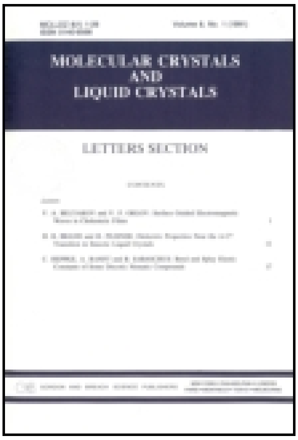

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Effects of Post Annealing Temperatures on Sputtered Indium Tin Oxide Films for the Application to Resistive Touch Panel

Soo Min Lee [a] , Jeong Min Lee [a] , Sang Jik Kwon [a] & Eou Sik Cho [a]
[a] Department of Electronics Engineering , Gachon University , 1342 SeongnamDaero, Sujeong-gu, Seongnam , Gyeonggi-do , 461-701 , Republic of Korea
Published online: 08 Jan 2014.

To cite this article: Soo Min Lee , Jeong Min Lee , Sang Jik Kwon & Eou Sik Cho (2013) Effects of Post Annealing Temperatures on Sputtered Indium Tin Oxide Films for the Application to Resistive Touch Panel, Molecular Crystals and Liquid Crystals, 586:1, 138-146, DOI: 10.1080/15421406.2013.853510

To link to this article: http://dx.doi.org/10.1080/15421406.2013.853510

Mol. Cryst. Liq. Cryst., Vol. 586: pp. 138–146, 2013

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421406.2013.853510

Effects of Post Annealing Temperatures on Sputtered Indium Tin Oxide Films for the Application to Resistive Touch Panel

SOO MIN LEE, JEONG MIN LEE, SANG JIK KWON, AND EOU SIK CHO*

Department of Electronics Engineering, Gachon University, 1342 SeongnamDaero, Sujeong-gu, Seongnam, Gyeonggi-do, 461-701, Republic of Korea

Indium tin oxide (ITO) films were deposited on glass substrates by in-line DC sputtering and were annealed at different temperatures in the main chamber of sputter. The post-annealing effects on the optical and electrical properties of the ITO films were investigated and analyzed by various measurement systems. The results show that a higher annealing temperature makes an improvement on the electro-optical properties of the ITO films. The resistivity of the ITO films was reduced from 8.90×10^{-4} Ω·cm to 2.91×10^{-4} Ω·cm and the transmittance was increased from about 76.91% to 82.15% after post annealing at 300 °C in vacuum. The post annealed ITO glass was used in the fabrication of resistive touch panel and it was possible to obtain the better linearity characteristics than those from the touch panel fabricated with non-annealed ITO glass.

Keywords Indium tin oxide (ITO); in-line DC sputtering; linearity; post-annealing; resistive touch panel

Introduction

Touch panels are increasingly growing as the devices of user interface for the applications such as ATMs, kiosks, PDAs, cellular phones, and so on. Until now, several types of touch panel such as a resistive type, a capacitive type, an infrared type, and an acoustic wave type each have been developed with their own characteristics. Although the capacitive type touch panels are rapidly developed in recent years, the analog resistive type touch panel systems are also being widely used because of their simple structures and high writing resolutions. Figure 1 shows the schematic drawing of the so-called 4-wire analog resistive type touch panel and its sensing mechanism. The resistive type touch panel consists of two indium tin oxide(ITO) layers deposited on glass or polyethylene terephthalate (PET). It is necessary to have a finite resistance and a higher transmittance of ITO films used in the resistive type touch panel. The sheet resistance of the ITO film is typically in the order of 400±50 Ω/□ with a thickness of 50 nm [1–3]. The transmittance of ITO film higher than 87% is also required at 550 nm for the application to the high end products.

*Address correspondence to Prof. Eou Sik Cho, Department of Electronics Engineering, Gachon University, 1342 SeongnamDaero, Sujeong-gu, Seongnam, Gyeonggi-do, 461-701, Korea (ROK). Tel.: (+82) 31-750-5297; Fax: (+82) 31-750-5830. E-mail: es.cho@gachon.ac.kr

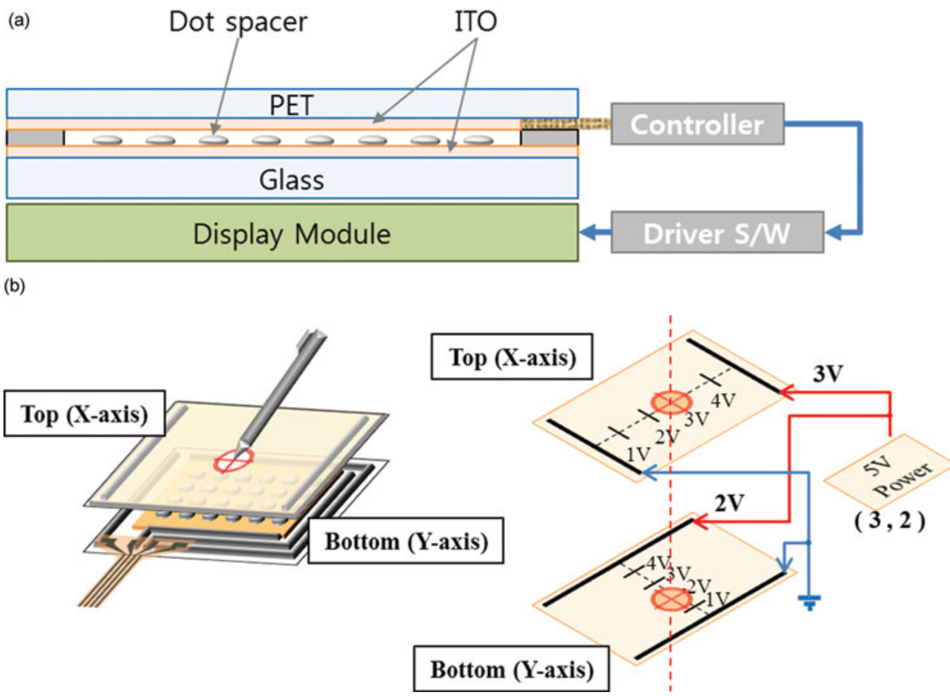

Figure 1. (a) Structure of the resistive type touch panel and (b) a principle of the position acquisition.

Usually, an ITO PET film has been used as the top sheet and an ITO glass substrate as the bottom sheet of the resistive type touch panel. For the improvement on the driving of the resistive touch panel, the ITO layer on glass substrate has been deposited at a relatively high temperature such as 300∼400 °C [4]. However, the high-temperature deposition may take time because the temperature of the deposition equipment such as sputter should be increased before the deposition and also decreased after the deposition at a steady step. Therefore, it is possible to find a new method to reduce the process time without any degradation of the quality of ITO as a result of high temperature deposition. Room-temperature deposition and post-annealing such as rapid thermal annealing (RTP) may be considered to reduce the process time [5–6].

In this experiment, the ITO films were sputtered at a room temperature and post annealed at various temperatures. For the simplicity of the experiment, the post-annealing was carried out in the main chamber of the in-line sputter. By measuring the optical and electrical characteristics of the ITO films, the characteristics of the post annealed ITO films were investigated and compared with those without post annealing. Then the ITO films were applied to the fabrication of the resistive type touch panel and investigated in terms of the driving ability of the touch panel.

Experimental

At a room temperature, ITO films were deposited about 1000 Å by in-line DC magnetron sputtering at a power of 1.5 kW on a glass substrate. Figure 2 shows the schematic of in-line sputtering system. The in-line sputtering system consists of a loading chamber and

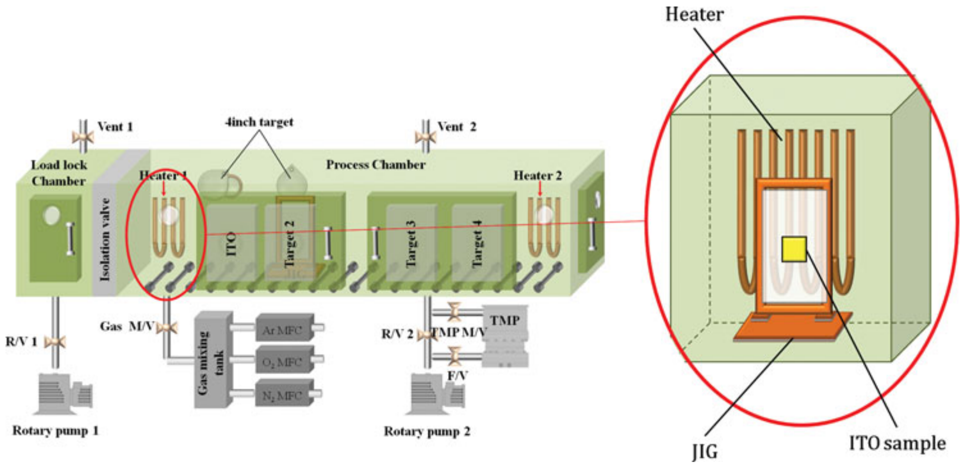

Figure 2. System configuration of the in-line sputter for the ITO deposition on the glass substrate.

a process chamber with a rectangular cathode source and a tubular heater. The sputtering ITO target (540 × 165 × 7 mm^3) was composed of In_2O_3 and SnO_2 in a weight proportion of 9:1 with a purity of 99.99% and was bonded to a water-cooled backing plate. For the in-line sputtering of ITO, the glasses with a size of 100 mm × 100 mm were attached to a large soda-lime glass loaded on the jig plate as shown in Fig. 2. During the sputtering, the

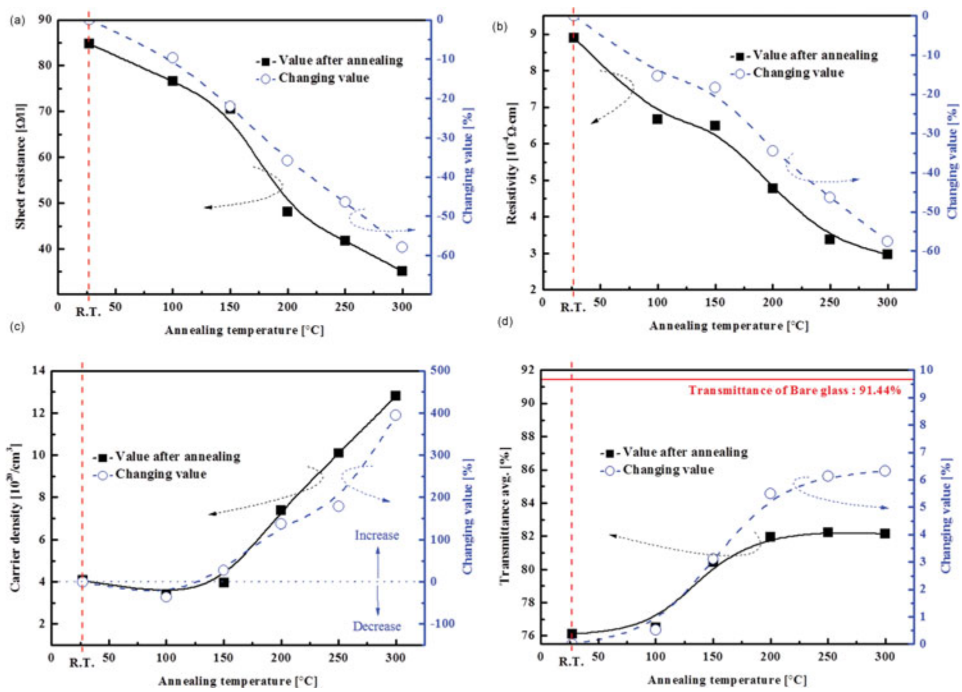

Figure 3. (a) Sheet resistance, (b) resistivity, (c) carrier density and (d) transmittance for the ITO films annealed at various temperatures.

gas mixture of Ar 50 sccm and O_2 1.5 sccm was maintained and the pressure was kept at 0.8 Pa. After the sputtering, the ITO glasses were moved in front of the tubular heater in the main chamber of the in-line sputter as shown in Fig. 2. Then post-annealing was carried out for 30min in a vacuum condition of 10^{-6} Torr at various temperatures from 100 to 300 °C.

The sheet resistances of ITO films were measured using a standard 4-point-probe. The resistivity, hall mobility and carrier concentration of the ITO films were measured and calculated using Hall-effect measurement by the Van der Pauw method. The transmittances of the ITO films were measured in the spectral range from 200 to 800 nm with a HP845X UV-vis spectrometer. The morphological property of the ITO layers was analyzed by scanning electron microscopy (SEM, Hitachi S-4700).

In order to examine the feasibility of the post-annealed ITO glass as an electrode screen of a resistive-type touch panel, 2 resistive touch panels with 7 inch diagonal size of view area were fabricated. One was fabricated with the post-annealed ITO glass as a bottom sheet and the other with the non-annealed ITO glass. For the operation, the manufactured touch panels were connected to a personal computer (PC) through the driver circuit. Then the real voltage of various points on the touch panels was measured by using a digital multimeter (FLUKE 12) for the investigation of the linearity of the resistive touch panels and the effect of the post-annealing.

Results and Discussion

The electrical and optical properties of the post annealed ITO films can be evaluated by measuring the electrical resistivity, carrier density, and transmittances as shown in Fig. 4. Figure 4(a) shows the sheet resistance of the post annealed ITO films and its changing value depending on the post annealing temperature. It shows that the sheet resistance decrease as the annealing temperature increases. It changed from 84.78 Ω/□ (R.T) to 35.15 Ω/□ (300 °C). The resistivity was also monotonically decreased from 8.9×10^{-4} Ω·cm to 2.97×10^{-4} Ω·cm with increasing annealing temperature as shown in Fig. 4(b).

In a commonly used expression, the electrical resistivity depends on two major factors; carrier density and mobility, expressed as an equation, $\rho = 1/qn\mu$. The electron carrier concentration and its change value were obtained as a function of annealing temperature as shown in Fig. 4(c). It was markedly increased when the annealing temperature was 150 °C. It was possible to obtain the electron carrier concentration from 2.79×10^{20} /cm^3 (R.T) to 12.8×10^{20} /cm^3 (300 °C). It is somewhat well known that the ITO film deposited at a low temperature less than 150 °C remains amorphous partially or completely [7–9]. It is also possible to conclude that the temperature of post annealing process has the same effect on the ITO film quality as the deposition temperature.

Optical properties of the ITO film mainly depend on the crystal quality and the electron carrier concentration. Figure 4(d) shows the optical transmission of the post-annealed ITO films. With the increasing annealing temperature, the ITO films give higher transmittance from 76.91% (R.T) to 82.15% (300 °C) at visible regions. At a higher temperature than 200 °C, the transmittance remains practically constant. It is possible to explain the strict dependences of the optical transmission on the crystal quality of the ITO film because all the ITO samples have the same thicknesses.

Figure 5 shows the surface morphologies of the post annealed ITO films. One sample was just deposited at a room temperature and the other was post annealed at 300 °C after deposition. The results show that the ITO grains slightly grow as a result of post annealing process [10].

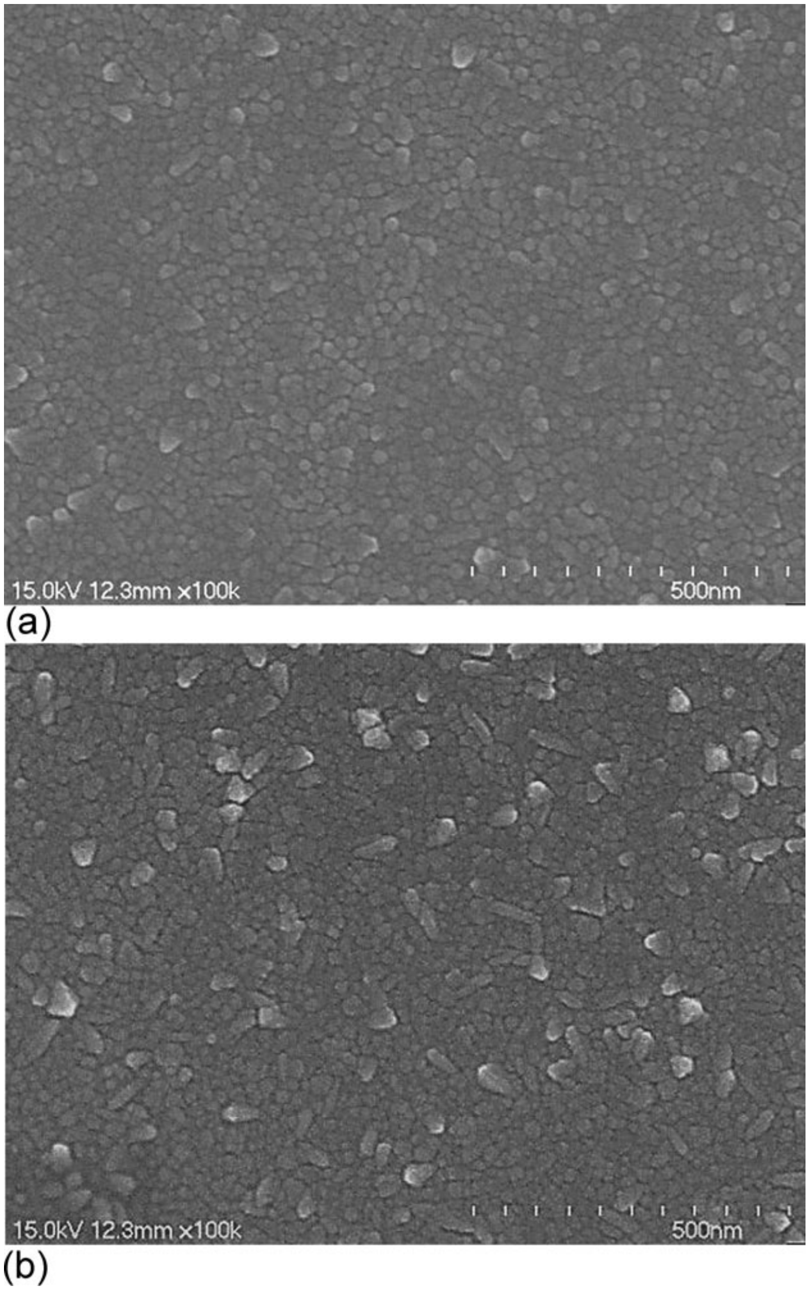

Figure 4. SEM surface topography of ITO films (a) not annealed and (b) annealed at 300 °C.

Using the two ITO glasses as the bottom sheet, the resistive type touch panels were fabricated and the linearity test was carried out. The linearity was calculated as following.

$$\text{Linearity}\,(\%) = \frac{V_m - V_n}{V_e - V_s} \times 100 \tag{1}$$

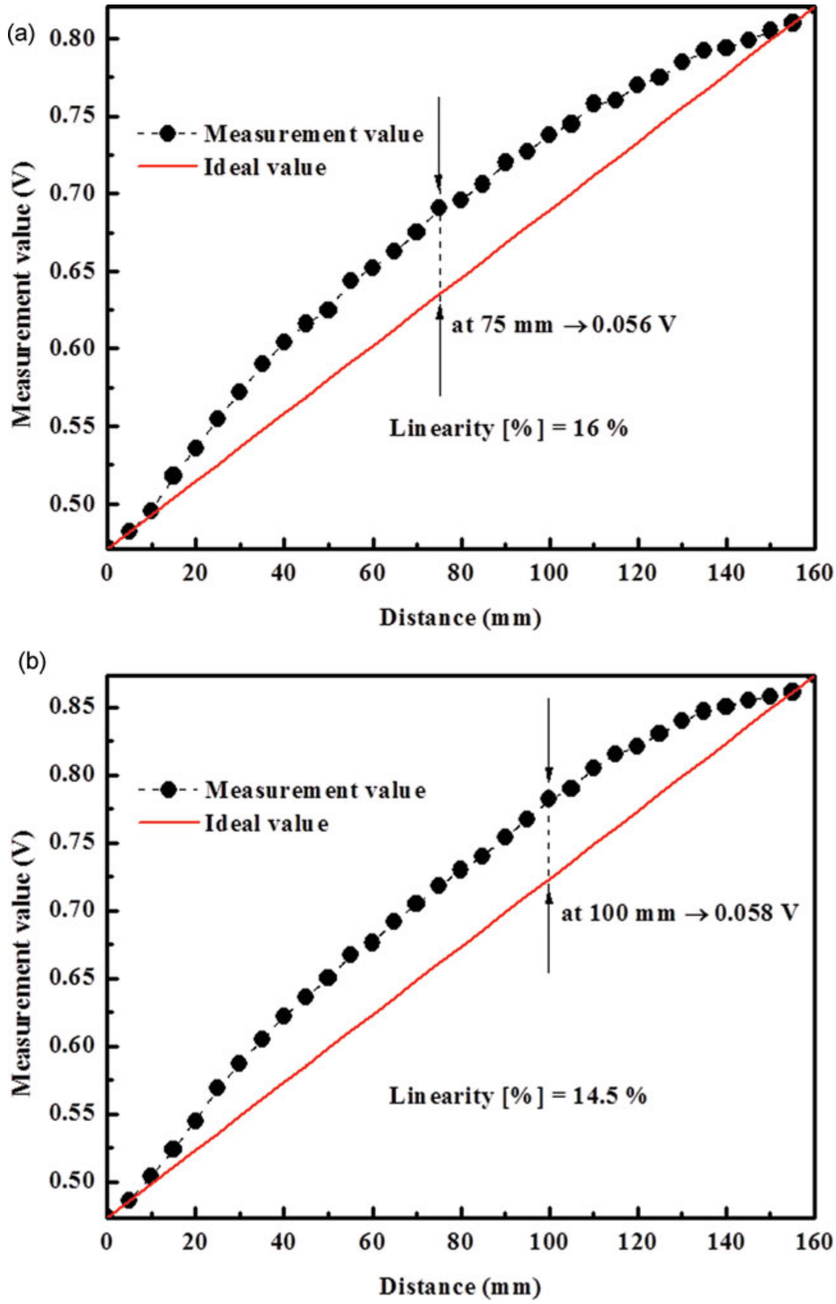

Figure 5. The linearity test result at X-axis obtained from the resistive type touch panel fabricated with ITO films (a) not annealed and (b) annealed at 300 °C.

When the top sheet and the bottom sheet of resistive type touch panel are contacted, the ideal voltage and the measured voltage are defined as V_m and V_n, respectively. V_e and V_s are defined as the maximum voltage and the minimum voltage of all the measured voltages. As the linearity has come close to zero, the resistive type touch panel is expected to show

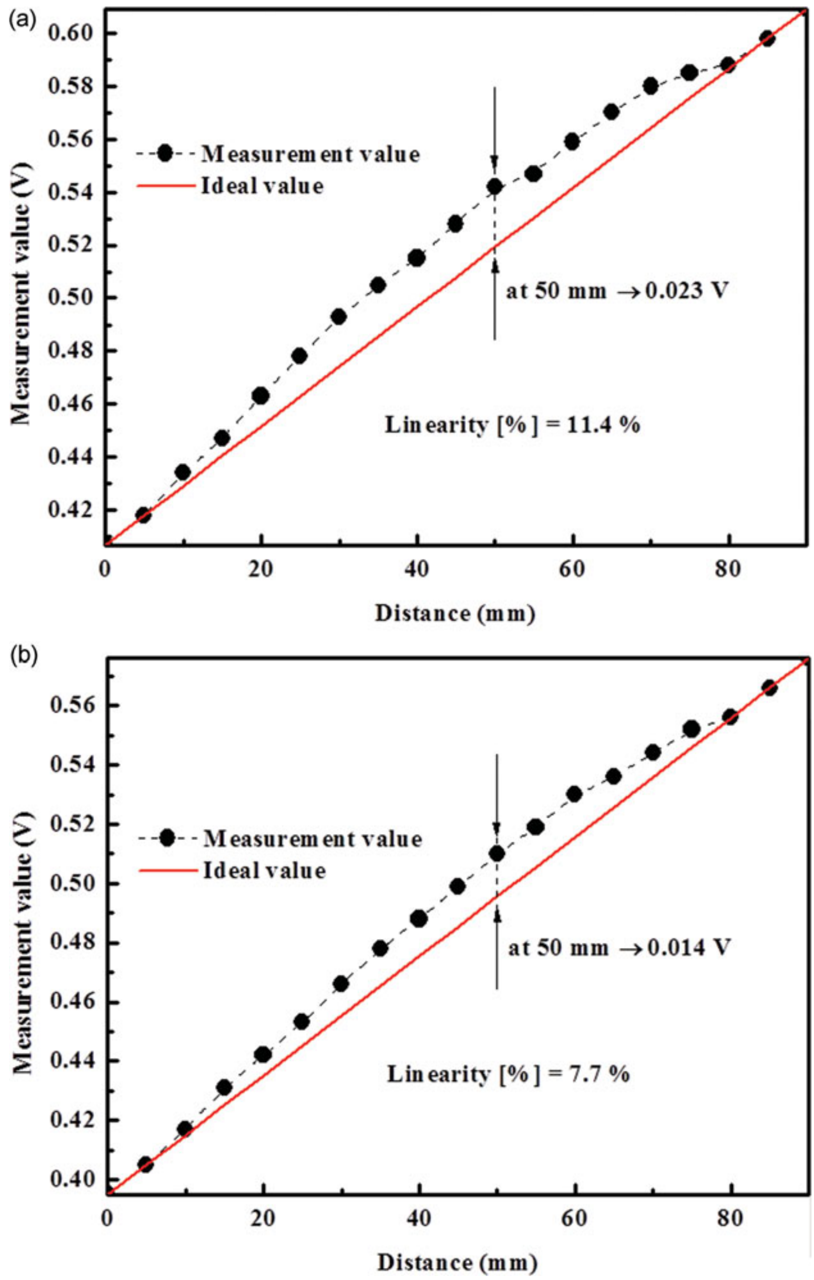

Figure 6. The linearity test result at Y-axis obtained from the resistive type touch panel fabricated with ITO films (a) not annealed and (b) annealed at 300 °C.

a better driving ability. The ideal voltages in this experiment were calculated as following.

$$\text{X ideal voltage}\,(\text{V}_{\text{n+1}}) = V_n + [(V_{160} - V_0) \div 32]$$
$$\text{Y ideal voltage}\,(\text{V}_{\text{n+1}}) = V_n + [(V_{90} - V_0) \div 18] \quad (2)$$

V_{n+1} and V_n are defined as the n+1 th and n th ideal voltages, respectively [11]. V_0 and V_{160} are the one edge and the opposite edge of x-axis of the resistive touch panel with the x-length of 160 mm, respectively. V_0 and V_{90} are the one edge and the opposite edge of y-axis of the touch panel with the y-length of 160 mm, respectively.

Figures 5(a) and (b) show the linearity test result at X-axis obtained from the resistive type touch panel fabricated with ITO glassed of Figures 4(a) and (b), respectively. From the results, the X-axis linearity was obtained as 16% and 14.5% from Figures 5(a) and (b), respectively. Figures 6(a) and (b) show the linearity test result at Y-axis obtained from the same touch panel fabricated with ITO glassed of Figures 4(a) and (b), respectively. The Y-axis linearity was obtained as 11.4% and 7.7% from Figures 6(a) and (b), respectively. It was possible to conclude that the linearity result at Y-axis showed the significant difference from the resistive type touch panels fabricated with the non-annealed and the annealed ITO glasses. In case of the linearity at X-axis, the resistance of top sheet ITO PET was measured since the voltage of bottom sheet ITO glass was grounded. On the other hand, the resistance of bottom sheet ITO glass was measured because the voltage of top sheet ITO PET was grounded when the linearity at Y-axis was obtained and calculated. Therefore, the post-annealed ITO glass is expected to make a better effect on the driving ability of the resistive type touch panel.

Conclusions

Indium tin oxide (ITO) films were deposited on glass substrates by in-line DC sputtering and were annealed in the main chamber of sputter. The post-annealing results show that a higher annealing temperature makes an improvement on the electro-optical properties of the ITO films. The post annealed ITO glass was used in the fabrication of resistive touch panel and it was possible to obtain the better linearity characteristics than those from the touch panel fabricated with non-annealed ITO glass.

Acknowledgment

This work was supported by the Korean Research Foundation (KRF) grant funded by the Korean government (MEST) (No. 2012R1A1A2042186). The fabrication of the resistive touch panel was supported by the Meeredp Incorporation.

References

[1] Colegroveand, J., & Hreh, C. (2010). Touch Panel Market Analysis. – *DisplaySearch*.
[2] Akinwunmi, O. O., Eleruja, M. A., Olowolafe, J. O., Adegboyega, G. A., & Ajayo, E. O. B. (1999). *Opt. Mater.*, *13*, 255.
[3] Wu, X., Mulligan, W. P., & Coutts, T. J. (1996). *Thin Solid Films*, *286*, 274.
[4] Chong, M. K., Pita, K., & Silalahi, S. T. H. (2009). *Mater. Chem. Phys.*, *115*, 154.
[5] Ho, C.-Y., Tu, T.-Y., Wang, C.-C., & Kang, Y. *Recent Researches in Telecommunications, Informatics, Electronics and Signal Processing*, ISBN: 978-1-61804-005-3.
[6] Negin, M., Alireza, K., Ebrahim, A. S., Sheida, B., & Hadi, M. M. (2009). *Iran. J. Chem. Chem. Eng.*, *28*, 57.
[7] Boehme, M. (2005). *Surf. Coat. Technol.*, *200*, 932.

[8] Yang, C. W. O. (1998). *J. Appl. Phys.*, *83*, 145.
[9] Zhang D. H., & Ma, H. L. (1996). *Appl. Phys. A, 62*, 487.
[10] Chong, M. K., Pita, K., & Silalahi, S. T. H. (2009). *Mater. Chem. Phys.*, *115*, 154.
[11] COMFILE technology, CUWIN 7inch Touch panel specification - *Analog Touch Panel Summary*. p. 13.