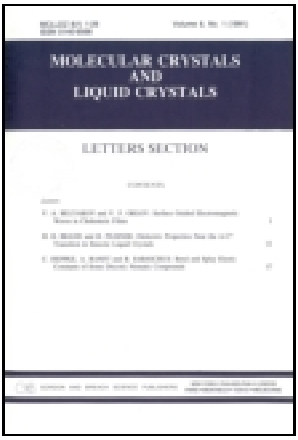

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Plastic Liquid Crystal Display with Polarizers Integrated Inorganic Conducting and Alignment Layers

Phil Kook Son [a] , Suk-Won Choi [a] , Sung Soo Kim [b] & Seok-Cheol Ko [c]

[a] Department of Advanced Materials Engineering for Information & Electronics and Regional Innovation Center-Components and Materials for Information Display , Kyung Hee University , Yongin , Republic of Korea

[b] Department of Chemical Engineering, and Regional Innovation Center-Components and Materials for Information Display , Kyung Hee University , Yongin , Republic of Korea

[c] Industry-University Cooperation Foundation , Kongju National University , Chungnam , Republic of Korea

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Plastic Liquid Crystal Display with Polarizers Integrated Inorganic Conducting and Alignment Layers

PHIL KOOK SON,[1] SUK-WON CHOI,[1] SUNG SOO KIM,[2] AND SEOK-CHEOL KO[3,*]

[1]Department of Advanced Materials Engineering for Information & Electronics and Regional Innovation Center-Components and Materials for Information Display, Kyung Hee University, Yongin, Republic of Korea
[2]Department of Chemical Engineering, and Regional Innovation Center-Components and Materials for Information Display, Kyung Hee University, Yongin, Republic of Korea
[3]Industry-University Cooperation Foundation, Kongju National University, Chungnam, Republic of Korea

We investigated polarizer integrated conducting and alignment functions SiO_2/ITO/SiO_2 films on polarizer films for the high transmittance and contrast ration of liquid crystal (LC) cell. SiO_2/ITO/SiO_2 films were directly deposited on polarizer films using r. f. magnetron sputtering system at room temperature, which are used as substrates for plastic liquid crystal displays. To align LC molecules, we exposure on SiO_2 film surfaces with low-energy ion beam. Transmittance of twisted nematic (TN) and electrically controlled birefringence (ECB) cell with SiO_2/ITO/SiO_2/polarizer was higher by 3%∼5% than those of SiO_2/ITO/glass/polarizer in average visible wavelength.

Keywords High transmittance; ion beam; ITO; liquid crystal; polarizer; SiO_2

Introduction

In recent years, the demand for flexible panel display has rapidly increased. Plastic liquid crystal displays (LCDs) have much attention due to their several merits, such as light weight, thinner package, and increased bending capability over the conventional flat LCDs fabricated with rigid glass substrates [1]. However, transmittance of plastic LCDs is generally lower than that of conventional LCDs because plastic substrates have relatively lower transmittance than glass substrates. As one of the essential thermo-plastic polymeric materials, polyethylene terephthalate (PET) has been widely used in various fields since its discovery in the 1940s due to its high tensile and impact strength, adequate CO_2 retention, optical clarity, and design flexibility. Even though these properties of PET have expedited

*Address correspondence to Prof. Seok-Cheol Ko, Industry-University Cooperation Foundation, Kongju National University, Chungnam 314-701, Korea (ROK). Tel.: (+82)41-850-0528; Fax: (+82)41-856-0544. E-mail: suntrac@kongju.ac.kr

its commercial uses in high-value/low-cost applications, its thermal stability is not good and thus, generally it cannot be used with thermal treatment processes with high temperatures to generate a crystalline structure. Due to this, flexible transparent conducting electrodes deposited on plastic film at low temperature during production inevitably have several disadvantages over those deposited on glasses, such as low-transmittance, low-conductivity, and a greater number of defects. Herein, we propose novel plastic LCDs adopting intriguing substrate structure to attain higher transmittance performance.

Indium tin oxide (ITO) film has been widely used as a transparent, conducting electrode in liquid crystal displays, light emitting diodes, and solar cell devices. For this kind of film, numerous publications have addressed the challenges of achieving low resistivity and high transmission - an unusual combination of properties in this type of material [2, 3]. Higher transmission requires a material with a band-gap greater than approximately 3.0 eV whilst higher electrical conductivity necessitates a high number of free electron carriers with high mobility. With the creation of oxygen vacancies and by substitutionally doping the In^{3+} sites in In_2O_3 with Sn^{4+}, the free carrier density can be increased sufficiently to move the Fermi level into the conduction band whilst the band-gap remains similar to that of the host (In_2O_3). Thus, careful control of the deposition parameters during film growth results in coatings that are with both electrically conductive and transparent to visible light.

Various techniques have been developed for liquid crystal (LC) alignment such as the rubbing method, [4] photo alignment, [5] obliquely evaporation of an inorganic film, [6] and ion beam alignment [7, 8]. Rubbed-polyimide (PI) is still being used widely as an LC alignment in mass production of LC displays. The ion beam alignment was introduced recently to overcome the drawbacks of rubbing, such as static charges, creation of debris, and so on. However, there are still unresolved issues associated with the mechanism of LC alignment. Stöhr *et al*. reported on PD of LC effects on an alignment surfaces related to the orientational bonding order in rubbed, ion-beam-treated polyimide, and ion-beam-treated diamond-like-carbon films, by using the near-edge x-ray absorption fine structure measurements analyses.

In this work, we employ polarizers integrated conducting and alignment functions. Figure 1 show a schematic drawing of the polarizers integrated LC cells structure. Proposed substrate structure is SiO_2/ITO/SiO_2 films on polarizer films. Thus, SiO_2/ITO/SiO_2 films were directly deposited on conventional polarizer films using r. f. magnetron sputtering system, which are used as substrates for plastic LCDs. We deposited SiO_2 and ITO thin films on polarizers via r. f. magnetron sputtering system at room temperature. Then, low-energy ion beam treatment on outside SiO_2 films was performed to align the LC molecules. Transmittance performances are compared between the twisted nematic (TN) and electrically controlled birefringence (ECB) cell with SiO_2/ITO/SiO_2/polarizer and that with SiO_2/ITO/SiO_2/glass/polarizer in visible ranges, respectively. In order to evaluate the physical properties of the ITO and SiO_2 film deposited by the proposed technique, we used atomic force microscopy (AFM) and transmittance.

Experimental

As a shown in Fig. 2, The deposition of the ITO and SiO_2 film on polarizer surfaces, via a r. f. magnetron sputtering system, was performed using method: SiO_2 particles were deposited on a polarizer surfaces by an argon (49.5 sccm) and oxygen gases (0.5 sccm) that were used as the inert gas in the chamber. The base pressure of the chamber was around 10^{-6} torr, while the working process pressure was around 10^{-2} torr. The film with thickness of 20 nm was deposited the range of a room temperature. ITO particles were

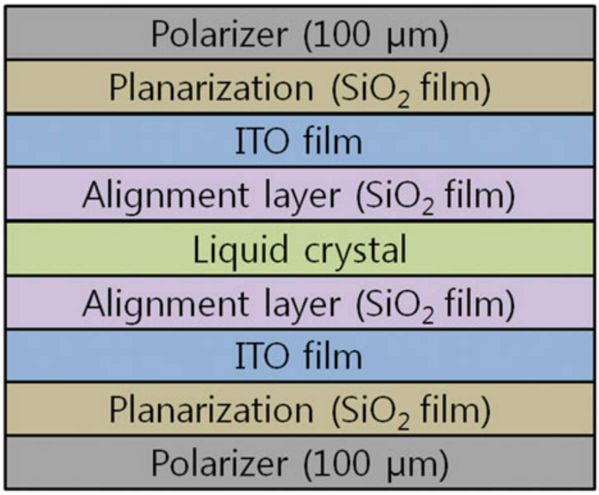

Figure 1. A schematic drawing of the polarizers integrated LC cells structure. Proposed substrate structure is SiO_2/ITO/SiO_2 films on polarizer films.

deposited on a polarizer surfaces by argon (49.7 sccm) and oxygen gases (0.3 sccm) that were used as the inert gas in the chamber, respectively. The base pressure of the chamber was around 10^{-6} torr, while the working process pressure was around 10^{-2} torr. The film with a thickness of 20 nm was deposited the range of a room temperature. Therefore, the film with a total thickness of 60 nm (SiO_2/ITO/SiO_2) was deposited the range of a room

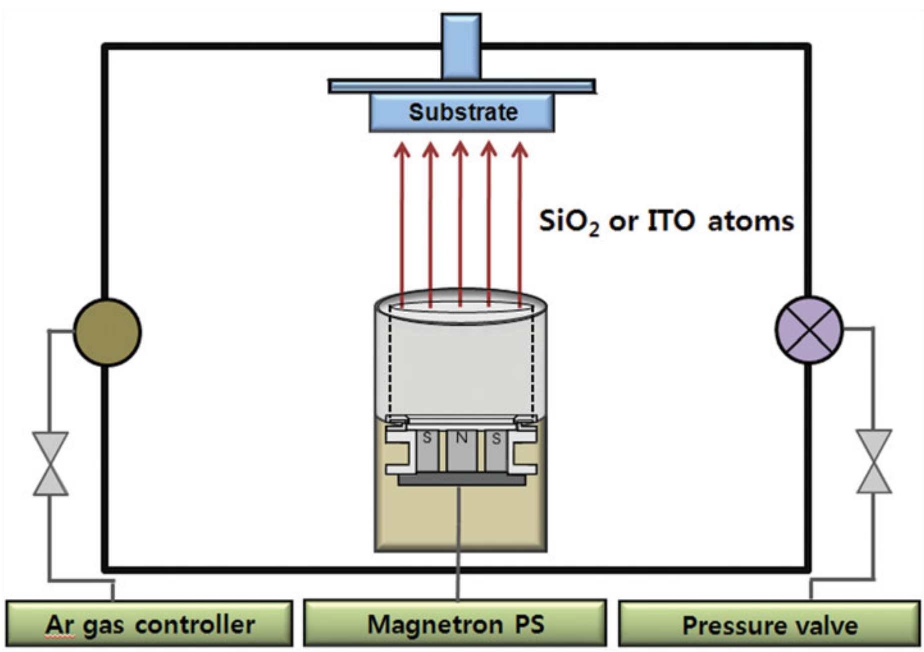

Figure 2. A schematic drawing of r. f. magnetron sputtering system.

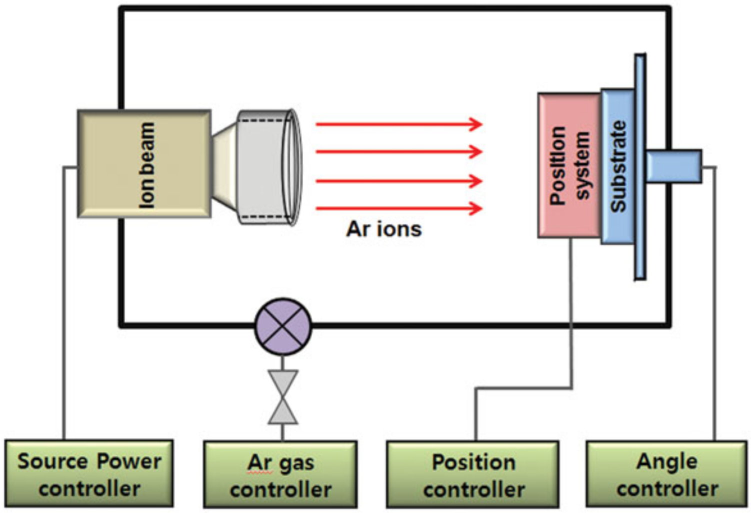

Figure 3. A schematic drawing of ion beam system.

temperature. SiO_2/ITO/SiO_2/Polarizer surface was bombarded by a low-energy argon ion beam at room temperature. Figure 3 show a schematic drawing of ion beam system. A cold hollow cathode (CHC) type of ion source was used to produce the ion beam. The base pressure of the chamber was around 10^{-6} torr, while the working process pressure was around 10^{-4} torr. The ion beam energy, incident angle, exposure time, and flux density were 120 eV, 20°, 10 sec, and 5×10^{14} ions/s·cm^2, respectively. TN and ECB cell cells with a cell-gap of 4.8 and 4 μm were fabricated with a positive LC "Merck MLC-0223," respectively. Also, we compared TN with ECB cell with SiO_2/ITO/SiO_2/polarizer and that with SiO_2/ITO/glass/polarizer in visible ranges, respectively.

Results and Discussion

To obtain more information about the ITO, non-treated SiO_2 and ion beam-treated SiO_2 film on polarizer surfaces, we measured the morphologies properties of the polarizer surfaces. Figure 4 (a)–(c) shows the morphologies of ITO/SiO_2/polarizer, non-treated SiO_2/ITO/SiO_2/polarizer and ion beam-treated SiO_2/ITO/SiO_2/polarizer, respectively, measured via AFM. We found that the surface roughness of ITO/SiO_2/polarizer, non-treated SiO_2/ITO/SiO_2/polarizer and ion beam-treated SiO_2/ITO/SiO_2/polarizer was 1.315, 1.182 and 2.021 nm, respectively. Therefore, we found that ion beam-treated SiO_2/ITO/SiO_2/polarizer films were increased than non-treated SiO_2 films/ITO/SiO_2/polarizer.

Figure 5 shows images of TN cells between crossed polarizers without and with the electric field. However, upon applying an electric field to a cell, non-uniform alignment and disclination lines can be observed. On the other hand, with the ion beam exposure, we can achieve uniformity in switching behavior upon applying an electric field. Figure 6 shows the transmittance performances are compared between the TN cell with SiO_2/ITO/SiO_2/polarizer and that with SiO_2/ITO/glass/polarizer in visible ranges. We found that TN cell of SiO_2/ITO/SiO_2/polarizer were higher about 5% than that of SiO_2/ITO/glass/polarizer at average visible wavelength. The measured contrast ratio of a

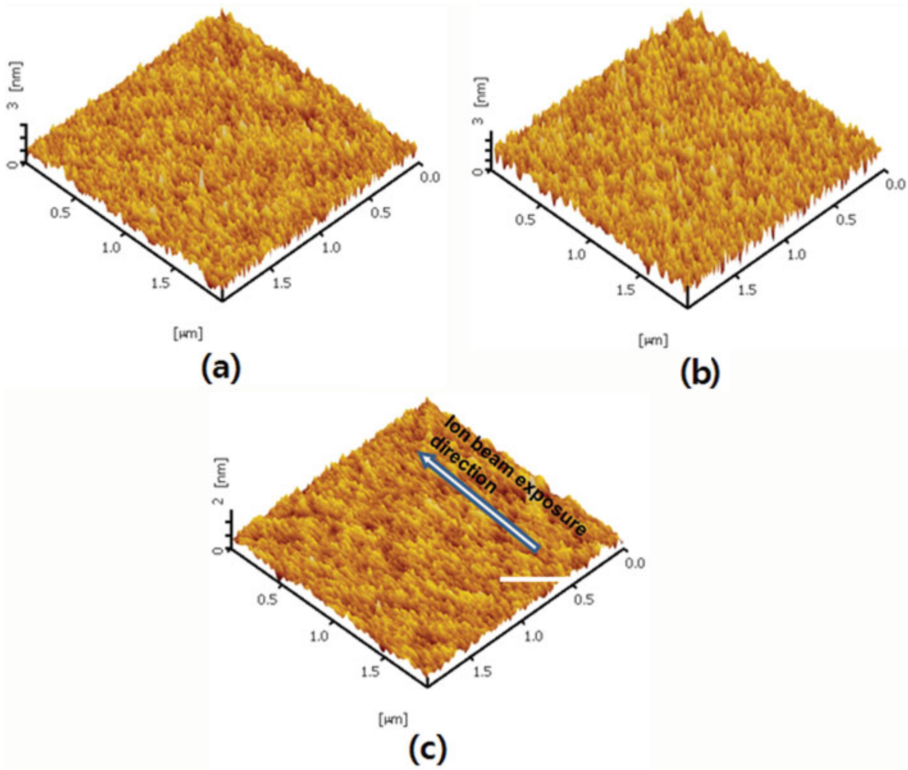

Figure 4. (a) ∼ (c) shows the morphologies of ITO SiO_2/polarizer, non-treated SiO_2/ITO/SiO_2/polarizer and ion beam-treated SiO_2/ITO/SiO_2/polarizer film surfaces, respectively, measured via AFM.

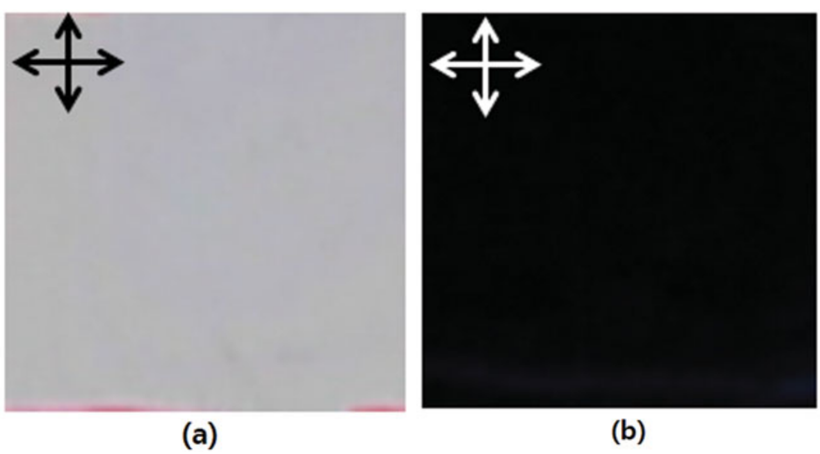

Figure 5. The images of TN cells between crossed polarizers (a) without and (b) with the electric field.

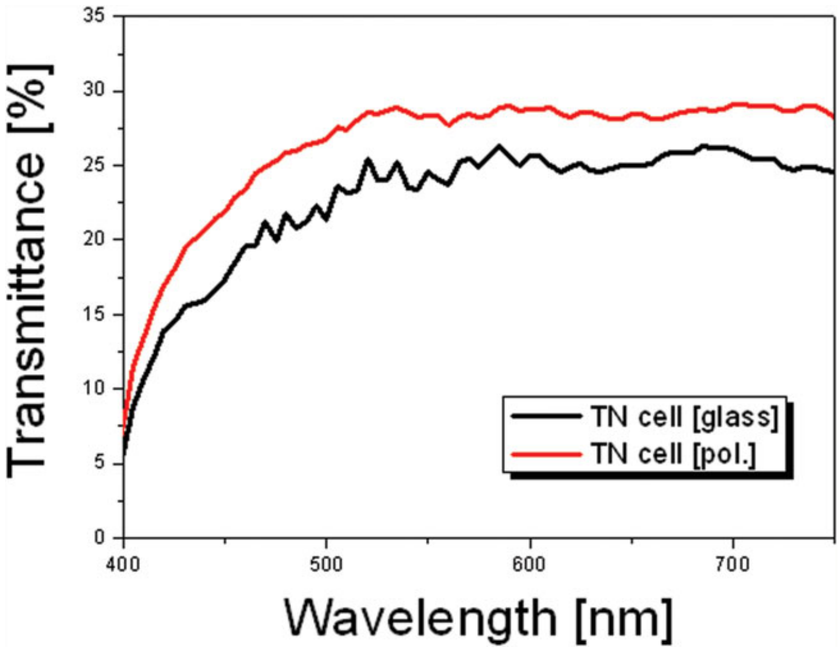

Figure 6. Transmittance are compared between the TN cell with SiO_2/ITO/SiO_2/polarizer and that with SiO_2/ITO/glass/polarizer in visible ranges.

TN cell with SiO_2/ITO/SiO_2/polarizer and that with SiO_2/ITO/glass/polarizer in the normal direction was about 323 and 298 at 550 nm, respectively.

Figure 7 shows images of ECB cells between crossed polarizers without and with the electric field. With the ion beam exposure, we can achieve uniformity in switching behavior upon applying an electric field. Figure 8 shows the transmittance performances are compared between the ECB cell with SiO_2/ITO/SiO_2/polarizer and

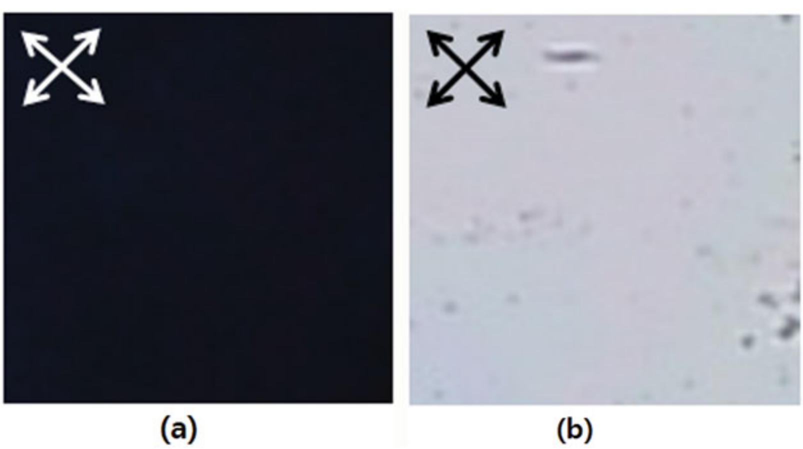

Figure 7. The images of ECB cells between crossed polarizers (a) without and (b) with the electric field.

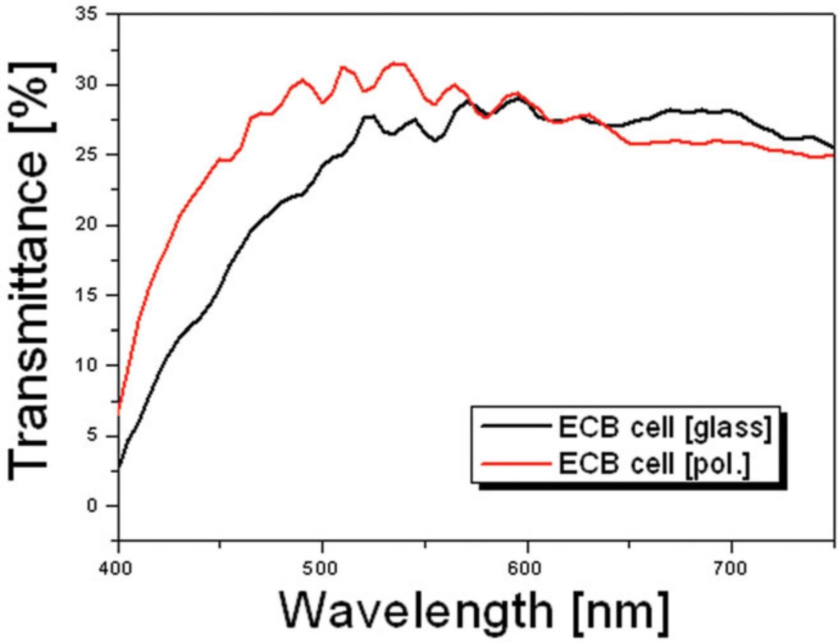

Figure 8. Transmittance are compared between the ECB cell with SiO_2/ITO/SiO_2/polarizer and that with SiO_2/ITO/glass/polarizer in visible ranges.

that with SiO_2/ITO/glass/polarizer in visible ranges at average visible wavelength. We found that ECB cell of SiO_2/ITO/SiO_2/polarizer were higher about 3% than that of SiO_2/ITO/glass/polarizer. Therefore, we suggest that polarizers integrated conducting and alignment functions SiO_2/ITO/SiO_2/polarizer have high transmittance than conventional LC cells of SiO_2/ITO/glass/polarizer. The measured contrast ratio of an ECB cell with SiO_2/ITO/SiO_2/polarizer and that with SiO_2/ITO/glass/polarizer in the normal direction was about 338 and 319 at 550 nm, respectively.

Conclusions

We manufactured polarizers integrated conducting and alignment functions SiO_2/ITO/SiO_2/polarizer films. We deposited SiO_2 and ITO thin films on polarizers via r. f. magnetron sputtering system at room temperature. Then, low-energy ion beam treatment on outside SiO_2 films was performed to align the LC molecules. Transmittance of TN and ECB cell with SiO_2/ITO/SiO_2/polarizer was higher about 3∼5% than those of conventional SiO_2/ITO/glass/polarizer in average visible ranges. Using our structure, higher transmittance-plastic LCDs can be fabricated.

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