The Electrical Properties Improving of ITO Films on Cholesteric Liquid Crystal Layer by Using Two-steps Deposition Process

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Abstract- **Indium tin oxide (ITO) films have been deposited at room temperature by DC magnetron sputtering and grown on a cholesteric liquid crystal (Ch-LC) layers. The surface morphology and electrical properties of ITO thin films was analyzed by scanning electron microscope, 3-dimension microscope and four-point prober. In a systematic study, the enhancement of electrical properties of ITO films was achieved by a novel two-steps deposition process. In addition, it was apparent that the surface roughness of ITO films deposited on Ch-LC layers by two-steps process was improved as well. A surface roughness of 0.509 μm and a sheet resistance of 87.98 ohm/sq has been obtained by two steps process.**

BACKGROUND

Transparent conducting oxides (TCOs) are widely used in optoelectronic device including thin film transistor-liquid crystal displays (TFT-LCDs), light emitting diodes (LEDs), organic light-emitting diodes (OLEDs), touch panels, and solar cells. In general these layers have good characteristics for optoelectronic device application such as low resistivity and high transmission in the visible region. Indium tin oxide (ITO) is popularly applied for optoelectronic device because of its resistivity and an optical transmission can reach to $1{\sim}3 \times 10^{-4}$ Ω-cm and above 90% in the visible region, respectively [1-2]. There are several deposition methods used to prepare ITO films such as sol-gel method [3], sputtering [4], evaporation [5], and pulsed laser deposition (PLD) [6]. The sputtering is general technique to deposit ITO films.

Recently, the color flexible reflective cholesteric liquid crystal displays (Ch-LCDs) has been developing and transparent conducting electrodes were used on color stacking structures to fabricate the devices [7]. Transparent conducting polymer layers were used into color stacking structures because of the conducting polymer layers provide flexibility and ruggedization properties. However the conducting polymer layers have higher sheet resistance of 1~2 kΩ/□ than typical ITO films [8].

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For color stacking Ch-LCD, the electrical properties are very important. In this work, a novel deposition process was proposed to obtain lower sheet resistance of ITO films. In addition the sheet resistance of two-steps deposition process of ITO films were investigated and compared with one-step deposition process.

CURRENT RESULTS

The ITO thin films were deposited by DC magnetron sputtering system (type: ULVAC SIV-3040). The sizes of base material PET/ITO/Ch-LC substrates were 3.5 ×4.5 inch^2. The thicknesses of our sputtering ITO films were 100 nm in all different conditions. The structures of our devices were PET (125 μm)/ITO (70 nm)/Ch-LC layer (10 μm)/one step sputtering ITO (100 nm) and PET (125 μm)/ITO (70 nm)/Ch-LC layer (10 μm)/two step sputtering ITO (100 nm), as showed in Fig. 1.

Sample 1 has been empty of any ITO films on Ch-LC layers surface. Sample 2 is prepared by one-step deposition process, which was used 2.3 KW of DC power at room temperature. Sample 3 and 4 are prepared by two-steps deposition process at room temperature. Sample 3 was deposited 30 and 70 nm of ITO film thickness on layer 1 and 2, respectively. Sample 4 was deposited 50 and 50 nm of ITO film thickness on layer 1 and 2, respectively. In addition, the sample 3 and 4 were used the same DC power condition for layer 1 and 2 growth. The Ch-LC layers surface had larger size and a great deal of holes without ITO films deposition as shown in Fig. 2 (a). Fig. 2 (b) showed the one-step ITO deposition could get smaller size and fewer holes than Ch-LC layers only. There are smaller size and lower number of holes during two-steps deposition process as shown in Fig. 2 (c) and (d). It is apparent that different surface morphologies result from different deposition processes on sample 1~4. The surface morphologies of different ITO films and Ch-LC layers are appeared as shown in Fig. 3.

After ITO films deposition on Ch-LC layers, the average roughness could be decrease compared to that of initial Ch-LC layers. The average roughness (Sa) were measured by 3D microscope as shown in Fig. 4. The higher average roughness could be observed after one-step deposition process and the Sa value was 0.656 μm on sample 2. However, the Sa values of two-steps deposition process were lower than one-step deposition process. The lower Sa values of P3 were 0.509 and 0.581 μm in sample 3 and 4, respectively.

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The best Rs uniformity value of 5.41% could be observed in Fig. 5. The trends of Rs uniformities were the same with sheet resistances of ITO films. The relatively low sheet resistance and surface roughness could be achieved by two-step process.

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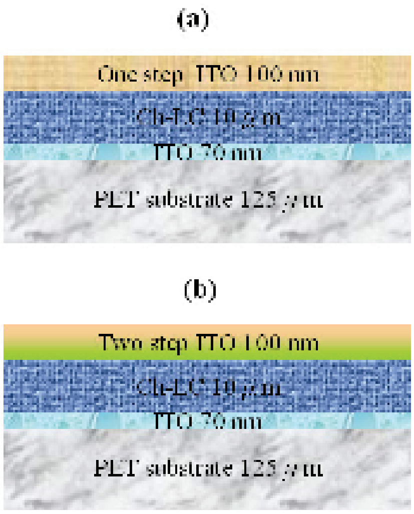
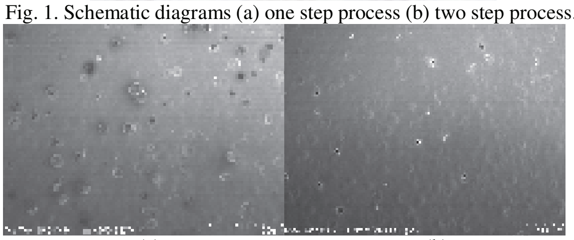
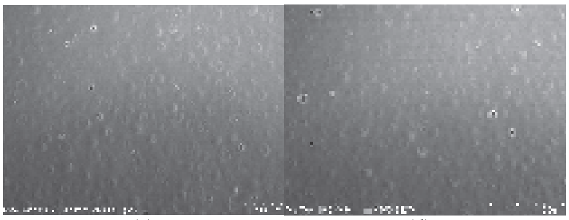


Fig. 1. Schematic diagrams (a) one step process (b) two step process.



(a) (b)



(c) (d)

Fig. 2. Top view SEM images of (a) Ch-LC layer only, (b) One-step ITO (100 nm) on Ch-LC layer, (c) Two-steps ITO (30+70 nm), (d) Two-steps ITO (50+50 nm).

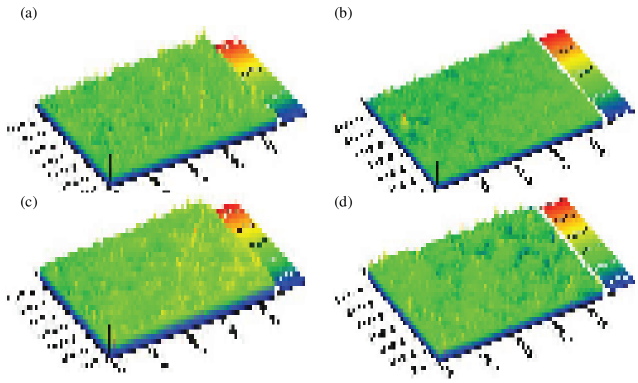


Fig. 3. The surface morphology of (a) Ch-LC layer only, (b) One-step ITO (100 nm) on Ch-LC layer, (c) Two-steps ITO (30+70 nm), (d) Two-steps ITO (50+50 nm).

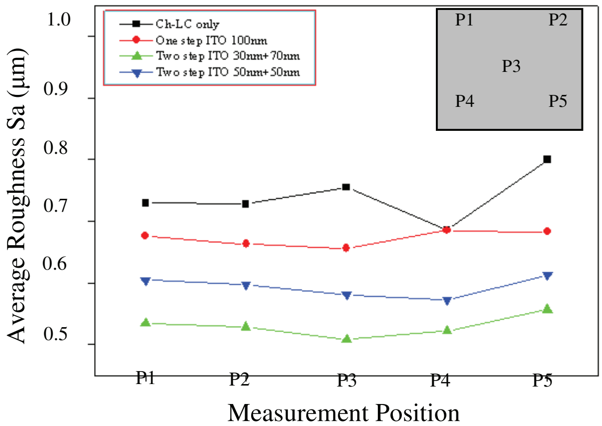


Fig. 4. Average roughness Sa measured by 3D microscope.

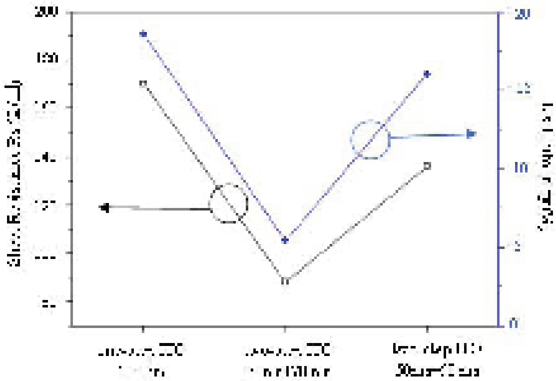


Fig. 5. Variation of sheet resistance (Ω/□) and Rs uniformity as a function of processing conditions for ITO films.