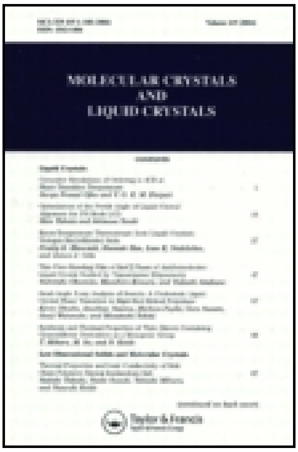

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Inorganic Layer for Homogeneously Aligned Crystals Using Ion Beam Irradiation

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Inorganic Layer for Homogeneously Aligned Crystals Using Ion Beam Irradiation

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The authors introduce variable liquid crystal (LC) properties via ion beam (IB) irradiation on the ZrO_2 layers. A uniform LC alignment characteristic was achieved on the ZrO_2 thin film, and the pretilt angle was about 1.2°. We have shown that the pretilt angle can be controlled by changing ion beam parameters, such as the ion beam energy, the angle of incidence, and the irradiation time. The low pretilt angle for the nematic liquid crystal (NLC) on the ZrO_2 thin film treated by ion beam irradiation could be adopted in planer alignment LCD liquid crystal display (LCD) applications as in-plane switching and fringe-field switching modes. The thermal stability of the ZrO_2 thin film was sustained until 210°C. We also have shown that a liquid crystal cell aligned homogeneously by the ion beam irradiation exhibits the voltage-transmittance curve similar to that of a rubbed polyimide cell.

Keywords Liquid crystal alignment; ZrO_2 thin film; Ion beam irradiation; Pretilt angle

Introduction

Liquid crystal display (LCD) has demonstrated a various of flat panel display applications, from small-portable to large display devices. As the demand for large LCD-TVs has increased, so has the demand for high quality and performance LCDs. To achieve high quality and high resolution LCDs, it is necessary that the liquid crystal (LC) alignment effect be uniform on a substrate [1]. A rubbing method has been widely used to align liquid crystal (LC) molecules on the polyimide (PI) surface. LCs are aligned due to the induced anisotropy on the substrate surface [2–5]. Rubbed PI surfaces have suitable characteristics such as uniform alignment and a high pretilt angle. Rubbing promises a safe alignment in many experiments, but static, dust, and a limitation on a uniform alignment is the disadvantage for large glass subtrates [6, 7]. Thus we strongly recommend a non-contact alignment technique for future generations of large, high-resolution LCD. Over the past several years, several alternative alignment techniques have been reported for inducing anisotropy on the alignment layer surfaces by noncontact methods including traditional oblique deposition,

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photo-alignment, nanostructured alignment surfaces, and plasma treatment [8–10]. The IB-induced alignment has been intensively studied on inorganic and organic surfaces. More specifically, suitable LC alignment has been attained using a Kaufman-type IB Gun to orient the LCs on diamondlike carbon (DLC) films and many optically transparent films, such as SiC, SiO, and SiNx, have also been investigated as potential candidates for inorganic alignment materials [11, 12]. Among the many other potential inorganic materials, we investigated the E-beam evaporation layer controlled deposition of ZrO_2 thin films for LC alignment layer due to its high dielectric constant, relatively low leakage current, and large band gap [13, 14]. In this article, we studied the homogeneous alignment effect of NLC and generation of pretilt angle using the ion beam irradiation method on the ZrO_2 thin films surfaces. The pretilt angles generated on the ZrO_2 were displayed under carefully controlled conditions such as an incident angle, energy, and exposure time.

Experimental

The ZrO_2 thin film layers were deposited on indium-tin-oxide (ITO)-coated Corning 1737 glass substrates by E-beam evaporation, at an average deposition rate of 2 Å/s at room temperature. Before the deposition, the ITO-coated glass was cleaned with a supersonic wave in a trichloroethyl-acetone-methanol-deionized water solution for 10 min and was then dried with N_2 gas. The 10 Å ZrO_2 thin films, which were measured using a surface profiler alpha step and a field emission-scanning electron microscope (FE-SEM), were exposed to the IB at irratiation irradiation time ranging from 30 to 120 sec at increments of 30 sec, 45 degree at an exposure angle, and intensity of 2.0 KeV using a DuoPIGatron-type IB system. The IB chamber was initially evacuated to a base pressure of about 10^{-6} Torr, and the working pressure was maintained at about 10^{-4} Torr with an Ar gas flow of 1.4 SCCM (SCCM denotes cubic centimeters per minute at STP). The dosages of Ar^+ IB plasma were 10^{14}–10^{15} ions/cm^2 energy The ITO-coated glass substrates with the ZrO_2 layers on the ITO surfaces were assembled in an antiparallel configuration with a cell gap of 60 μm in order to measure the tilt angles using the crystal rotation method (TBA 107 tilt-bias angle evaluation device; Autronic). The LCDs were assembled with a cell gap of 5μm in order to examine the EO characteristics. Commercial Negative LCs ($Tc = 75°$C, $\Delta\varepsilon = 8.2$; MJ001929, Merck Corp.) were used for the LCD fabrication.

Results and Discussion

Figure 1 shows the microphotographs of the NLC alignment effect on the various IB irradiation times of the ZrO_2 thin film layers. Figure 1(a) shows the microphotograph on a ZrO_2 thin film of the IB irradiation time for 30 sec, and Figs. 1(b)–(d) shows the microphotographs of ZrO_2 thin films of 60, 90, and 120 sec, respectively. As can be seen, uniform switching behavior was achieved without deviated alignment and local defects.

Figure 2 shows the LC pretilt angle variation according to incident time of IB irradiation on the ZrO_2 thin film which is irradiated as the incident angle of 45° and intensity of 2.0 KeV. The LC pretilt angle has the stable pretilt angle value at range from 0.5 to 0.3°, and the pretilt angle gradually decreases with increasing incident time of the IB irradiation. As a result, homogeneous alignment of NLC and the control of pretilt angle were achieved by the incident time of the IB irradiation.

We assumed that the IB irradiation time induced the change of contact angle, as depicted in Figure 3. There is an important relationship between the surface energy on the

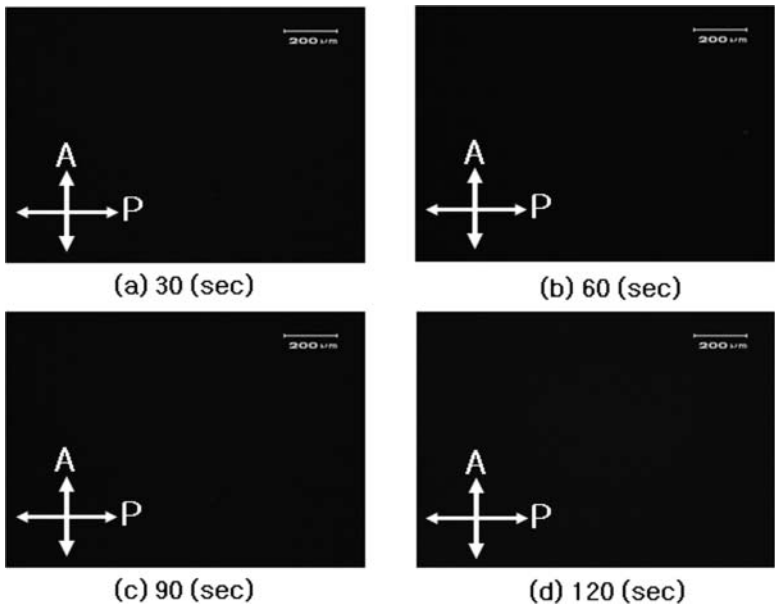


Figure 1. Photomicroscope images of LC cells with ZrO_2 layers produced using the IB irradiation as a function of incident time: (a) 30, (b) 60, (c) 90, and (d) 120 sec.

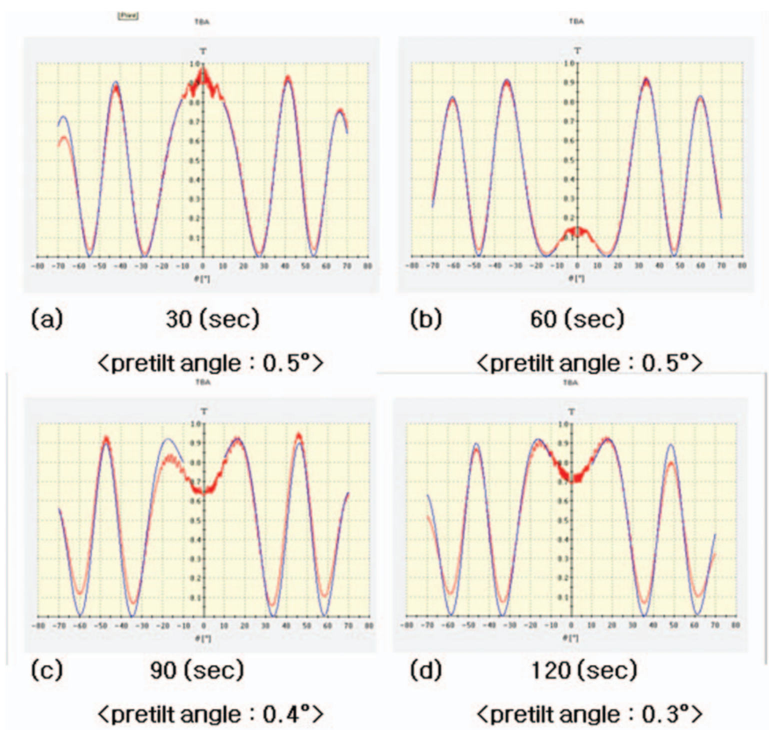


Figure 2. Pretilt angles of LCs on the ZrO_2 layers as a function of incident time.

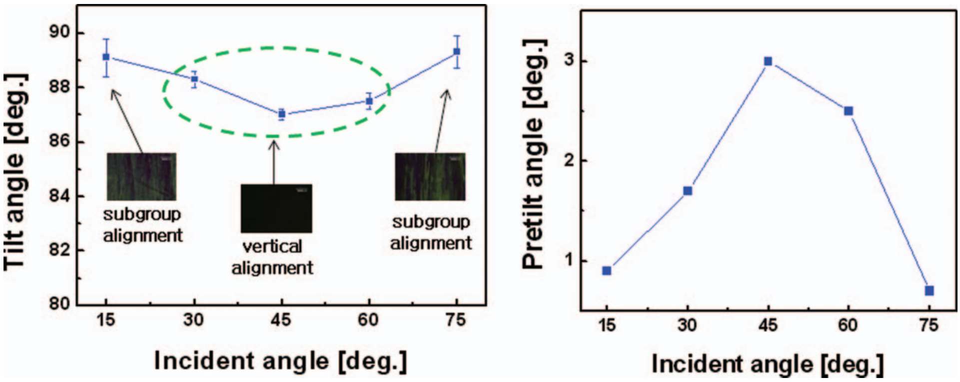
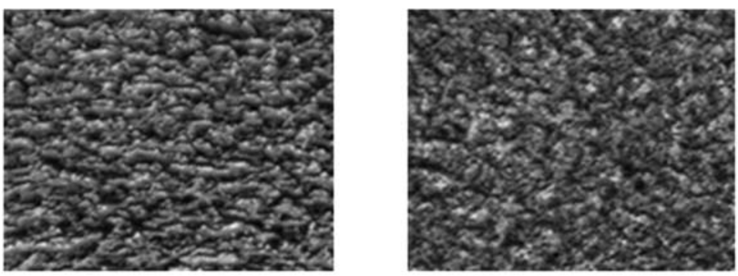


Figure 3. Comparison of contact angle results in terms of LC alignment under the IB irradiation: (a) 30, (b) 60, (c) 90, and (d) 120 sec.

treated ZrO_2 surface and the alignment of LC molecules. The IB irradiation time increased, the contact angle increased. The contact angles of NLC on the ZrO_2 thin film surfaces with IB conditions of 2.0 KeV, 45°, and 30, 60, 90, and 120 sec were optimized at 63, 64, 64, and 65°, respectively. This revealed that the irradiation of the IB attributed to the creation of the pretilt angle by breaking $ZrO_{2.}$ This indicated that the activated amorphous network that had large polarizability, attributed to a stronger interaction with LC molecules. A physical



(a) Before IB (b) After IB irradiation at 90 s

Ion beam irradiation time [s]	rms roughness [nm]
Before irradiation	4.8
30	4.3
60	3.9
90	2.5
120	2.6

(c) Values of rms roughness before and after IB irradiation

Figure 4. AFM images of ZrO_2 surface as the IB irradiation: (a) AFM image before IB, (b) AFM image after IB, (c) rms values.

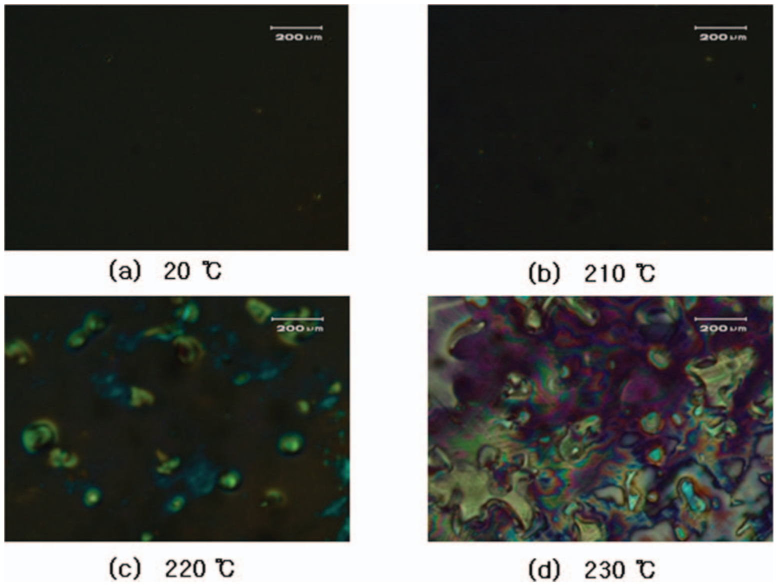


Figure 5. Photomicroscope images of IB aligned LC cell on the ZrO_2 layers as a function of annealing temperature. Annealing temperatures were 210, 220, and 230°C.

investigation using AFM was performed, as the contact angle is also related to the surface morphology.

The rms roughness values of the IB irradiated ZrO_2 layer as a function of the incident angle and intensity under the same conditions are shown in Figure 4. The rms roughness changed from 4.3 to 2.6 nm. The glancing signs on the ZrO_2 grains with the namoscale pits induced by IB irradiation were observed, as shown on the right side Figure 4(b). Consequently, the change in the surface features of the ZrO_2 film by formation of the namoscale pits is related to the variable contact angles and pretilt angles.

Figure 5 shows the thermal stability experiment microphotographs of an LC cell with a ZrO_2 film. To determine LC anchoring energy, a thermal stability experiment was carried

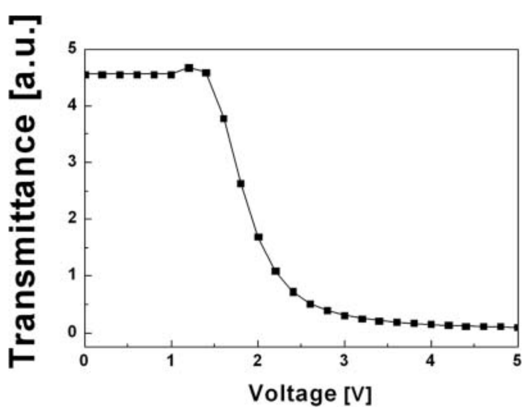


Figure 6. Light transmission as a function of the voltage applied to the TN cell using under the IB irradiation.

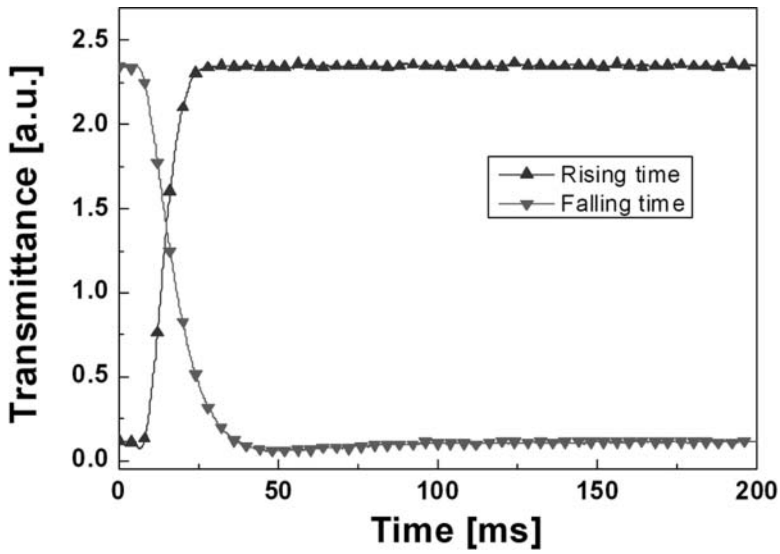


Figure 7. Response time as a function of voltage for TN cells.

out. After each LC cell was annealed by specific heat and cooled slowly, the LC alignment effect was observed from a microphotograph. The LC alignment remained constant during the application of heat within the 50–230°C temperature range. After applying heat at 220°C, The LC alignment was destroyed. On the basis of this result, we determined that uppermost the thermal stability limit of the ZrO_2 film is 210°C. Without taking times into account, the results of the thermal stability experiment were the same.

Figure 6 shows a plot of the V-T characteristics in the TN cells homogeneously aligned on the IB irradiated ZrO_2 layers under the same condition. The transmission characteristics were identical for the two alignment methods when applying 5 V to each cell. The threshold voltage of the IB irradiated ZrO_2 film was 1.85 V. Also, Figure 7 shows the response time characteristic of a TN cell. The rising time was 8.9ms, and the decay time was 16 ms.

Conclusions

In this paper, we studied about LC alignment effect and control of pretilt angle using the IB irradiation method in new alignment layer the ZrO_2 thin film. We achieved a good alignment characteristic using the IB alignment method on the ZrO_2 film when times of the IB irradiation are 30, 60, 90, and 120 sec at the E-beam. We achieved the low preitlt angle of about 0.3–0.5° when IB conditions were irradiation time of 30, 60, 90, and 120 sec. Also, IB alignment method using the ZrO_2 film had thermal stability up to 210°C. Therefore, IB alignment method using the ZrO_2 film was achieved the homogeneous alignment of NLC, the control of stable pretilt angle and good thermal stability of manufactured LC cell. Moreover, the EO characteristics were also achieved.

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