23" LCD TV by using ALT plasma beam alignment technology

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ABSTRACT

The alignment of liquid crystal (LC) is one of the key issues of liquid crystal display (LCD) technologies. In this study, we aligned polyimide (as the LC alignment layer) by ALT plasma beam and to realize the stability and characteristics of this technology. The characteristics such as anchoring energy, pre-tilt angle, voltage holding ratio(VHR) and residual direct current(Rdc) were discussed. Besides, we applied it to the in plane switch (IPS) mode 23" WXGA real panel, the performance parameters and electrical properties were measured and compared with those of rubbing alignment. From the result, we demonstrated a successful LC alignment treatment process in real panel by ALT plasma beam.

INTRODUCTION

The most common technique of LC alignment is an unidirectional rubbing on special polymer films. The rubbing process involves rubbing the polyimide film with a cloth attached to a rotational roller. This process may cause damage to the TFT devices and the bus lines through mechanical and electrical static discharge (ESD). It also creates cloth-fiber particles and polyimide flakes which must be removed by post-rubbing cleaning, increasing the number of process steps. However, the rubbing process causes surface deterioration, generation of electrostatic charges and dust on the aligning surfaces. Besides, it is not a good way to be applied on the large-area flat panel display for the poor yield rate. Replacement of the rubbing process with a more controllable and cleaner process is strongly desired.

A number of non-contact LC alignment methods have been proposed in attempting to replace the rubbing process. Among them, a well-known approach to non-mechanical planar or tilted planar alignment by using flux of low energy ions (50-300 eV) on the polyimide film was developed by IBM. The principal advantage of this innovation was that the ion bean affected only the top layer of the alignment film. Secondary non-contact alignment technique, named photo-alignment method, in which light irradiation caused surface anisotropy was studied for many years. This method was relatively simple, but the corresponding strength of alignment, qualified by the anchoring energy coefficient, was relatively weak. Besides, some photo-aligned substrates had poor photo and thermal stability, even though a deep UV treatment has been introduced. Third non-contact alignment process named plasma beam alignment (PBA) technique was used in this study, in which the aligning substrate was treated with a flux of plasma that was extracted and accelerated. The feature of this process consists in the oblique treatment of LC aligning substrates with a directed flux of plasma (atoms, ions, electrons or mixtures thereof), which treat on the substrate [1-3] or etch it [4,5]. Avoiding mechanical contact with the aligning substrate, PBA methods could minimize surface damage and contamination. Simultaneously, the alignment uniformity was improved and the pattering of LC alignment was simplified. That is the reason why the PBA is a very promising candidate to replace the traditional rubbing procedure in the next generation. To realize LCD modes in commonly used, strong anchoring energy ($W>10^{-4}$ J/m3) and small pre-tilt angle ($\theta<7°$) are required.

In this study, The performances of 23" WXGA IPS mode real panel were checked to realize the stability and characteristics of this process. We measured the physical properties of pre-tilt angle, voltage holding ratio (VHR), residual direct charge (Rdc), surface anchoring energy. These physical properties were compared and discussed with those of rubbing alignment.

EXPERIMENTAL

Polyimide SE-5310 is commercial product, which is designed for LC alignment by rubbing process for an application of the IPS mode. The film is deposited on glass substrates coated with indium tin oxide. The thickness of the PI film is about 30 nm. The PI layer has high transmittance at short wavelengths around 380nm.

The irradiation set-up is based on anode layer thruster (ALT) [6,7] specially designed to produce collimated flux of ions from practically any gaseous feed. The latter one is suitable to treat large-area surfaces by tilting the source. The dose and incident angle were tested of the Plasma beam condition and the optical anisotropy of the surface was measured. Higher anisotropy of the Plasma irradiated, it can be get better performance of LC alignment.

The anode layer thruster with the race track shape of the discharge channel and argon as a working gas were introduced in this work. The Ar+ ions mechanism is non-reactive etching on the aligning substrate. The pressure P in the source chamber was 10-3 ~10-5 Torr, and the current density j of Ar+ ions were determined. The distance between the plasma outlet and the irradiated substrate was about 5-15 cm. The source was irradiated slantwise. The plasma beam incidence angle was varied between 0° (normal to the substrate) and 80°.

We have replaced the rubbing roller by a low-energy ALT plasma source, available commercially. There is thus no need to wash a rubbed surface to remove debris or to bake it in a furnace to remove the effects of washing. There is also no reliability issues associated with the unpredictable local degradation of the roller. We have manufactured 1 mega pixels displays using in-plane switching mode (23-inch) in LCD TV

RESULT AND DISCUSSIONS

Table 1 shows the experiment parameters of the plasma beam align process. The substrate with a dimension of up to 550x650 mm^2 can be treated by the current system. The plasma beam incident angle can be adjusted to the range between 0°~90° and was set between 10°~70° in this study. The chamber was evacuated to a base pressure of approximately 10^{-5} torr. The monomer flow rates were controlled by a mass flow controller with a flow rate between 0 to 100sccm and the working pressure was set in the range of 10^{-2}~10^{-4} torr.

Items	Specifics
Substrate size	550x650 mm^2
Base pressure	~10^{-5} Torr
Working pressure	10^{-2}~ 10^{-4} Torr
Power	0~1000 V
Working gas	Ar, N_2, H_2 and etc.
Flow rate	0~100sccm
Plasma beam angle	10°~70°
Velocity	0~100 mm/s

Table 1 The experiment parameters of the plasma beam aligned process

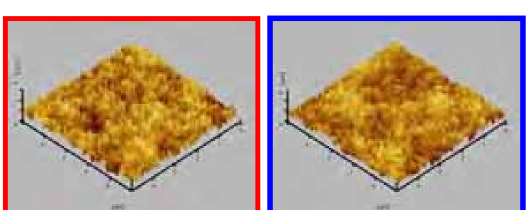

Fig. 1 The AFM images of the PI film (a) before and (b) after plasma beam aligned.

Figure 1 show the AFM images of the PI film before and after plasma beam aligned. For the untreated PI shown in Fig. 1(a), it can be seen that the topography is very smooth with a root-mean-square roughness of only 0.22nm. After plasma beam aligned (Fig. 1(b)), the morphology was almost similar to compare with the raw material and the roughness was also in the same value (0.22nm). For the mostly common technique performed to obtain the liquid crystal alignment was rubbed the alignment film to induce micro-grooving. Then the liquid crystal will parallel or perpendicular to the direction of the process. Otherwise, the plasma beam alignment method has no micro-scratches comparing with the cloth rubbing method. According to this result, we suggest the mechanism of sputter etching or ion bombarding was not the major influence of the plasma beam alignment.

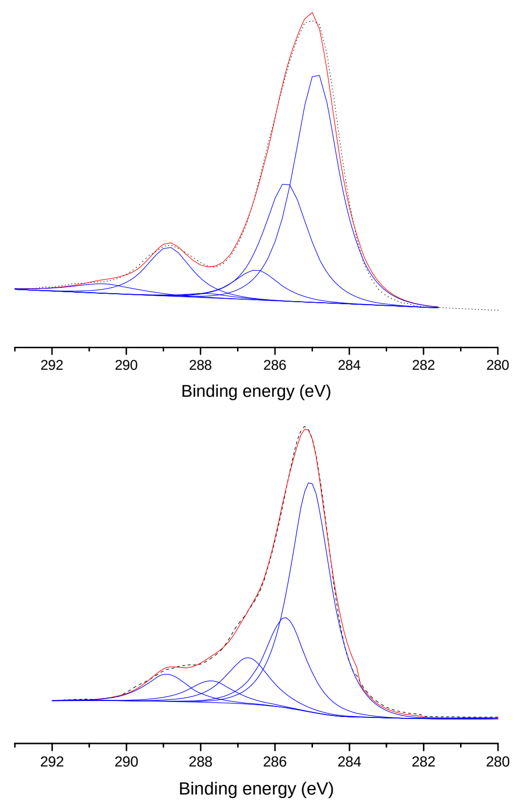

Fig. 2 C1s core-level XPS spectra of (a) the blank and (b) the plasma treated PI.

The XPS C1s core level spectra of the PI before and after plasma beam alignment were shown in figure 2. For the spectra taken before aligned (Fig. 2(a)), the component peak at 284.8eV is attributed to the carbon atoms of benzene rings, and this is the criterion for correcting the binding energy scale. The component peak at 285.7eV was major ascribe to the C-N of the imide ring. The peak of 286.5eV corresponds to a C-O single bond and binding energy at 288.5eV corresponds to carbonyl carbon (C=O) in imide ring. Figure 2(b) shows the spectra taken after plasma beam alignment. It can observe that both of the intensity and configuration of the component was changed. For the peak at 288.8eV, the intensity decreases to compare with the blank one. This is related to the reduction of oxygen in carbonyl groups. Besides, the intensity of C-O at 286.5eV increased, indicating the destruction of the raw materials. Thus, we suggest the alignment by plasma beam may be due to the breakdown of π-bonds of the imide rings, phenyl rings and carbonyl groups and the alignment mechanism obtained using a plasma beam alignment might be different form that obtained rubbing because no grooving effect and topography change was observed.

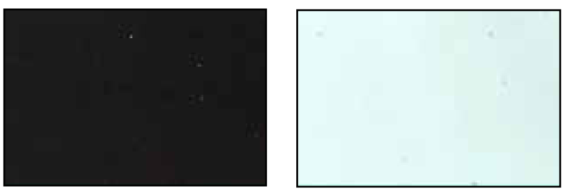

Fig. 3 The POM micrographs of the substrate treated with plasma beam alignment

Figure 3 shows dark-state and bight-state POM micrographs of the LC cell constructed with a plasma beam alignment process. For the previous reports indicated that the rubbing process may produce streaking defects. Otherwise, excellent LC alignment without grooving effect was observed via plasma beam exposure as shown in this picture. It can illustrate that plasma beam exposure was suitable for LC alignment.

Specimen	Pre-tilt angle (deg)	Anchoring energy (J/m^2)	VHR(%)	Rdc(mV)
P1	1.22	$1.46x10^{-5}$	96.78	125
P2	1.32	$1.49x10^{-5}$	96.16	95
P3	0.65	$1.04x10^{-5}$	97.11	106
P4	0.71	$1.00x10^{-5}$	95.04	123
R1	1.346	$2.08x10^{-4}$	96.42	102
R2	1.323	$1.12x10^{-4}$	93.61	83

Table 2 The pretilt angle, anchoring energy, VHR and Rdc of the specimen treated with plasma beam (P) and rubbing (R) process.

Table 2 shows the pretilt angle, anchoring energy, VHR and Rdc of various samples treated with three different recipes. P1, P2 are treated with same parameters, same with P3, P4 and R1, R2. The experimental result of the test cells shows that the control of the pretilt angle is possible and can ranges between 0.5 to 1.5 degree. Thus, the plasma beam can be applied to liquid crystal with a low pretilt angle such as IPS or TN mode. The anchoring energy of the plasma beam aligned LC cells was also listed in Table 2 and the value of these date were at the order of 10^{-5} was lower then one order of rubbing method. Otherwise, VHR and Rdc were similar to that of using rubbing alignment respectively. The values performed by plasma beam are much larger than those (~10^{-7}) measured for rubbed polystyrene films [8], but are lower about two order than those observed for the rubbed films of conventional PIs currently used in the LC display industry [9,10].

Fig. 4 Photograph of the first TFT-LCD panel (23-inch) performed by plasma beam aligned technique in the world.

Figure 4 shows the photograph of the real panel with a dimension of 23 inch. It was fabricated by the 2nd generation equipment designed by ITRI in Taiwan. Since the apparatus is based on anode layer thruster (ALT) which can produce collimated flux of ions from the ionization gas and has been used on satellites for the near-term propulsion. This type of sources is also used in a variety of plasma etching and plasma deposition systems. Otherwise, to compare with the ion beam aligned technique it possessed the characteristics of lower price, dimension enlarges ability, fairly low static electric effect and the component is east to fabricate.

CONCLUSIONS

We measured the parameters and electrical properties of LC cell which is aligned by ALT plasma beam technology. It was found that the pre-tilt angle, VHR and Rdc were similar to that of using rubbing alignment respectively. However, the surface anchoring energy in the test LC cell using PBA was lower than that by rubbing. The above-mentioned parameters and electrical properties represent the performance index of LCD panel, from the results of the 23" WXGA real panel, it can be proved that plasma beam for polyimide alignment film treatment is possible. The plasma beam alignment can be applied to LCD panels which need lower and precise pre-tilt angle control such as IPS or TN mode.

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