Preparation and characterization of high transmittance and low resistance index matched transparent conducting oxide coated glass for liquid crystal on silicon panel

Chang Young Jang[1], Woo Sung Paik[1],
Bum Ho Choi[2]*, Young Back Kim[2] and Jong Ho Lee[2]
[1]Selcos Co. Ltd, Suwon, GyoungGi, 443-813, Korea
[2]National Center for Nanoprocess and Equipments, Korea Institute of Industrial Technology, GwangJu, 500-484, Korea
TEL:82-62-600-6510, e-mail: bhchoi@kitech.re.kr

Keywords : Index, transparency, conducting oxide, resistivity, LCoS

Abstract

High transmittance and low resistance index matched transparent conducting oxide (IMTCO) coated glass was prepared and characterized. IMTCO was deposited by RF magnetron sputtering with the thickness of 15nm and 90nm thick anti-reflection layer was evaporated. To modify surface to hydrophilic, in-situ plasma treatment was also performed. IMTCO coated glass exhibited 96.6% of transmittance in the wavelength range of 400~700nm which is relatively high value compared to commercially available IMTCO glass. The sheet resistance uniformity was measured to be 1.53%.

1. Introduction

Liquid crystal on silicon (LCoS) display panel is promising candidate for low cost, high resolution display for large scale projection display [1-2]. LCoS display has many advantages such as high aperture, fast response time, high resolution and low manufacturing cost. In these days, LCoS display panel was applied to display industry such as mobile projection display, head mount display, electronic board. LCoS display panel consist of 4 major parts: transparent conducting oxide (TCO) and anti-reflection layer coated glass, single crystal silicon thin film transistor backplane, optical engine for driving the LCoS display panel and liquid crystal. Among them, high transparent and low reflectance index matched TCO (IMTCO) glass is key component of LCoS display. Up to now, development of high quality IMTCO glass was a bottleneck for commercializing LCoS display panels to large area high resolution display. IMTCO glass affect the efficiency, resolution, and yield of LCoS display panel. Especially, high transmittance IMTCO glass consumed in Korea display industry has been imported in whole quantity from Europe and Taiwan. Therefore, localization of IMTCO glass is the pressing matter.

In this work, high transparent in visible ray range IMTCO layer with low resistivity was prepared by RF magnetron sputtering technology and characterized. To enhance transparency in visible range ray, single layer of anti-reflection coating was designed and prepared by simple e-beam evaporation method. Furthermore, to modify the surface to hydrophilic for subsequent bonding process with liquid crystal, in-situ plasma treatment was employed, result in low contact angle and low roughness variation.

2. Experimental

The staring material was Corning 1737 glass with a size of 200 x 200 mm^2. First of all, oxygen (O_2) plasma treatment was performed with a plasma power of 300 Watt. The O_2 flow rate was 30 sccm, and treatment time was 120 sec. The O_2 plasma treatment can remove the organic particle for clean surface and modify the surface state. Secondly, 15nm thick TCO layer was RF magnetron sputtered onto the glass. Tin doped Indium oxide (ITO) which was employed as a TCO material is one of the most widely used TCO material. In general, ITO surface is commonly treated under O_2 plasma or ultraviolet to modify the surface. The base pressure of sputter system was 5 x 10^{-6} Torr and the working pressure was kept to 0.5 mTorr during the deposition process. The Ar and O_2 flow rate was maintained to 100 and 0.5 sccm, respectively. During the sputtering process, the temperature of substrate was kept 350℃. To obtain high uniformity, the substrate was rotated with an rpm of 20. To modify surface from hydrophobic to hydrophilic, in-situ plasma treatment was carried out once more. In our case, O_2 plasma was also used in sputtering chamber without breaking the vacuum, and the treatment conditions are the same as the first one. Thirdly, anti-reflection layer was e-beam evaporated for high transmittance. SiO_2 and ZrO_2 double layer was coated as an anti-reflection layer with thickness of 91 and 130 nm, respectively.

Atomic force microscope was used for measuring surface morphology and roughness of IMITO surface (PSI XE-200). 4-point probe was used for measuring sheet resistance of IMITO thin layer (Napson RT-3000). Transmittance and reflectance of deposited ITO and anti-reflection layer was measured in visible ray range (wavelength range of 400-700 nm). Contact angle measurement system was employed to characterize the surface modification to hydrophilic surface.

3. Results and discussion

Figure 1 shows typical AFM image of surface of ITO layer taken from the center and edge of the sputtered samples. To evaluate the surface morphology, measurement was performed more than 20 samples and 9 points for each sample. The average roughness was measured to be 0.0905nm in root mean square value, which is considerably lower value than that of commercially available ones. Moreover, the roughness difference measured between center and edge was around 2%, which is also low value considering the size of substrate 200 x 200mm^2. The sheet resistance measured from the 15 nm thick ITO surface showed 100.9Ω/□ and resistance uniformity was 1.53%. To get averaged sheet resistance, the data were taken also from the 9 points was. Compared with other reports, the sheet resistance of commercially available IMTCO glass was around 15 and 25 %, respectively [3-4]. The low sheet resistance was

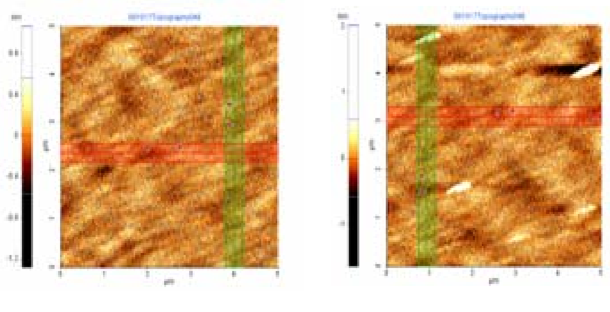

Fig. 1. AFM image of IMITO surface taken from center and edge.

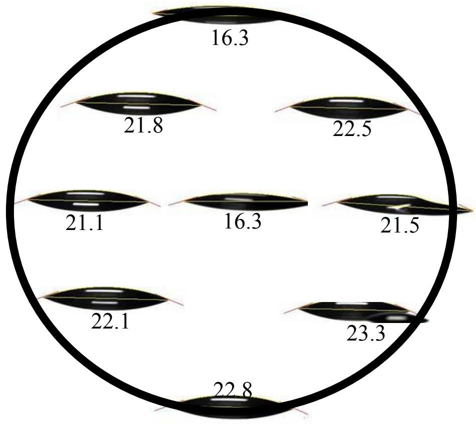

Fig. 2. Contact angle map taken from the 9-points after in-situ plasma treatment.

originated from the relatively smooth surface as can be seen from Fig. 1. This low value of sheet resistance might be adopted to high resolution LCoS display panel.

Figure 2 shows contact angle measurement results taken from the 9 points. As denoted from the Fig. 2, contact angle was varied from 22.8 to 16.3^o, and the average value was 20.8 ^{o}. As mentioned before, O_2 plasma treatment was performed 2 times before and after ITO sputtering process. Although each plasma treatment has the different purpose for cleaning and surface modification, the results we have obtained are very similar. Due to plasma treatments, surface of substrate was almost perfectly cleaned, result in smooth ITO sputtered layer. Moreover, the contact angle was also improved from 40 to 20.8 ^{o} owing to in-situ plasma treatment after deposition of ITO layer. The low contact angle, which means surface modification to hydrophilic, can pave the way for bonding process to liquid crystal.

Figure 3 shows transmittance of IMTCO glass measured in the wavelength of visible ray range. In case of bare glass, the transmittance was almost below 925, which shows averaged value of 91.9 %. However, 15 nm thick ITO coated glass exhibited maximum transparency of 98.58 %. The averaged value taken 3 times from the different samples was 94.85, 94.87 and 96.60 %, respectively. In general, transmittance of TCO film was affected by surface morphology. In our case, surface morphology was improved by controlling the sputtering condition and in-situ plasma treatment. As mentioned before, the averaged surface roughness after plasma treatment was 0.095nm. This value is around one order of magnitude lower than that of commercially available one [5]. According to other reports, the surface

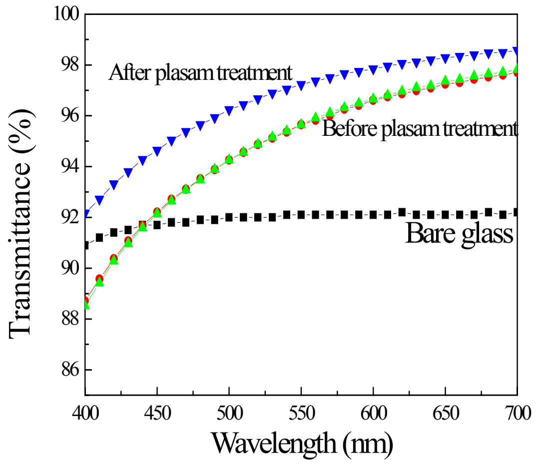

Fig. 3. Transmittance of IMITO glass before and after in-situ plasma treatment. Black filled square denotes bare Corning 1737 glass.

roughness measured by AFM was 0.9 and 0.265 nm, respectively. It can be assumed that in-situ plasma treatment in sputtering chamber can modify the surface of ITO, result in smooth surface, low sheet resistance and finally high transmittance in the visible wavelength range.

4. Summary

Table I summarize the characterization results of IMTCO glass compared to commercially one. As can be seen Table 1, the characteristics of IMTCO glass prepared in this work exhibited remarkably high quality compared to that of previous ones. The measured characteristics such as transmittance in visible light range, low resistivity, resistance uniformity, surface uniformity and contact angle showed superior quality compared to commercially available ones which is imported from Europe and Taiwan. The developed IMTCO glass has the quality adopted to LCoS display panel with high resolution and large size. This work opens up the possibility of localization of IMTCO glass which is key component of LCoS display panel.

TABLE 1. Summary of characterization results of IMITO glass and comparison to commercially available ones.

Characteristics	Results	Presently used one
Transmittance (%)	96.6	94.1
Sheet Resistance (Ω/□)	100.9	116.52
Resistance Uniformity (%)	1.53	14.67
Surface Roughness (nm)	0.095	0.9
Contact angle (^{o})	20.8	26.8

5. References

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