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# Electro-optical Characteristics of Twisted Nematic (TN)-Liquid Crystal Display (LCD) on a Polyimide Surface Exposed to an Ion Beam (IB) with New Type Equipment

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*We studied liquid crystal (LC) alignment with ion beam (IB) on polyimide and electro-optical characteristics of twisted nematic (TN)-liquid crystal display (LCD) on the polyimide surface using obliquely ion beam (IB) exposure with new IB type equipment (DuoPIGatron type ion gun). A good uniform alignment of the nematic liquid crystal (NLC) alignment with the ion beam exposure on the polyimide surface was observed. In addition, it can be achieved the good EO properties of the ion-beam-aligned TN-LCD on polyimide surface. Also the EO characteristics of the ion-beam-aligned TN-LCD on a polyimide (PI) surface with ion beam exposure using new type IB equipment is almost the same as that of ion-beam-aligned TN-LCD on a polyimide (PI) surface with ion beam exposure using Kaufman-type Ar ion gun.*

**Keywords:** alignment; DuoPIGatron; ion beam; NLC; polyimide; response time

## INTRODUCTION

A rubbing method has been widely used to align liquid crystal (LC) molecules on the polyimide (PI) surface. LCs are aligned by inducing anisotropy on the surface of a substrate. This surface is usually a polymer such as polyimide, coated on a glass substrate [1–7]. Rubbed

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polyimide surfaces have suitable characteristics such as uniform alignment and a high pretilt angle. However the rubbing method has some drawbacks [8]. These include the debris left by the cloth during the rubbing process in an otherwise clean room environment; concern with electrostatic discharging and its influence on the electronic circuitry below the thin polyimide film. Thus a non-contact alignment technique would be highly desirable for future generations of large, high-resolution LCDs.

A number of alternative alignment techniques have been reported [9–12]. Most recently, the LC aligning capabilities achieved by ion beam (IB) exposure on the diamond-like carbon (DLC) thin film layer have been successfully studied by P. Chauhari *et al*. Also we studied about ion beam (IB) alignment method on the diamond-like carbon (DLC) thin film layer [13,14]. This method has used the IB beam exposure with Kaufman-type Ar ion gun. This system uses low IB energy. However it is difficult to apply for large-scale manufacturing. And then none of these have so far been implemented in large-scale manufacturing.

Also the ion beam irradiated polyimide was also applied to the alignment of LC. Most of them mainly focused on basic cell parameters and fundamental mechanism [15–18].

Therefore, in this research, we developed new type IB equipment (DuoPIGatron type Ar ion gun) [19–20] for large-scale manufacturing. So we studied LC alignment effects and the electro-optical (EO) performances of the ion-beam-aligned TN-LCD with oblique ion beam exposure on the polyimide surface using new-type IB system.

## EXPERIMENTAL

We used a polyimide surface as alignment layer [Nissan Chemical Industries Co. Ltd.]. The polymers were uniformly coated on indium-tin-oxide (ITO) electrodes using the spin-coating method, and imidized at 220°C for 1 h. The thickness of the PI film was set at 500 Å. The polyimide layer was used by an Argon ion beam with Kaufman-type Ar ion gun and new type Ar ion gun (DuoPIGatron Ion Source), respectively. The general type (Kaufman type Ar ion gun) and new type (DuoPIGatron type Ar ion gun) IB exposure system are shown in Figure 1, and Figure 2, respectively. For new type (DuoPIGatron type) Ar ion gun, the plasma source should be capable of producing a quiescent, uniform, and dense plasma in order to produce a well collimated, high current density beam. Thus, new type (DuoPIGatron type) ion gun is suitable for large scale area exposure with high uniformity. The IB energy with Kaufman type Ar ion gun was 200 eV,

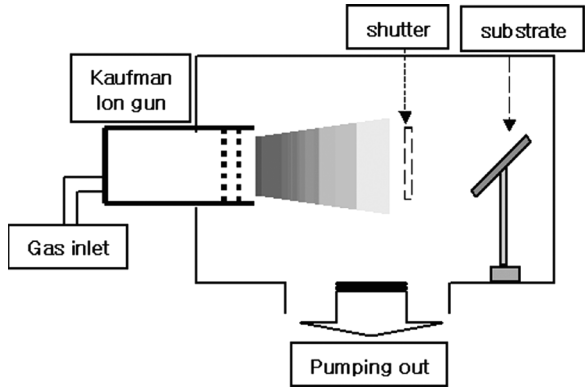


**FIGURE 1** The IB exposure system using Kaufman type Ar ion gun.

and the IB energy with new-type Ar ion gun was 500 eV. The energy, integrated dose, and the angle of the plane of the substrate with respect to the ion beam were varied. After irradiation, two types of test samples were fabricated. One was arranged in an anti-parallel configuration, which was used for pretilt angle measurements. The other was the twisted nematic (TN) test sample, which was used for Electro-Optical measurement. After substrates coated the polyimide surface were bombarded by the ion beam, the two substrates were assembled

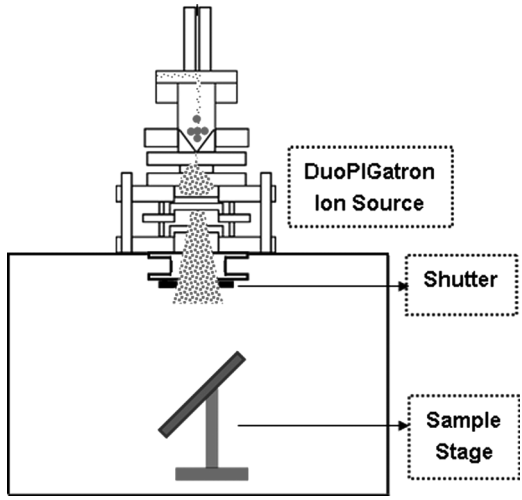


**FIGURE 2** The IB exposure system using new type Ar ion gun.

together and filled with a nematic liquid crystal (NLC) ($T_c = 72°C$, $\square\varepsilon = 8.2$, MJ001929 from Merck Co.) for TN test samples. The thickness of the liquid crystal cells for TN test sample was 5 μm. In addition, the thickness of the liquid crystal cells for pretilt test sample was 60 $\mu$m. 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 and response time characteristics of ion-beam aligned TN-LCD were measured by LCMS-200 (Electro-Optical Measurement, from Sesim Photonics Technology) equipment. Also the residual DC voltage properties of ion-beam aligned TN-LCD were measured by a Capacitance-Voltage hysteresis method.

## RESULTS AND DISCUSSION

Figures 3 show the microphotographs of aligned NLC using the IB exposure with Kaufman-type and new-type Ar ion gun source. NLC cells using the IB exposure with Kaufman-type and new type Ar ion gun source showed the good alignment. Also the LC aligning capability using the new type Ar ion gun source is the same as that using Kaufman-type and new-type Ar ion source.

Figure 4 shows the relationship between the transmittance and the incidence angle of NLC by measuring the pretilt angle using the crystal-rotating method with Kaufman-type and new-type Ar ion beam exposure system on the PI surface. As shown in Figure 4 (a), LC cell which was irradiated with ion beam on PI surface, shows the relationship between the transmittance and the incidence angle of LC cell injected positive dielectric NLC. The graph is almost symmetrical on an axis of symmetry, and the calculation shows that the pretilt angle


(a) (b)

**FIGURE 3** Micrographs of the ion beam aligned on PI film cells (in crossed Nicols).

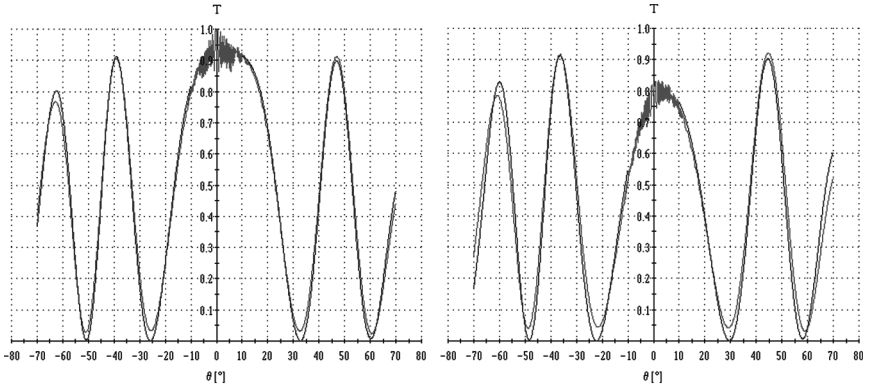


**FIGURE 4** The relationship between transmittance and incidence angle on PI film with the ion beam exposure.

is about 1 degree, which is considered to be a low angle. In the result LC cell which was irradiated ion beam on its PI surface shows homogeneous alignment if positive dielectric NLC is injected.

Figure 5 shows micrographs of the ion-beam-aligned TN-LCD with Kaufman type and new type Ar ion beam exposure system on the PI surface. Monodomain alignment of the two kinds of ion beam aligned TN-LCDs can be observed.

We show in Figure 6 a good transmission of light as a function of applied voltage across twisted nematic liquid crystal cells made of Kaufman type and new type Ar ion beam exposure system on the PI layers. An excellent voltage-transmittance (V-T) curve can be achieved in the ion beam aligned TN-LCD with new type ion beam exposure system on the PI surface for 1 min. Also the ion beam aligned TN-LCD with new type ion beam exposure system on the PI surface shows the same stable curve as that with Kaufman type ion beam exposure system on the PI surface; the threshold voltage of the ion beam aligned TN-LCD with new type ion beam exposure system on the PI film surface is lower than that of the ion beam aligned TN-LCD with Kaufman type ion beam exposure system on the PI surface. Consequently the new type ion beam system can be achieved good V-T characteristics of the ion beam aligned TN-LCD.

Figure 7 shows the response time characteristics of the ion beam aligned twisted nematic liquid crystal cells made of Kaufman type and new type Ar ion beam exposure system on the PI layers. Considering transmittance of response time characteristics, fast response time

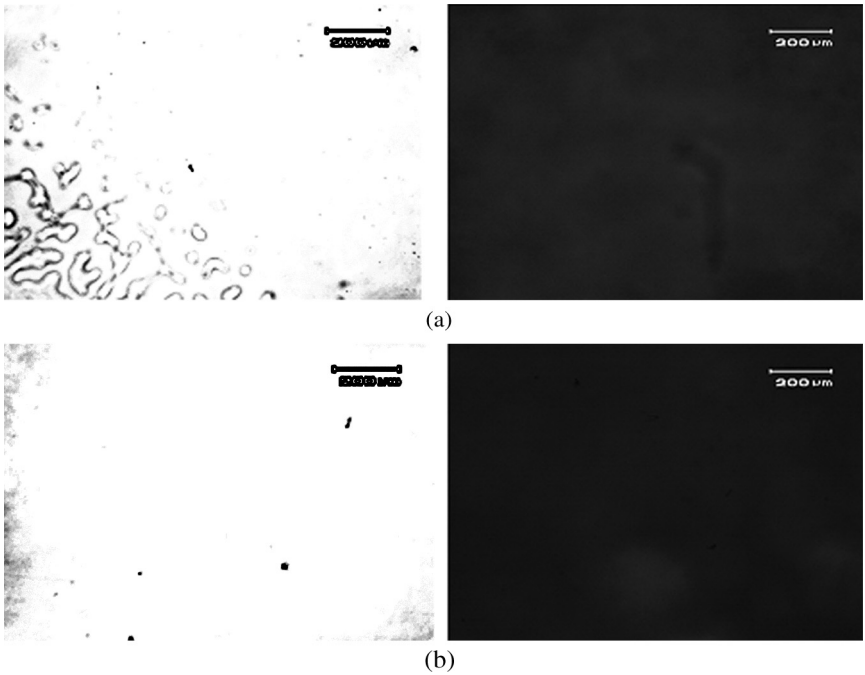


**FIGURE 5** Micrographs of the two kinds of ion beam aligned TN-LCDs with oblique ion beam exposure on the PI layers for 1 min (in crossed Nicols); (a) Kaufman type Ar ion gun (b) new type Ar ion gun.

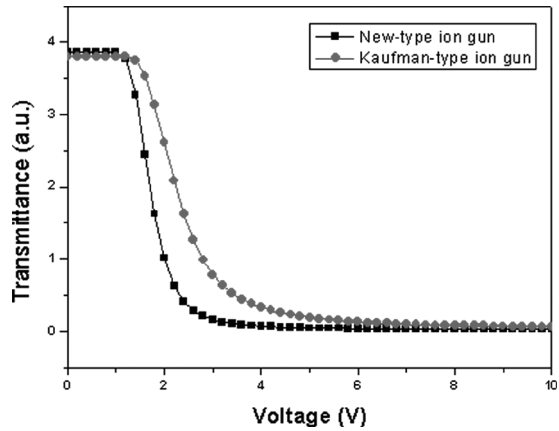


**FIGURE 6** V-T curves of the two kinds of ion beam aligned TN-LCDs with oblique ion beam exposure on the PI surface.

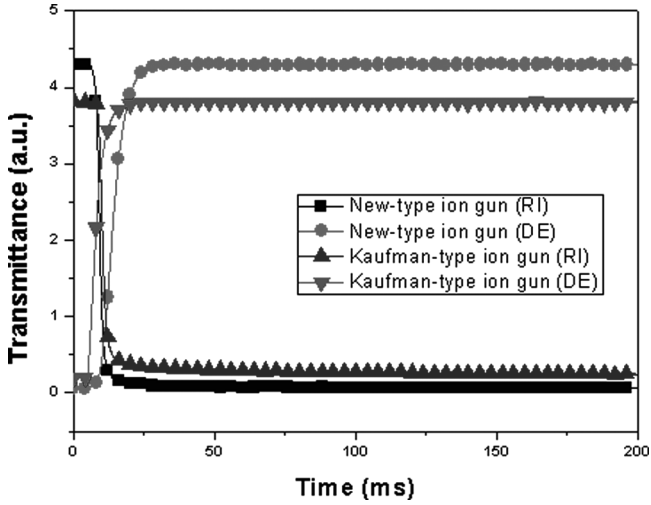


**FIGURE 7** Response time characteristics of the two kinds of ion beam aligned TN-LCDs with oblique ion beam exposure on the PI surface.

of ion-beam-aligned TN-LCD using new type ion beam system on the PI surface was optically measured to be about 16.8 ms. That is the reason why we achieved uniform aligning capability on the PI surface. In other words the uniform aligning capability is very important because it affects the LC alignment stability and Electro-Optical performances of LC operation modes using PI surface. However transmittance of ion beam aligned TN cell using Kaufman type ion gun is lower than that of ion beam aligned TN cell using new type ion gun.

Image sticking was also very important factor for the functioning of displays. This arises from residual charges that accumulate in a local region as the voltage is left on. When the voltage is removed, the image survives and gradually fades away with time as the charge is dissipated. We show in Figure 8 the Capacitance-Voltage characteristics of the ion beam aligned twisted nematic liquid crystal cells made of ion beam exposure with Kaufman type and new type Ar ion gun on the PI layers. The residual charge characteristics of ion beam aligned TN cell using the new type ion beam system have a little; the increased value of the residual charge was very small. However the hysteresis curve of the ion beam aligned TN-LCD using Kaufman type ion beam system was high; the increased value of the residual charge was high. We evaluated the residual DC voltage characteristics using capacitance-voltage characteristics. That method is the same as used by Nissan chemical. Nissan chemical, alignment layer manufacturing

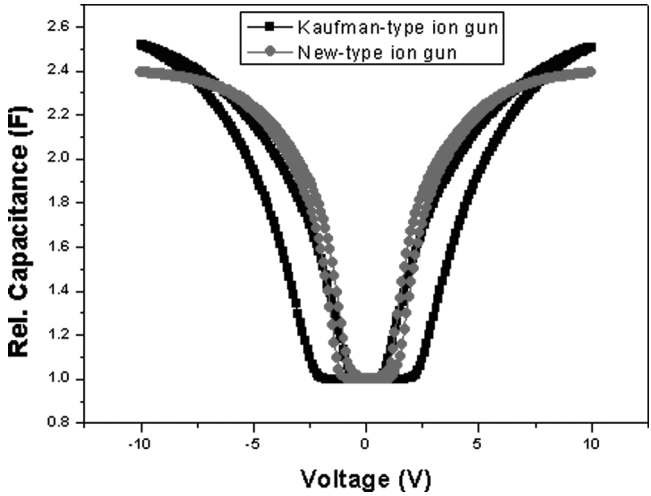


**FIGURE 8** Capacitance-voltage characteristics of the two kinds of ion beam aligned TN-LCDs with oblique ion beam exposure on the PI surface.

company of Japan, uses capacitance-voltage characteristics as evaluation method. That method measures residual DC voltage by changing DC bias voltage, which was measured by electrical capacity of liquid crystal panel from the gap of C-V hysteresis curve. As a result, a good characteristic was achieved on the new type ion beam system, as a new ion beam source using alignment method.

Consequently the EO characteristics of the ion beam aligned TN-LCD using new type ion bean system are better than those of the ion beam aligned TN-LCD using Kaufman type ion bean system.

## CONCLUSIONS

In conclusion, LC alignment effects and generation of pretilt angles with ion beam irradiation, the EO performances of the ion beam aligned TN-LCD on the polyimide surface using new type ion gun source were studied. The good V-T curves in comparison with the polyimide were observed for the ion beam aligned TN-LCD with ion beam exposure on the polyimide surface using new type ion gun source. Also the fast response time characteristics in the polyimide layer can be achieved for the ion beam aligned TN-LCD on the polyimide surface using new type ion gun source. And the residual DC voltage of the ion beam aligned TN-LCD on the polyimide surfaces using new type ion gun source was good. Therefore it was found from the result that

new type ion gun is suitable for liquid crystal alignment and large scale application.

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