass LC shutter(Left) and plastic LC shutter(Right)

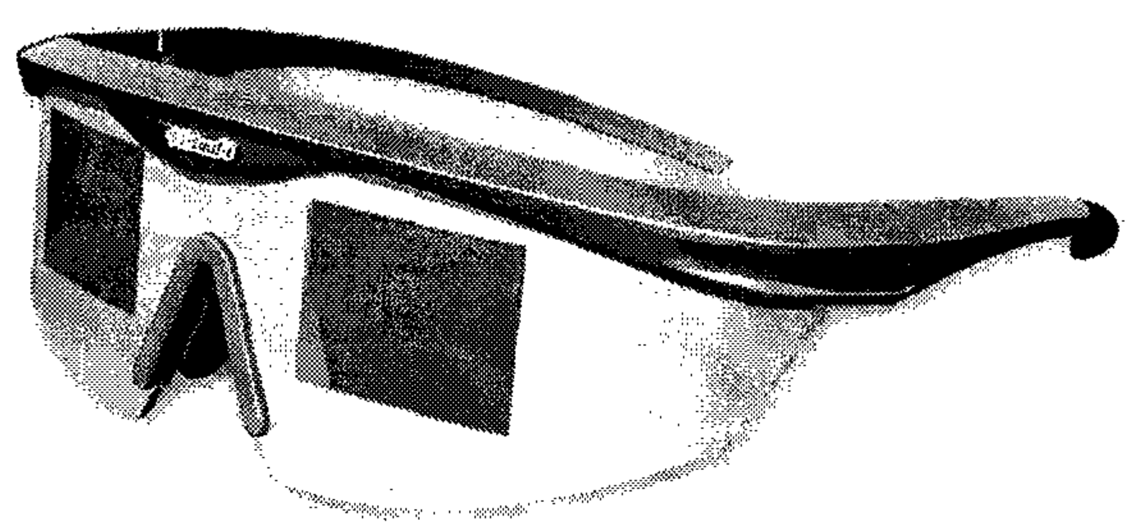


Figure 5: 3D Shutter glasses, *Virtual-i*™

4. Conclusion

These days, most of the stereoscopic displays use liquid crystal shutter these days. Glass LCDs used for stereoscopic 3D goggles are not so comfortable for long time use. It is needed to realize lighter and comfortable eye-wear. With the aid of our unique process, we could realize liquid crystal shutters based on plastic substrate. Plastic liquid crystal devices can be better solutions for 3D shutter glasses and also LCDs.

5. Acknowledgment

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6. References

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