

## Aligning Capabilities for Vertical-Alignment (VA) Liquid Crystal Display using AZO Film

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### Abstract

We have investigated liquid crystal (LC) aligning capabilities and electro-optical (EO) characteristics of transparent electrodes as Al-doped ZnO (AZO) substituting indium tin oxide (ITO). The experiment results show that a uniform vertical LC alignment on AZO electrodes based on a rubbed polyimide (PI) surface were achieved. A high pretilt angle of about  $88^\circ$  was obtained. EO performances of the VA cell on rubbed PI surfaces with AZO electrodes are almost the same as that of the VA cell with ITO electrodes. These results appeared that AZO electrodes as transparent electrodes of LCDs could substitute ITO electrodes.

**Key Words** : AZO, ITO, Vertical alignment, Rubbing, Polyimide, NLC, Transparent conducting oxides

### 1. INTRODUCTION

Transparent electrodes are indispensable for most of the flat panel display (FPD) as liquid crystal display (LCD). Nowadays, transparent conductive oxide films, based on indium tin oxide (ITO) have been widely applied to FPD such as LCDs and organic light emitting diodes (OLEDs) due to low electrical resistivity and high optical transparency[1,2]. However small amount of indium deposits increases production costs gradually and ITO film is unstable in the hydrogen plasma atmosphere in the fabrication process. Currently, Al-doped ZnO (AZO) film is regarded as an attractive candidate for transparent conductive oxides due to low resistivity, high transparency, high thermal stability, and relatively low cost[3]. Nowadays, the vertical alignment (VA) mode is one of the most using LCD mode. The major advantages of the VA cell over the other mode are the much wider viewing angle, a

uniform gray scale and reduced color shift[4-6]. Previously, VA characteristics of the nematic liquid crystal (NLC) on the various treated substrates have been reported[7-11].

In this study, we report on the feasibility of applying AZO films to display device as transparent electrode, and reported the electro-optical characteristics of VA cells using AZO electrodes as compared with ITO electrodes.

### 2. EXPERIMENTAL

Al-doped ZnO (AZO) and indium tin oxide (ITO) electrodes deposited on glass, which was made up for Samsung Corning Co. LTD were used in this experiment. The glass substrates were first cleaned with standard cleaning procedures (TCE - acetone - methanol) and then rinsed in deionized water. The AZO electrodes were prepared by rf magnetron co-sputtering method. ITO electrodes deposited also prepared for comparative study. The schematic diagram of sputter system is shown in Fig. 1. Polyimide (PI) was uniformly coated with the thickness of 500 nm on AZO and ITO electrodes using a spin-coating method. The PI layers on AZO and

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Received : 2006. 10. 27

Accepted : 2006. 11. 7

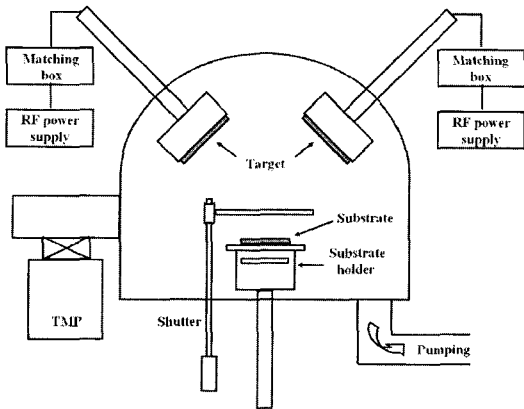


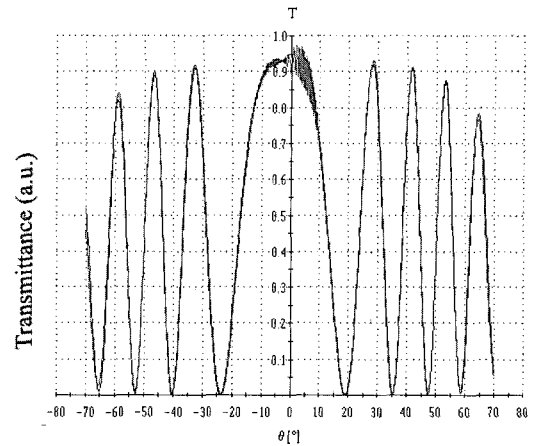
Fig. 1. The schematic diagram of sputter system used.

ITO electrodes were imidized at 140 °C for 1 hr and then the surfaces of the PI layers were rubbed by rubbing machine (rubbing strength = 0.5 mm). After rubbing, two samples were filled with a NLC ( $T_c = 75\text{ }^\circ\text{C}$ ,  $\Delta n = 0.077$ ,  $\Delta\epsilon = 8.2$ ) for VA test. The thickness of the liquid crystal cells for VA-mode and pretilt test samples were 4  $\mu\text{m}$  and 60  $\mu\text{m}$ , respectively. The pretilt angle of anti-parallel cell was measured by a crystal rotation method. LC alignment effects were observed using a polarized microscope. In addition Voltage-Transmittance (V-T) and response time characteristics of these VA-LCDs were measured by LCMS-200 (Electro-Optical Measurement, from Sesim Photonics Technology Co. LTD) equipment.

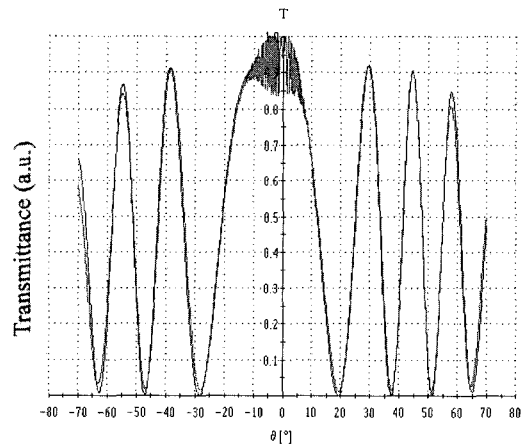
### 3. RESULTS AND DISCUSSION

Figure 2 show the microphotographs of rubbing aligned NLC using AZO and ITO electrodes. NLC cells using these electrodes showed the good alignment. Also, the LC aligning capability using AZO electrodes is the same as that using ITO electrodes.

Figure 3 shows the relationship between the transmittance and the incidence angle for NLC on the PI surface with ion beam exposure by measuring the pretilt angle using the crystal-



(a) AZO



(b) ITO

Fig. 2. The relationship between transmittance and incidence angle for NLC on the PI thin films using the two kinds of transparent electrodes (in crossed Nicols).

rotating method. A shift of symmetric point from point 0 was measured on the PI thin films with AZO and ITO electrodes. The calculation shows that the pretilt angles are AZO : 87.8°, ITO : 86.2°, which is considered to be a perpendicular pretilt angle. In the result LC cells which were AZO and ITO films show vertical alignment.



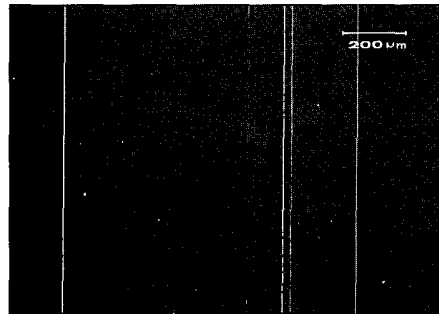
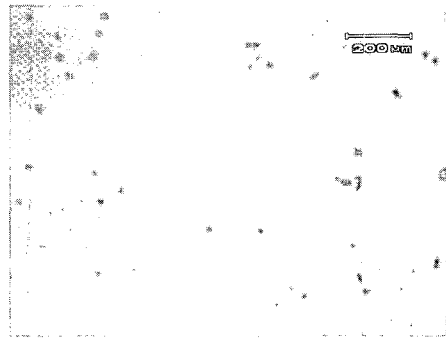
(a) AZO



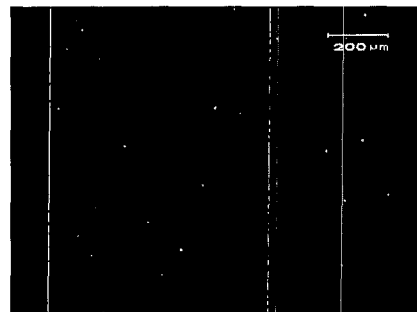
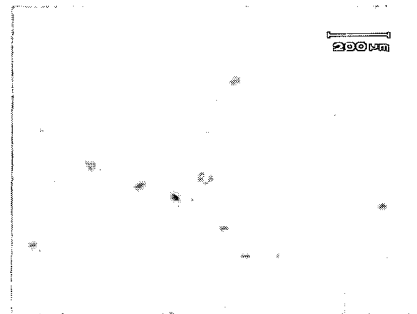
(b) ITO

Fig. 3. Micrographs of the rubbing aligned cells using the two kinds of transparent electrodes(in crossed Nicols).

The microphotographs show the operations of the rubbing-aligned VA cells using AZO and ITO electrodes as shown in Fig. 4. When the electrical field is applied to the cells (on-state), LC aligned perpendicular to the direction of the electric field. Thus, Liquid crystal polarized light, both the VA cells clearly transmit the visible light generated from backlight units (the observed black spots in the figure are due to the spacers). In the off-state, the light transmission is prohibited resulting in dark images, which indicates the mono domain alignment of the NLC in both the VA cells.



(a) AZO



(b) ITO

Fig. 4. Microphotographs of VA cell using the two kinds of transparent electrodes(in crossed Nicols).

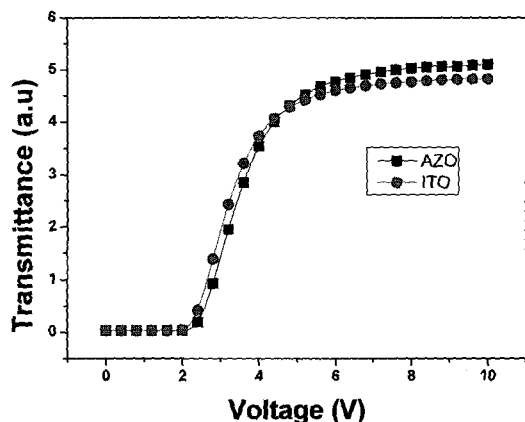


Fig. 5. V-T curve of two kinds of VA-LCD on the rubbed PI surfaces with different transparent electrodes.

Figure 5 shows the V-T characteristics of both the rubbing-aligned VA cells on the AZO and ITO electrodes. In Fig. 5, threshold voltages at the transmittance of 10 % are 2.49 V and 2.44 V for AZO and ITO electrodes cells, respectively while voltages at the transmittance of 90 % are 5.13 V and 4.97 V for AZO and ITO electrodes cells, respectively. The slopes of V-T curve in the transmittance range of 10 to 90 % are almost identical for both the cells. It is noted that the threshold voltage of the VA cells with AZO electrodes is higher than that of the VA cell using ITO electrodes. It is relevant to the resistivity of AZO electrodes is higher than that of ITO electrodes.

Figure 6 shows the response time characteristics of the rubbing-aligned VA cell using AZO and ITO electrodes. The response time of AZO electrodes VA cell is 21 ms (rising time : 9.8 ms, decay time : 11.2 ms) while that of ITO electrodes VA cell is 18.9 ms (rising time : 8.1 ms, decay time : 10.8 ms). Both cells showed fast and stable response time characteristics.

#### 4. CONCLUSION

In this article, LC alignment effects and generation of pretilt angles with homeotropic polymer,

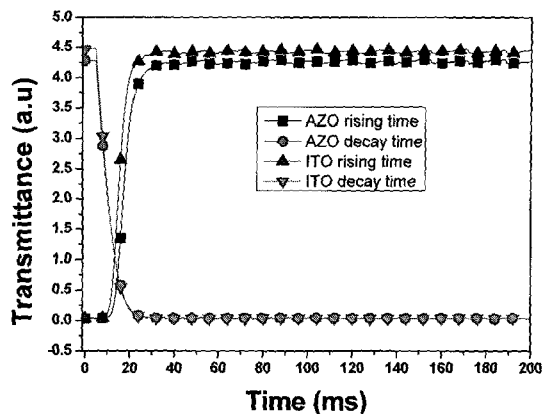


Fig. 6. Response time characteristics of the VA-LCD on the rubbed PI surfaces with different transparent electrodes.

the EO performances of the rubbing aligned VA cells using AZO in comparison with ITO electrodes were studied. The VA cells employing AZO electrodes showed the monodomain alignment and the pretilt angle generated obtained 88°. The good V-T curves were observed for the rubbing aligned VA cells using AZO electrodes in comparison with ITO electrodes. Also the fast response time characteristics can be achieved for the rubbing aligned VA cells using AZO electrodes in comparison with ITO electrodes. It was found from the results that AZO electrodes as transparent electrodes of LCDs could substitute ITO electrodes.

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