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PLASMA BEAM ALIGNMENT OF LIQUID CRYSTAL WITH IMPROVED ALIGNMENT STABILITY

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ABSTRACT

A method of plasma beam treatment providing liquid crystal (LC) aligning substrates of improved alignment stability is described. In this method the aligning substrates are obliquely treated with a plasma flux containing alignment and passivation agents simultaniously. This method is applicable for the substrates of organic and inorganic origin. During this treating process, good pretilt angle stability and alignment quality ares much promised.

1. INTRODUCTION

On the cell process of modern flat panel of liquid crystal displays (LCD) manufacture, the uniformity and stability of a large-sized liquid crystal aligning film is strongly demanded. To realize LCD modes in commonly used, strong anchoring energy ($W>10^{-1}$ erg/cm3) and small pretilt angle ($\theta <5^{\circ}$) are required. The induced alignment should also be suited on the large area substrates, as well as patterned to enhance viewing angle of LCD. The electrooptic performance sets additional demands, such as strongly reduced RDC and acceptable VHR, which partially relate to alignment method and alignment materials.

Traditionally, the unidirectional rubbing treatment procedure is widely used in the LC alignment technologies. However, because of the mechanical contact problem, this procedure suffers from serious drawbacks on the large area substrates. For this reason, development of new non-contacted alignment process overcoming intrinsic problems of rubbing alignment is of great actuality. Ion beam irradiation method is one of the non-contact LC alignment method[1][2]. In this method, surface of the alignment substrate is obliquely treated with a flux of ions, which causes anisotropic deposition or etching of the substrate preliminarily deposited. The latter kind of processing based on the beam of Ar+ ions with the low energy of about 50-600 V. Later on, similar treatment conditions were achieved by using a beam of accelerated Ar plasma [3] [4] [5] [6].

In spite of "gentle" treatment by using the low-energy ions, the induced LC alignment is rather unstable in the months scale. The degradation of the azimuthal anchoring is notable. To understand reasons of the alignment aging, the influence of ions on the aligning material should be considered. Within the energy range of 50 eV-5,000 eV, used in the experiments on LC alignment, collisions of ions and accompanying neutrals with the molecules of the aligning substrate result in the breaking of chemical bonds. The arising dangling bonds (free radicals) are very reactive. They react with LC causing its partial degradation. The aligning substrate adsorbs impurities arose in the degradation process that leads to modification of boundary conditions and parameters of LC alignment. These processes run slowly that explains slow degradation of LC cells.

USP 6485614 (2002)[7] suggested a passivation method with two procedure including alignment and passivation steps. The substrate treatment by ion beam with the hydrogen atoms to prevent degeneration and inactivity of the treated substrate was described in the above patent. The fault of this method was a separated process and required different facilities for alignment and passivation. After irradiation with Ar+ flux, the argon gas was evacuated and the hydrogen gas is then introduced into the vacuum chamber. These hydrogen atoms were extremely reactive and able to neutralize dangling bonds, which were created during the ion bombardment step. For this process, hydrogen molecules should be dissociated in atoms by using heated tungsten filament assisting dissociation process. This action is costing and more complicated.

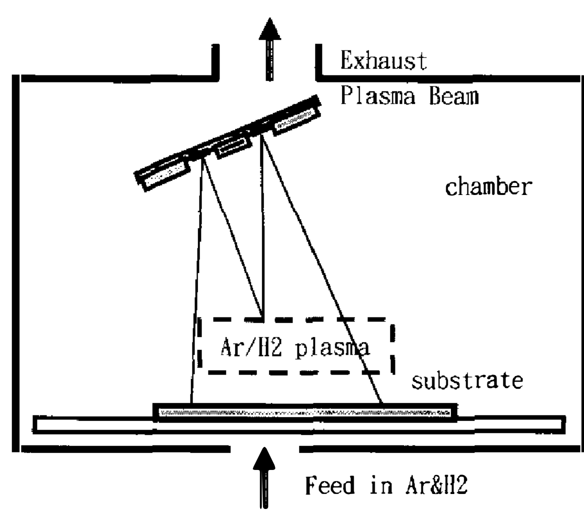

Fig.1 Process configuration of plasma beam system alignment

2. EXPERIMENTAL

The irradiation set-up is based on anode layer thruster (ALT) specially designed to produce collimated flux of ions from practically any gaseous feed. A scheme of the anode layer thruster is shown in Fig. 1. The source has permanent magnets at the inner and outer cathodes. The anode is above the inner and outer cathodes. Beside, these electrodes deformed the size and the shape of the discharge channel. The ion flux is formed in crossed electric **(E)** and magnetic **(H)** fields immediately within the discharge channel and thus it is a part of d.c. plasma generated in the discharge area.

Depending on the configurations of the discharge channel, the generated plasma fluxes contain a hollow cylinder like flate shape (Fig.2). The latter one is suitable to treat large-area surfaces (by tilting or translating the source). 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 (0.5-10) $*10^{-4}$ Torr, and the current density j of Ar^+ ions was determined.

The substrate holder was mounted in a vacuum chamber just under the discharge channel (Fig. 3). 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^o (normal to the substrate) and 80^o.

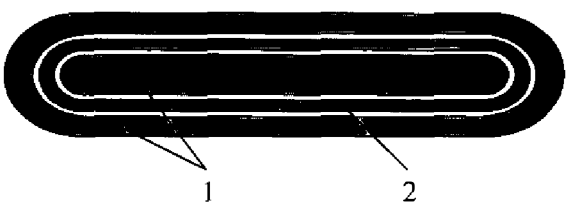

Fig.2 Geometry of the anode layer thruster (ALT) source. 1-Cathode; 2-Anode

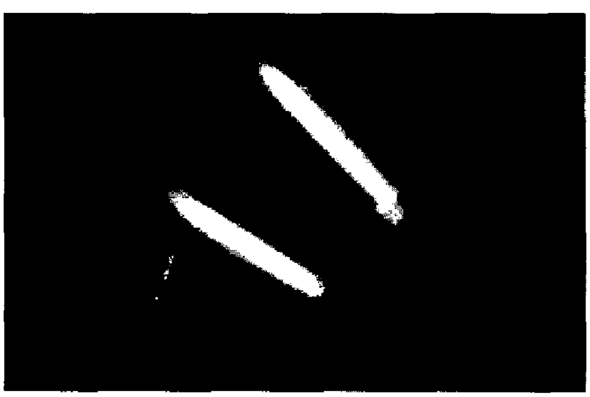

Fig.3 The part of plasma irradiation setup from view pore. One can see ALT mounted on the vacuum scanner and a pare of plasma "sheets"

3. RESULT AND DISCUSSION

The method of plasma beam treatment for liquid crystal alignment in which alignment and passivation processes of the bounding substrates are combined using the same plasma source. These processes will be carried out simultaneously in one step. This is achieved by using gaseous feed containing alignment Ar and passivation H2 agents. The operating conditions should be optimized and the plasma beam contained sufficient amount of argon and hydrogen atoms could deform alignment film and passivate dangling bonds in one step process.

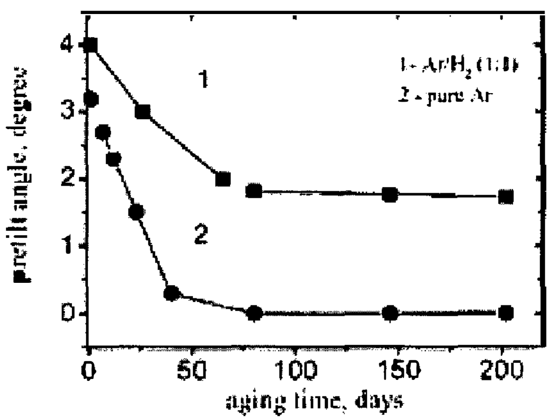

Fig.4 Pretilt angle versus aging time curves for the cells based on the plasma beam treated polyimide substrates (PI 2555, Dupont).

Fig.4 presented pretilt angle versus aging time curves for the cells based on the plasma beam treated polyimide substrates (PI 2555, Dupont). Treatment conditions: (1) Ar/H_2 plasma (with ratio of partial pressures 1:1), Ua=600 V, t=5 min; (2) Ar plasma (100%), Ua=600 V, t=5 min. Comparing with these two values of pretilt angle. It is clear to know that plasma treatment with Ar/H_2 gaseous is more stable than with pure Ar after long aging times. That means a higher anchoring energy with H_2 passivation would be found under this process.

Because of the influence of ions and accompanying neutrals with the molecules of the aligning substrate, the chemical bonds were broken. The arising dangling bonds (free radicals) are very reactive, and easy to react with LC. That is why the partial degradation was carried out that soon. The hydrogen ion is also easy to get together with dangling bonds (free radicals) and become stable bonding that directly proves the passivation of dangling bonds.

The information about the working gas is shown in the inset of the Figure.5 For plasma treatment the substrates were hold about 6 cm away from the discharge area. The irradiation conditions are E=600 V, treatment time=2 min for Ar and Ar/H_2 gases and E=1300 V, 2 min for H_2. The aging time was in room temperature for 70 days. By using Ar gas in plasma beam treatment, only the alignment film without passivation was found. If combined gas (Ar/He) was introduced in one-step process, the alignment and passivation film were observed. It can be also easier to compare the results from the introduced gas with Ar/H_2 to single gas. Besides, the stability of LC alignment is much better than single gas, especially in 1:1 Ar/H_2 mixed gas.

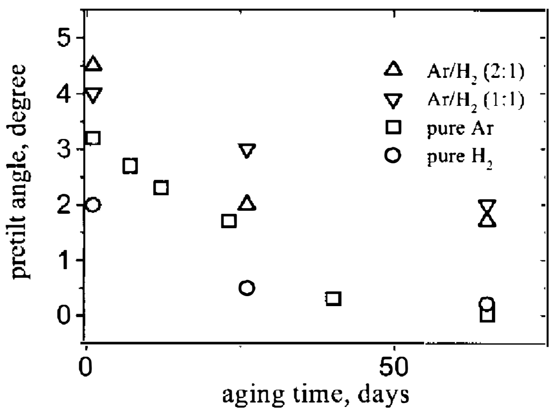

Figure.5 The pretilt angle VS cell aging time for the cells based on PI2555 substrates and filled with ZLI2293.

4. CONCLUSIONS

The result is a method of plasma beam treatment for liquid crystal alignment in which alignment and passivation processes of the bounding substrates are combined using the same plasma source. These processes may run simultaneously or step by step. This is achieved by using gaseous feed containing alignment (Ar, Kr, etc.) and passivation (H_2, CH_4, etc.) agents. The preferable plasma source is a closed drift thruster. The operation conditions are optimized so that generated plasma flux contains sufficient amount of hydrogen atoms of low energy to passivate dangling bonds appearing in the process of plasma treatment. As result, substantial improvement of the stability of LC alignment is observed.

ACHNOWLEDGEMENT

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