THE EFFECT OF ITO BUFFER LAYER ON PHYSICAL PROPERTIES OF AZO THIN FILMS DEOISITED ON GLASS AND PET SUBSTRATES

Negin Manavizadeh[1,2], Mojtaba Masoudi[1], Alireza Khodayari[2], and Ebrahim Asl-Soleimani[1]

[1]School of Electrical and Computer Engineering, University of Tehran, Tehran, Iran

[2]Islamic Azad University, Pardis Branch, Department of Electrical Engineering, Tehran, Iran

1. Introduction

Transparent conductive oxide (TCO) thin films such as Al doped zinc oxide (AZO) and tin doped indium oxide (ITO), due to their low resistivity and high transmittance, have been widely used as transparent conductive electrodes for various displays (Li et al., 2010; Minami, 2005) and photovoltaic devices (Manavizadeh et al., 2009; Bagherzadeh et al., 2009). In generally, TCO thin films were prepared by many methods such as spray pyrolysis (Lokhande & Uplane, 2000), pulsed laser deposition (Shin et al., 2011; Viespe et al., 2007), chemical vapor deposition (Gaskell & Sheel, 2011; Kim et al., 2010), sol–gel (D. Raoufi &T. Raoufi, 2009; Valencia et al., 2008) and sputtering method (Lei et al., 2010; Manavizadeh et al., 2009). Among these techniques, sputtering of TCOs is an interesting technique for all applications where low process temperatures are desired and the stoichiometry of the films are more controllable than other techniques (Manavizadeh and et. al., 2009).

Nowadays, the replacement to flexible polymer substrates is gaining a great interest (Fahland et al., 2001, Guille & Herrero, 2005) because it can give advantages such as lighter weight, higher shock resistance and scalable roll-to-roll preparation procedures.

In this work, we investigate the effect of ITO buffer layer on AZO physical properties on glass and flexible PET substrates. Results show that ITO buffet layer improves the quality of AZO thin films on both substrates. The Optical, electrical and morphological properties of AZO layer are analyzed by UV/VIS/IR spectroscopy, four point probes and SEM analyses. The quality of films deposited on buffer layer is found to be superior to those grown directly on a substrate.

Experimental

The substrates used in this study were micro slide glass (rigid substrate) and PET (flexible substrate). All substrates were cleaned by RCA method (DI water, ammonia, hydrogen peroxide 5:1:1). The ITO buffer layer (~100nm) was deposited on all substrates by RF sputtering at 250W power from an ITO source, with a purity of 99.99%. Subsequently, the AZO layer with a thickness of 100nm was deposited onto the ITO film on the corresponding substrates. The distance between the source and the substrates was 60mm. The vacuum chamber was evacuated down to a base pressure of about 6×10^{-6}Torr prior deposition. The reactive sputtering gas was high purity argon (99.999%). The deposition was carried out at a constant pressure of 20mTorr. In this work, ITO thin films have been grown by sputtering at room temperature simultaneously onto glass and PET substrates because of the weak thermal resistance of polymer substrates in high temperature. In order to study the physical properties of these layers, the morphological, electrical and optical properties of layers are analyzed by scanning electron microscopy (SEM), four point probe system (Keithley 196 & 224) and UV/VIS/IR spectrometer (Varian Cary 500), respectively.

2. Results and Discussion

In order to analyze the influence of the ITO buffer layer on the structure of AZO thin films, ITO transmittance property on both substrates was characterized and then AZO films deposited onto ITO layers were studied.

Optical transmittance spectra of the ITO on glass and PET substrates are shown in Fig.1. In order to compare the transmittance of the ITO coating deposited onto the glass and the polymer, it has been calculated from the transmittance Spectrum of the ITO-coated samples by subtracting the transmittance of the corresponding substrate. Results demonstrate that the average transmittance of ITO in visible range on Glass and PET substrates is 77.8% and 83%, respectively.

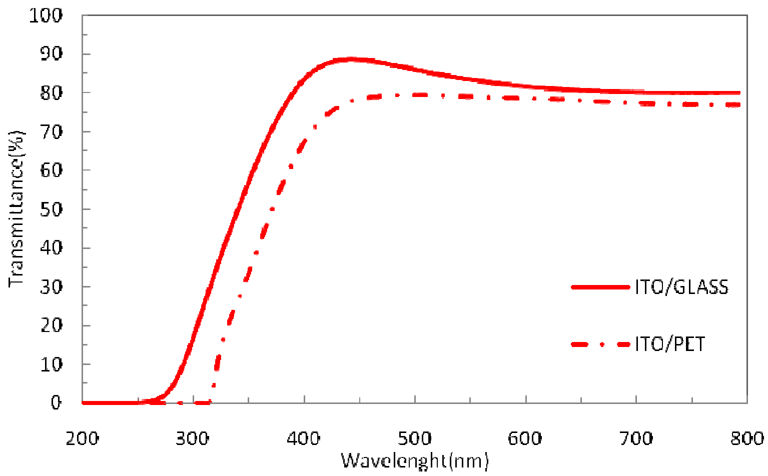


Fig. 1: Optical transmittance spectra for ITO layers on Glass and PET substrates.

Fig. 2 shows the transmittance spectra of AZO thin films deposited on Glass and PET substrates with and without ITO buffer layer. Although thick layer invariably have lower optical transmission due to optical scattering from longer optical path (Wong et al., 2004), the transmittance of AZO films are increased by applying the ITO buffer layer. Results show that the average transmittance of AZO varies from 83% to 89% on PET substrates and varies from 82% to 92% on glass substrates. This means that ITO buffer layer improves the transmission of AZO thin films on the glass and PET substrates.

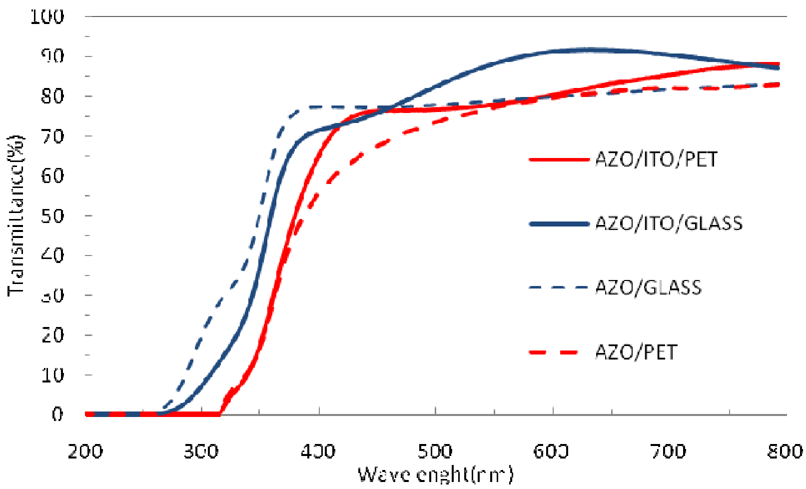


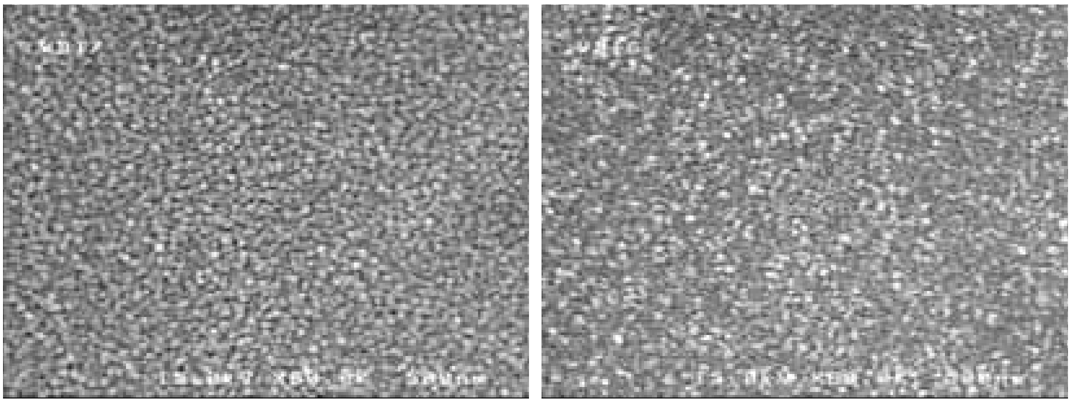
Fig. 2: Optical transmittance spectra for AZO thin films with and without ITO buffer layer on Glass and PET substrates.

The electrical resistivity of the films was measured by four point probe system. The measured values demonstrate that the application of ITO buffer layer reduces the resistivity of AZO film from 4.75×10^{-2} Ωcm to 6.9×10^{-4} Ωcm on glass substrate and from 2.27×10^{-2} Ωcm to 1.04×10^{-3} Ωcm on PET substrate which is due to increase of free electron concentration in AZO. The resistivity of the ITO layers on both substrates and AZO thin films with and without buffer layers are summarized in Table 1. Comparison of the results shows that resistivity of AZO thin film on glass substrate with ZnO buffer layer is the least. This is due to the highest number of vacancies. In other word, multilayer thin films show different physical properties other than the conventional monolayer thin films (Fallah et al., 2007). The quality of films deposited on buffer layer is found to be superior to those grown directly on a substrate (Fallah et al., 2007; Viespe et al. 2007).

Tab. 1: The Electrical Resistivity of ITO and AZO thin films on both substrates

Structure	Resistivity×10^{-4} (Ω-cm)
ITO/Glass	23.7
ITO/PET	10.1
AZO/Glass	227
AZO/PET	475
AZO/ITO/Glass	10.4
AZO/ITO/PET	6.9

Figure 3 shows the surface SEM images of ITO on glass and PET substrates before AZO deposition.

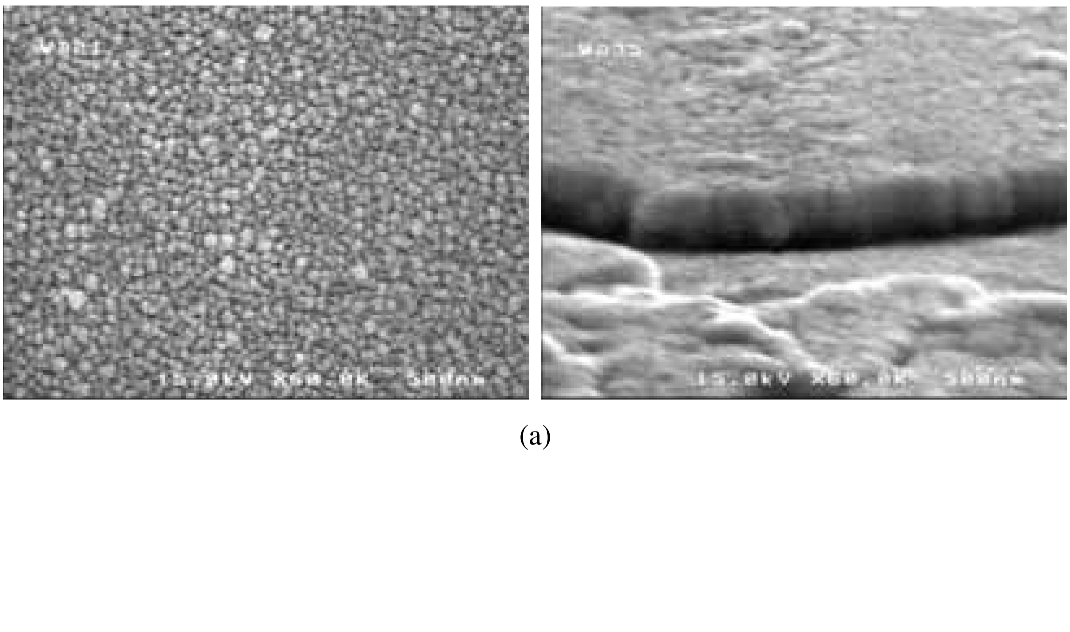


(a) (b)

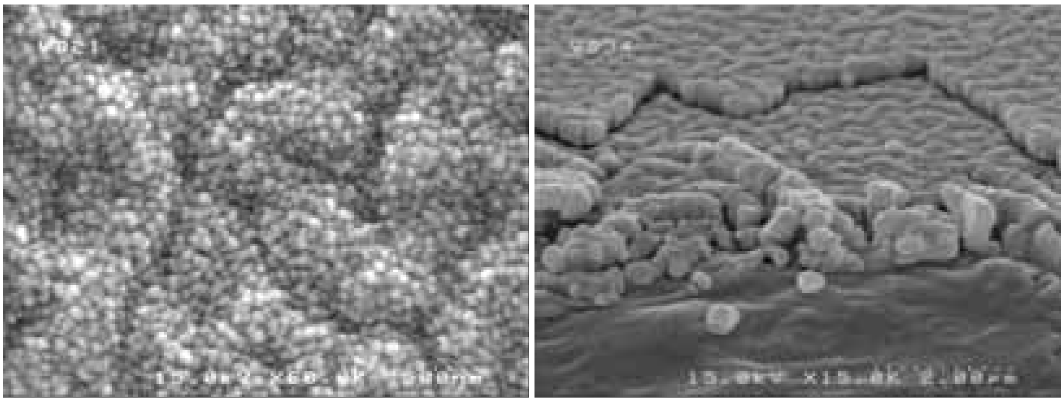
Fig. 3: SEM images of ITO on (a) glass and (b) PET substrates.

In order to investigate the morphological properties if AZO on glass and PET substrate in presence of ITO buffer layer, the surface and cross-sectional microstructure of AZO films has been imaged by SEM in Fig. 4 and Fig. 5. The SEM photograph reveals that the growth mechanism of the AZO films on the both substrates is 3-dimensional manner and a granular crystalline structure is formed, but on glass crystallizes in good order, and on PET substrate crystallizes disordered and results the higher resistivity of AZO on such substrates.

The SEM images reveal that the flat surface of the AZO thin film on ITO/Glass and ITO/PET is a result of the most perfectly matching crystal lattice of layer and substrate. SEM images of AZO thin films also show that AZO grains on Glass and PET substrate with ITO buffer layer are more uniform than AZO grains on bare glass and PET substrate.

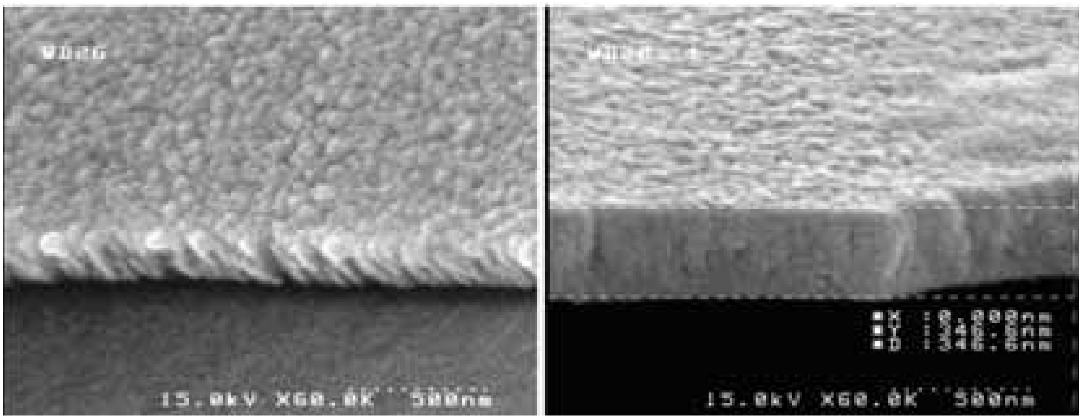


(a)

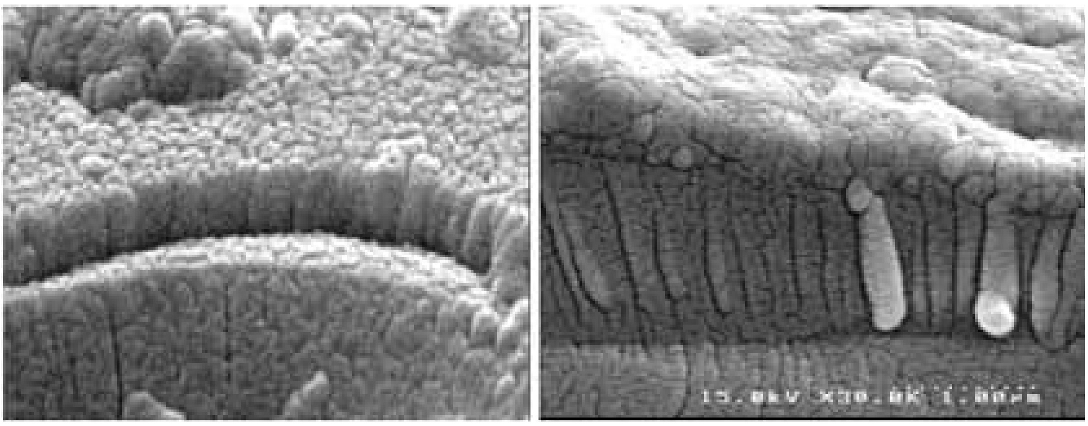


(b)

Fig. 4: The surface and cross-sectional SEM images of AZO on (a) glass and (b) PET substrates.



(a)



(b)

Fig. 5: The cross-sectional SEM images of AZO on (a) ITO/glass and (b) ITO/PET substrates.

3. Conclusions

Optical, electrical and morphological properties of AZO on glass and PET substrates with and without ITO buffer layer were analyzed. The quality of films deposited on buffer layer is found to be superior to those grown directly on a substrate. The morphological, optical and electrical studies reveal that ITO buffer layers improve the crystalline quality, optical and electrical properties of AZO thin films. The results indicate that the application of ITO buffer layer reduces the resistivity of AZO film from 2.27×10^{-2} Ωcm to 1.04×10^{-3} Ωcm on glass substrate and from 4.75×10^{-2} Ωcm to 6.9×10^{-4} Ωcm on PET substrate which is due to increase of free electron concentration in AZO. ITO buffer layer increases the AZO average transmission in visible region (400-800nm) to 92% and 89% on glass and PET substrates, respectively. The SEM images reveal that the flat surface of the AZO thin film on ITO/Glass and ITO/PET is a result of the most perfectly matching crystal lattice of layer and substrate. SEM images of AZO thin films also show that AZO grains on Glass and PET substrate with ITO buffer layer are more uniform than AZO grains on bare glass and PET substrate.

4. References

Bagherzadeh, S., et al., 2009. Investigation of ITO physical properties with and without ZnO buffer layer on different substrates. ISES 2009, South Africa.

Fahland, M., et al., 2001. Low resisitivity transparent electrodes for displays on polymer substrates. Thin Solid Films, 392, 334-337.

Gaskell, J. M., Sheel, D. W., 2011. Deposition of indium tin oxide by atmospheric pressure chemical vapour deposition. Thin Solid Films. In press.

Guille, C., and Herrero, J., 2005. Comparison study of ITO thin films deposited by sputtering at room Temperature onto polymer and glass substrates. Thin Solid Films. 480–481, 129–132.

Kim, D., Yun, I., Kim, H., 2010. Fabrication of rough Al doped ZnO films deposited by low pressure chemical vapor deposition for high efficiency thin film solar cells. Current Applied Physics. 10, S459-S462.

Lei, H., Ichikawa, K., Hoshi, Y., Wang, M., Uchida, T., Sawada, Y., 2010. A study of deposition of ITO films on organic layer using facing target sputtering in Ar and Kr gases. Thin Solid Films. 518, 2926-2929.

Li, Z. H., et al., 2010. Laser direct patterning of the T-shaped ITO electrode for high-efficiency alternative current plasma display panels. J. Applied Surface Science. 257, 776-780.

Manavizadeh, N., et al., 2009. Influence of substrates on the structural and morphological properties of RF sputtered ITO thin films for photovoltaic application. Thin Solid Films. 517, 2324-2327.

Minami, T., 2005.Transparent conducting oxide semiconductors for transparent electrodes. Semicond. Sci. Technol. 20, S35-S44.

Raoufi, D., and Raoufi, T., 2009. The effect of heat treatment on the physical properties of sol–gel derived ZnO thin films. Applied Surface Science. 255, 5812-5817.

Shin, J. –H., Shin, D. -K., Lee, H. –Y., Lee, J. -Y., 2011. Properties of multilayer gallium and aluminum doped ZnO (GZO/AZO) transparent thin films deposited by pulsed laser deposition. Transactions of Nonferrous Metals Society of China. 21, s96-s99.

Valencia, H.Y., Moreno, L.C., Ardila, A.M., 2008. Structural, electrical and optical analysis of ITO thin films prepared by sol–gel. Microelectronics Journal, 39, 1356-1357.

Viespe, C., Nicolae, I., Sima, C., Grigoriu, C., Medianu, R., 2007. ITO thin films deposited by advanced pulsed laser deposition. Thin Solid Films. 515, 8771-8775.