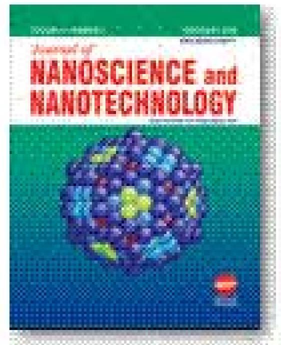
Index-Matched Indium Tin Oxide Electrodes for Capacitive Touch Screen Panel Applications



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Index-Matched Indium Tin Oxide Electrodes for Capacitive Touch Screen Panel Applications

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Index-matched indium tin oxide (ITO) electrodes for capacitive touch screen panels have been fabricated to improve optical transmittance and reduce the difference of reflectance (ΔR) between the etched and un-etched regions. 8.5 nm Nb_2O_5 and 49 nm SiO_2 thin films were deposited by magnetron sputtering as index-matching layers between an ITO electrode and a glass substrate. In case of 30 nm ITO electrode, a 4.3% improvement in the optical transmittance and a ΔR of less than 1% were achieved, along with a low sheet resistance of 90 Ω/□.

Keywords: Index Matched ITO, Capacitive Touch Screen Panel.

1. INTRODUCTION

Capacitive touch screen panels (TSPs) have been a subject of growing interest in recent years due to their intuitive user interfaces for portable electronic devices ranging from mobile phones to tablet PCs.[1,2] Capacitive TSPs are conventionally built with two transparent electrodes in parallel (two layers) or in series (one layer). Indium tin oxide (ITO) thin film is used in capacitive TSPs as a transparent electrode due to its excellent properties such as high conductivity and transparency. However, since the refractive index of ITO is much higher than that of the glass substrate, the air/ITO/glass/air system generates a lot of optical loss (approximately 16%) due to Fresnel reflectance at the interfaces.[3] Also, the reflectance difference (ΔR) between the etched and un-etched regions of ITO electrodes degrades the visibility as schematically shown in Figure 1(a). It would be very desirable to reduce both the optical loss at the air/ITO/glass interface and the ΔR without deteriorating other desired properties of the ITO film. (The process to minimize the optical losses and the ΔR is called index matching in this paper). Yan et al. reported index matching of an ITO electrode to a glass substrate for LCD applications by using porous ITO.[4] However, due to the porosity, the sheet resistance of the index-matched ITO is much higher than that of conventional ITO.

In this study, we have fabricated index-matched ITO electrodes for touch screen panel applications by using two index-matching layers (IMLs) between the ITO film and a glass substrate as schematically shown in Figure 1(b). An optical simulation tool was used to find the optimum thicknesses of the IMLs for 30 nm ITO electrode. The 30 nm index-matched ITO electrode is experimentally demonstrated to have a more than 4.3% increase in optical transmittance with low sheet resistance of 90 Ω/□ after 200 °C annealing. Moreover, ΔR less than 1% in the visible range is achieved.

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2. EXPERIMENTAL DETAILS

The first (Nb_2O_5) and the second (SiO_2) IMLs were deposited sequentially on a glass substrate using DC and RF magnetron sputtering systems, respectively. Ar-diluted O_2 gas (5%) was used for both IML depositions. The working pressure was 3.4 mTorr for both depositions. The DC power for Nb_2O_5 and the RF power for SiO_2 during the depositions were 210 W and 1300 W, respectively. An alkali-free glass (Corning 1737) and a chemically strengthened glass (strengthened depth of 10 μm) with dimensions of 100×100 mm were used for the glass substrate. A 30 nm ITO thin film was deposited on the second IML (SiO_2 layer) using a DC magnetron sputtering system. Ar-diluted O_2 gas (0.4%) and an ITO target (3 wt% SnO_2-doped In_2O_3) were used for the deposition. The DC power and the working pressure were 600 W and 5 mTorr, respectively. After the ITO deposition, heat treatment was carried out in a box furnace for 1 hour at 200 °C in vacuum condition.

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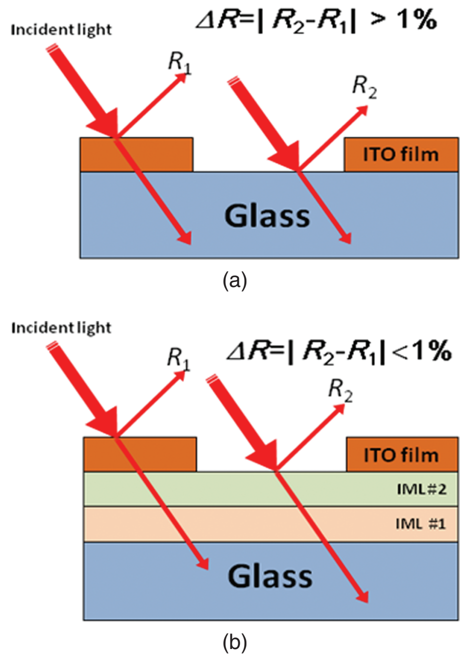

Fig. 1. Schematic illustrations of the ITO/glass (a) and ITO/IMLs/glass (b).

The thickness of each film was confirmed using a surface profiler (Alpha-step-IQ, USA). Both the optical transmittance and the reflectance were measured in the wavelength range of 400–700 nm using a UV-visible spectrometer (Hitachi U-3501, Japan). The refractive index and the extinction coefficient of each material were measured simultaneously in the wavelength range of 400–700 nm using spectroscopic ellipsometry.

3. RESULTS AND DISCUSSION

Figure 2 shows the measured optical dispersion (i.e., refractive index) curves of Nb_2O_5, ITO, and SiO_2 after 200 °C annealing for 1 hour in the wavelength range of 400 nm to 700 nm. The Nb_2O_5 (15 nm) and the SiO_2 (50 nm) thin films were deposited on Si substrates for the measurements using DC and RF magnetron sputtering systems, respectively. The refractive indices of Nb_2O_5 and SiO_2 at a wavelength of 550 nm are 2.28 and 1.49, respectively, which values are similar to those in previous reports.[5,6] A dc magnetron sputtering system was used for the deposition of the ITO (30 nm) thin film. The refractive index of 1.97 is obtained at a wavelength of 550 nm with virtually zero extinction coefficient (2×10^{-6}); this result is also similar to that of conventional ITO films.[7–9] Using an optical simulation tool with the obtained optical dispersion data, we were able to decide on the optimum thicknesses of the two IMLs (Nb_2O_5 and SiO_2) in order to induce the optical system to have high transmittance and low ΔR. In the case of using a 30 nm thick ITO film, the optimum thicknesses of the Nb_2O_5 and the SiO_2 are found to be 9.5 nm and 45 nm, respectively, by the simulation.

The measured transmittances of the bare glass (Corning), the ITO/glass, and the ITO/IMLs/glass samples are shown in Figure 3. Air was used as the reference for all the transmittance measurements. In Figure 3, the transmittance of the index-matched ITO (ITO/IMLs/glass) sample is very uniform and is only 4% lower than that of the bare glass in nearly whole visible range (460∼700 nm). A transmittance of 87.8% and a transmittance increase of 4.3% are achieved at 550 nm with our index-matching scheme. Moreover, the sheet resistance of the 30 nm index-matched ITO is not degraded and is as low as 90 Ω/□ ($\rho \sim 2.7 \times 10^{-4}$ Ω · cm). Our results indicate that the appropriate index-matching buffer layer system leads to both the reduction of optical loss and the improvement of the spectral uniformity without any electrical alteration of the ITO film.

The experimental transmittance and reflectance of the ITO/IMLs/glass and IMLs/glass samples are plotted in Figure 4(b) with the simulation results (Fig. 4(a)). Here, the ITO/IMLs/glass and the IMLs/glass correspond to unetched and etched regions, respectively, on the TSP as already defined in Figure 1(b). As can be seen in Figure 4(b), a ΔR between the IMLs/glass and the ITO/IMLs/glass of less than 1% has been achieved in nearly

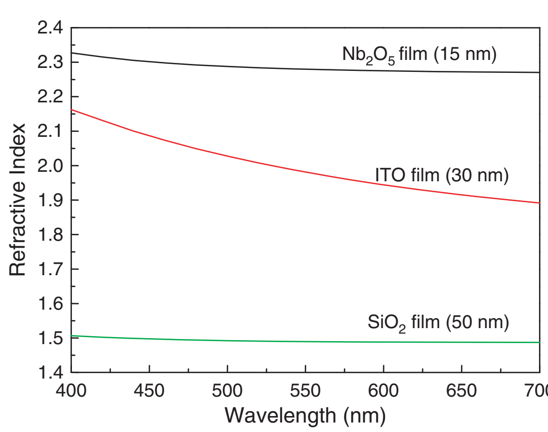

Fig. 2. Optical dispersion curves of the ITO and IMLs.

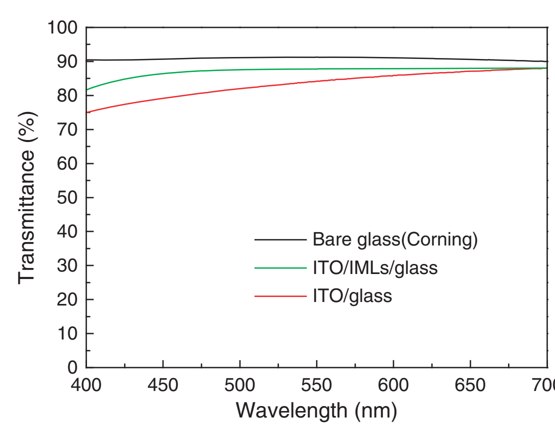

Fig. 3. Transmittance of bare glass, ITO/glass, and ITO/IMLs/glass.

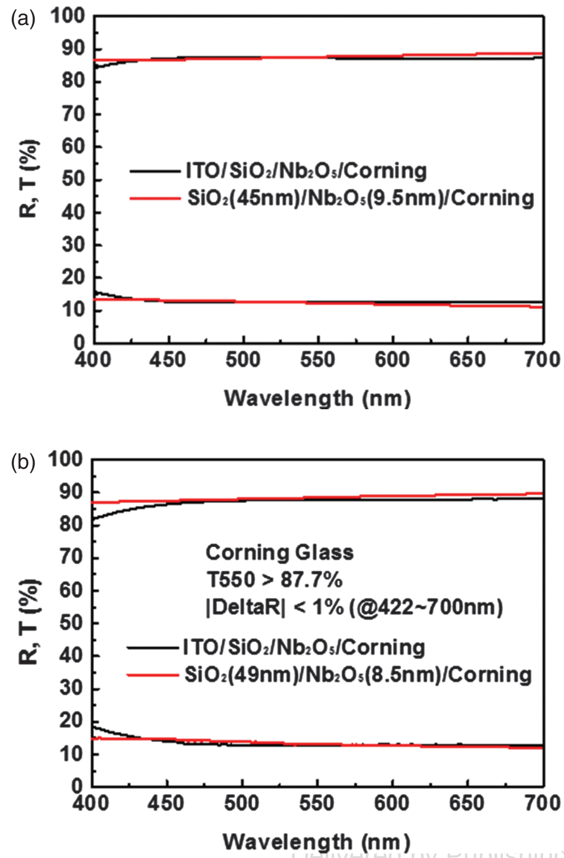

Fig. 4. Transmittance and reflectance of IMLs/glass and ITO/IMLs/glass: simulation results (a) and experimental results (b).

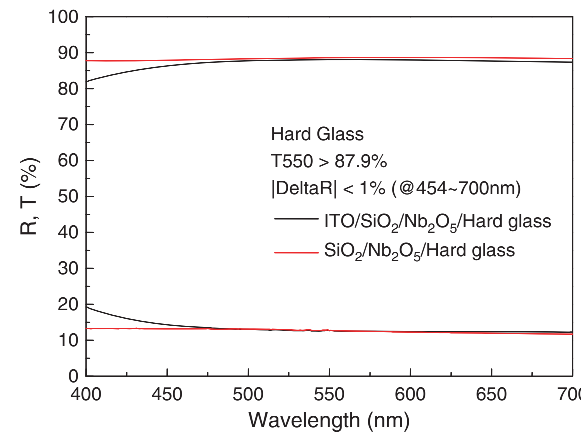

Fig. 5. Transmittance and reflectance of IMLs and ITO/IMLs on a chemically strengthened glass.

Fig. 6. Visibility of ITO patterns: non-index-matched ITO (left) and index-matched ITO (right).

whole visible range (422–700 nm). The slight deviation between the experimental data (Fig. 4(b)) and the simulation data (Fig. 4(a)) especially in the blue wavelength range (400∼430 nm) may originate from the fact that the deposited thicknesses are slightly different from the target thicknesses. We were able to determine the deposited thickness of each film using a fitting process that fits the experimental transmittance curve to the simulated curve. The determined thicknesses of the Nb_2O_5 and the SiO_2 films are about 8.5 nm and 49 nm, respectively. The deviation between the deposition and the target thickness is less than 12% for the two films. If the control of deposition time of each film is optimized, then further improvement could be possible.

For comparison, the IMLs and the ITO films were deposited on a strengthened hard glass and were optically measured as shown in Figure 5. In Figure 5, a ΔR of less than 1% was achieved for nearly whole visible range (454∼700 nm). However, the range of $\Delta R < 1\%$ is slightly narrow compared to that of the films on Corning glass. This difference may originate from the difference of the shapes of the optical dispersion curves of the two glasses (not shown here). The sheet resistance of the 30 nm index-matched ITO on the hard glass is similar to that on the corning glass (about 90 Ω/□).

Finally, we fabricated 4 inch touch screen panels with/without IMLs as shown in Figure 6. In Figure 6, one can see that the ITO patterns with the IMLs (right) are not visible to the human eye while those without IMLs (left) can be easily observed. Therefore, the index matching scheme presented in this study is very promising for the application of capacitive touch screen panels.

4. CONCLUSION

Index-matched ITO electrodes for capacitive touch screen panels have been fabricated to enhance optical transmittance and reduce ΔR between the etched and un-etched regions. 8.5 nm Nb_2O_5 ($n = 2.28$) and 49 nm SiO_2 ($n = 1.49$) thin films have been deposited by magnetron sputtering as index-matching layers between the ITO film and a glass substrate. A 30 nm index-matched ITO electrode is experimentally demonstrated to have more than 4.3% increase in optical transmittance with low sheet resistance of 90 Ω/□ after 200 °C annealing. A ΔR of less than 1% has been also achieved in nearly whole visible range.

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