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Synthesis and Characterization of AZO Thin-Films Grown by DC-Sputtering

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Hence, the optoelectronic industry is in demand of more efficient and better-enhanced materials to employ them as TE in this type of applications [1]. ITO is one the most used TCO, since it shows interesting optical and electrical properties like transmittance in the visible region ≈90% [2], electron mobility (about 49 cm^2/Vs) and resistivity (≈$1x10^{-4}$ Ωcm) [3]. AZO shows optical and electrical properties very similar to ITO's with the advantages of low cost and non-toxic nature of Al, chemical and good thermal stability, uniformity on the surface, better resistivity and transparency. The aim of this study was to obtain the optimal synthesis conditions for AZO thin films with similar or better properties than commercial TCOs.

A series of AZO films were growm by using physical vapor deposited (PVD) in a DC Sputtering system (Intercovamex V3), varying the PpO_2 (5, 10, 20, 30, 40, 50 y 75 mTorr), under power and argon flow constant. The selected aluminum contents (atomic ratio of Zn:Al) were 1:3, 1:7 and 1:12. The samples labeling as a function of partial pressure was made as follows: AZO1, AZO2, AZO3, AZO4, AZO5, AZO6 and AZO7, and their characteristics of percentage transmittance in the visible region, atomic ratio Zn:Al, band gap and thickness are summarized in Table 1. The thin films surfaces were characterized by scanning electron microscopy (SEM, JEOL JSM-7401F) and X-ray diffraction techniques (Panalytical X-Pro). The optical properties were made in a UV-Vis PERKIN-ELMER Lambda10. The electrical properties were obtained through the Hall Effect using the Van Der Paw method. An EGK equipment was used applying a magnetic field of 0.51T and a current of 50µA in order to determine the resistivity of the prepared thin films.

The SEM-SE micrographs of selected AZO thin films appears in Figs. 1 and 2. The film morphology consist of granular clusters and the film surfaces seem to be crack free. It is observed that the morphology of the samples with Zn:Al ratio of 1:3 (Fig. 1), noticeably changes with increase of PpO_2, the cluster sizes increase with increasing the oxy-gen partial pressure. The surface of deposited film at 5 mTorr is relatively smooth while the surface morphology of 50 mTorr films is strongly affected by PpO_2. The increase of Zn:Al ratio from 1:3 to 1:7 slightly increase the cluster sizes and decrease the smooth and homogeneity in surface films. By the other hand, by increasing of oxygen partial pressure of deposited samples with Zn:Al ratio of 1:7 (Fig. 2), decreases the porosity. The XRD results reveal the formation of single-phase, only ZnO phase was detected. With increasing PpO_2, the positions of diffraction peaks do not change significantly, but the aluminum content has a noticeable effect on the preferred orientation of main diffraction peaks. The maximum transmittance for the AZO1 film can be observed with a thickness around 200nm and an oxygen partial pressure of 5mTorr. The band gap of all films values were calculated applying the Kubelka-Munk theory using a UV-Vis spectrometer. For the ratios 1:3 and 1:7, the gap value does not change, but for the 1:12, an increment in the gap value can be observed. The lower resistivity value was observed for sample AZO1 with a mobility of 29.4929 cm^2/Vs and a carrier density of 2.7679x1020/cm^3.

Sample AZO1, with an oxygen partial pressure of 5mTorr, shows the best results with a resistivity of

7.6463x10^{-4} Ωcm, transparency at the visible region of 92.2% and, a stoichiometric ratio Zn:Al of 1:3. According to with the results, these films can be used as transparent electrodes for optoelectronic and photovoltaic applications due to the TCO similar values as ITO.

References:

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Table 1. General Information: % Transmittance, atomic ratio Zn: Al, electrical resistance, band gap and thickness of thin films grown by sputtering at different partial pressures of O_2.

Sample	Po (mTorr)	Transmittance (%)	Zn:Al	Resistance (Ω)	Band gap (eV)	Thickness (nm)
AZO1	5	92	1:3	66	3.4	200.0
AZO2	10	81	1:3	125	3.5	279.1
AZO3	20	87	1:12	130	3.8	184.5
AZO4	30	85	1:7	70	3.6	312.0
AZO5	40	87	1:7	75	3.6	281.4
AZO6	50	86	1:3	158	3.5	142.8
AZO7	75	85	1:7	150	3.6	288.5

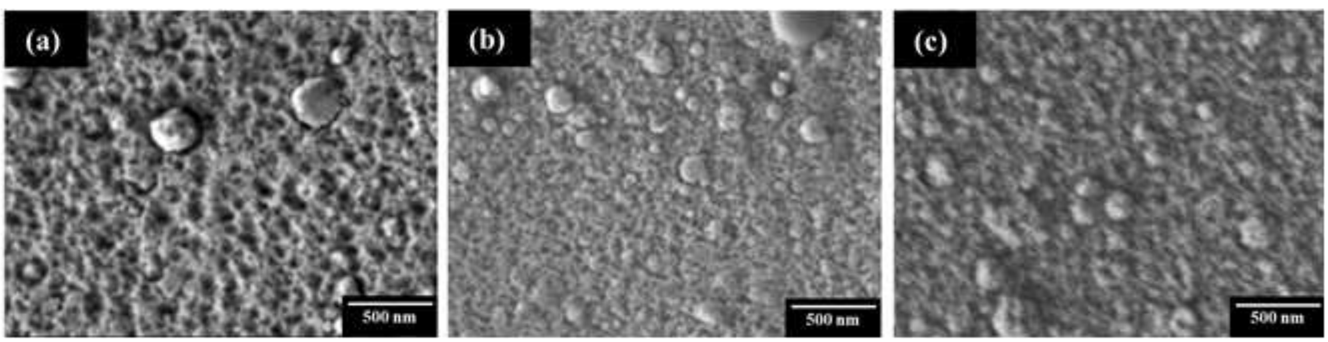

Figure 1. SEM-SE micrographs of thin films with a ZnO-Al ratio of 1:3 under: (a) 5, (b) 10 and (c) 50 mTorr of oxygen partial pressure.

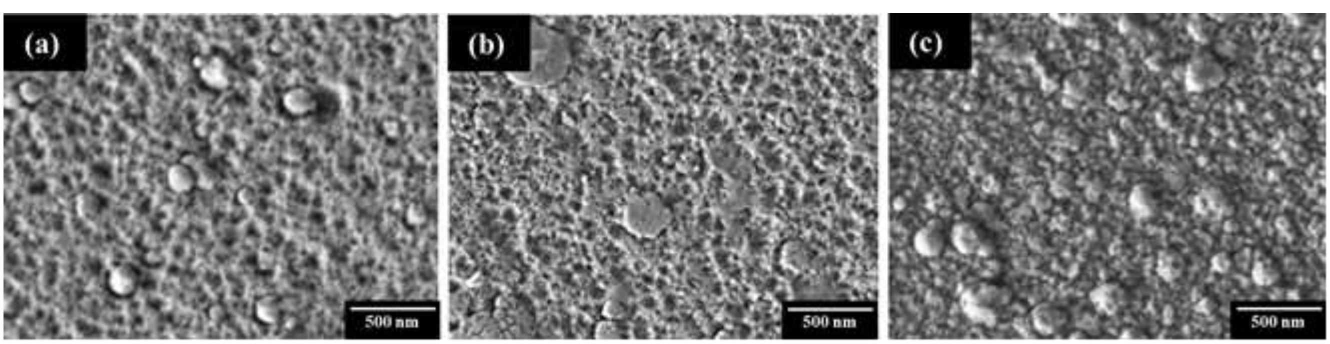

Figure 2. SEM-SE micrographs of thin films with a ZnO-Al ratio of 1:7 under: (a) 30, (b) 40 and (c) 75 mTorr of oxygen partial pressure.