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STRUCTURAL, OPTICAL AND ELECTRICAL PROPERTIES OF ALUMINIUM DOPED ZINC OXIDE THIN FILM BY RF MAGNETRON SPUTTERING METHOD

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ABSTRACT

Thin film of Al doped ZnO has been fabricated by depositing *n*-ZnO (5 mol% Al_2O_3 doped ZnO) layer on glass substrate. The XRD analysis confirms that all the three films have (002) preferential orientation with hexagonal wurtzite structure. From Hall measurement, all the films show*n n*- type conductivity with increased Career concentration which confirms the direct proportionality of career concentration with sputter time. The resistivity is found to be decreased with increase in sputter time due to fewer mismatches from the reflectance spectrum, the reflectance value is found to be as less as possible 35%. So that the films can be used as antireflection coating in solar cells. The Band gap energy of the films is found from Tauc's plot and it is found that (2.49eV) band gap value increases due to Burstein-moss effect.

KEYWORDS: Doping, ZnO, Photoluminescence, Reflectance.

1. INTRODUCTION

ZnO can be considered as an 'old' semiconductor which has been compelling research attention for a long time because of its applications in many scientific and industrials areas such as piezoelectric transducers, optical waveguides, acoustic media, conductive gas sensors, transparent conductive electrodes, varistors [Liu et al. (2005), Fording (1988), Sato and Katayama-yoshida (2001), Schmidt et al. (2000), Rashba (2000), Zhu et al. (2001)]. It has now received increasing attention and recognized as a promising candidate for applications related to its optoelectronic possibilities in the UV range. Its piezoelectric properties could also allow developing SAW filters to be integrated in future analog circuits for portable electronic for which there is a strong need. Furthermore, ZnO transparent thin-film transistors (TTFTs) are a recent and import and development in the emerging field of transparent electronics. These potential applications have boosted research related to the growth of high quality ZnO thin films by a lot of different techniques that need high quality substrates [Ando et al. (2001), Jin et al. (2001), Saeki et al. (2001), Ueda et al. (2001)]. That is why research related to the ZnO bulk growth has received a considerable interest during these last years. Because of the small ionic radii of its constituting elements, mainly the oxygen one, and of its subsequently very short and energetic chemical bond, ZnO has a very high melting point of about 1900°C. Furthermore, because of the high electron gativity of its oxygen and zinc and because of its usualoff- stoichiometry, ZnO shows an extremely high reactivity with any surrounding material at high temperature. This intrinsic property will be shown to affect strongly its growth [Fukumura et al. (1999), Fukumura et al. (2001), Jung et al. (2002)]. In this present work, we report that the effect of doping by the Al_2O_3 in ZnO. Doping is the one of the technique to alter the properties of metal oxide semiconductors.

2. MATERIALS AND METHODS

Al doped ZnO thin films are deposited on glass in a 13.56 MHz r.f. sputtering system with a ceramic target that is made of 98 wt. % high-Purity ZnO (99.999 % purity) and 5 wt. % Al2O3 (99.999 % purity) powders. The substrates are cut into 2 × 2 cm portions and cleaned. The distance between the target and the substrate is fixed at 10 cm. The working pressure is maintained at 5×10^{-2} Torr. The as-deposited AZO films are subsequently treated by XRD analysis, Hall Effect measurement, UV spectroscopy studies and I-V characteristics study.

3. RESULT AND DISCUSSION

3.1. X-RAY DIFFRACTION

Fig 1 shows the x-ray diffraction of the fabricated film. The results show that the fabricated films possess hexagonal wurtzite structure with (002) preferential orientation, which matches with the JCPDS, no: 036-1451.

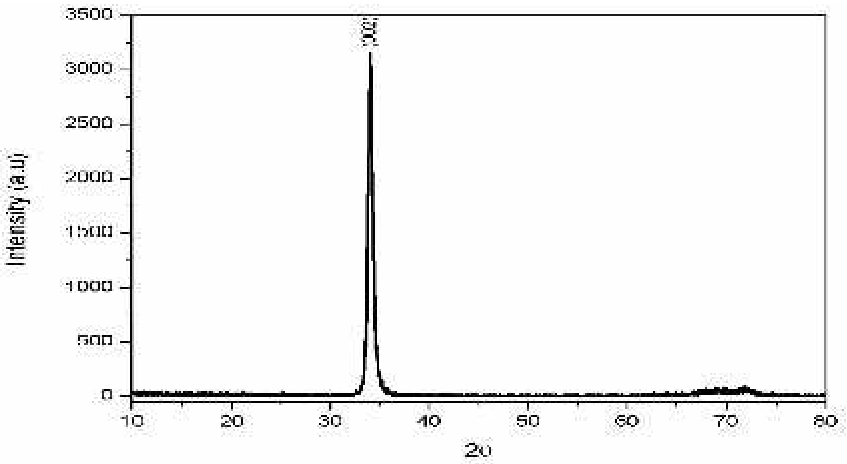

Fig 1. XRD pattern of Al doped ZnO

The preferential orientation is due to its lowest surface free energy which means that c-axis is perpendicular to the substrate. Particle size is determined by Scherrer formula.

$$D = 0.9\lambda/\beta\cos\theta$$

The calculated parameters and the particle size of the samples are shown in table 1.

Table-1. Calculated values of β, D and lattice parameters

Sample	FWHM(β)	Particle size(nm)	a Å	b Å	c Å
AZO	0.01007	14.40	3.4698	3.4698	5.2573

3.2. THICKNESS AND HALL EFFECT MEASUREMENT ANALYSIS

Thickness of the film was measured by ellipsometry and it is found to be 73.5nm.

Table-2. Hall Effect results

Sample	Career concentration(cm^{-3})	Resistivity (Ωcm)
AZO	-4.895×10^{16}	3.26×10^{3}

It is found that the thickness of the film in the nanometre range due to its less thickness. It is useful for the pn junction to fabricate the solar cell. From the Hall Effect measurement, the electrical properties of the fabricated were found it is found that the film shows *n*-type conductivity. In addition, the value of the resistivity and career concentration are tabulated in table 2 the electron concentration has been found and its value agrees with the journals (Norton et al. (2003)).

3.3. UV- VISIBLE SPECTROPHOTOMETER

The reflectance value of Aluminium doped ZnO thin film were found from the reflectance spectrum Fig.2. the reflectance value was found as less as possible 35%. This shows that all the fabricated films can be used as an anti-reflection coating for solar cells because of the low reflectance value [Kim et al. (2004), Sharma et al. (2003)]. The fabricated films have good anti-reflection properties in UV and visible region of electromagnetic spectrum in which minimum reflectance value has been observed at UV region.

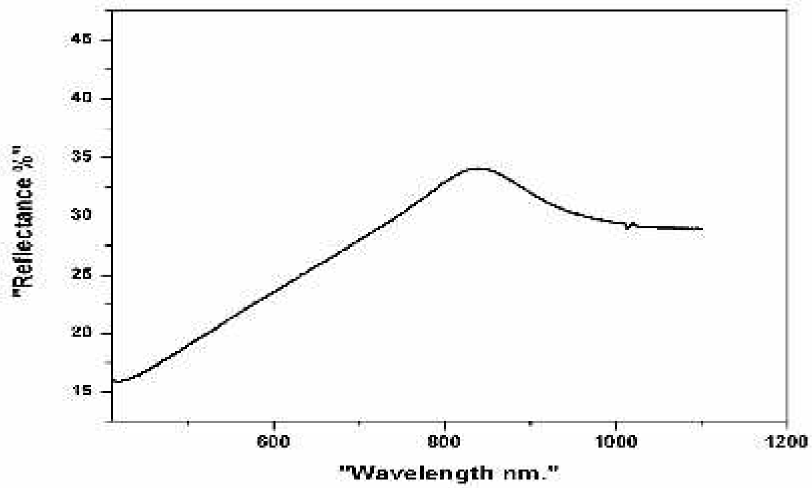

Fig 2. Reflectance spectra of the fabricated film

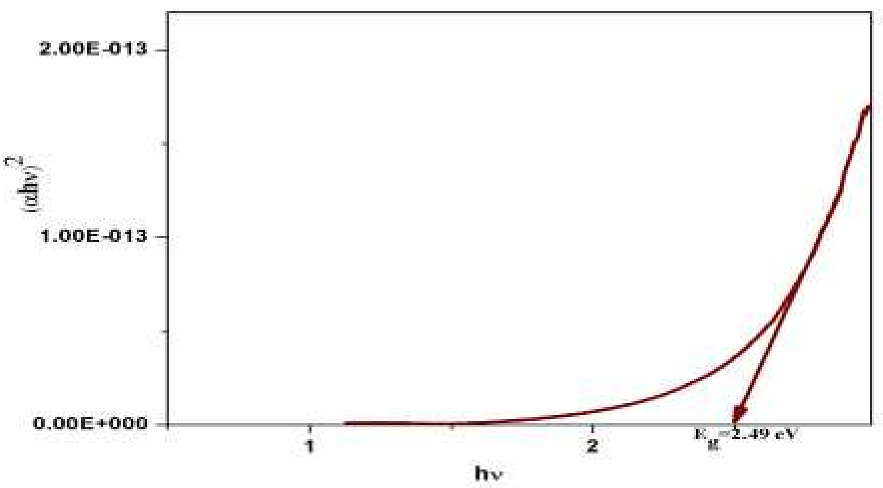

Fig 3. Tau's plot of the fabricated film

Tauc's plot is employed to determine the band gap of the fabricated films. Fig 3 depicts the plot between $(\alpha h\upsilon)^2$ and Energy ($h\nu$). The analysis of optical absorption spectra is one of the most productive tools for understanding the energy band gap (E_g) of crystalline materials. Reflectance spectra have been recorded using UV-Vis-NIR spectrometer [Rode et al. (2003)].

The optical energy gap, E_g has been calculated by considering a direct transition between the edges of valence and conduction bands. The band gap of the film is found to be 2.49eV.

3.4. I-V CHARACTERISTICS

I-V characteristics have been conducted under the dark and illumination condition using mercury lamp with help of resistance meter. It is seen from the graph there is no much variation in the conductivity under the dark condition. While for the illumination condition current little much varied with corresponding to applied voltage. Hence from the I-V measurement the Al doped thin film is better for solar cell application.

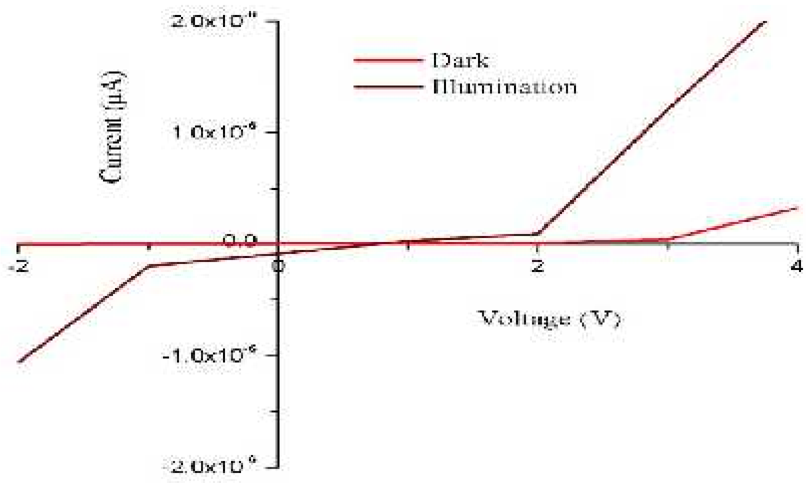

Fig.4 I-V Characterisation Graph

4. CONCLUSION

Thin film of Al doped ZnO has been fabricated by depositing *n*-ZnO (5 mol% Al_2O_3 doped ZnO) layer on glass substrate. The fabricated thin film was characterized for their structural, optical and electrical properties.

The XRD analysis confirms that all the three films have (002) preferential orientation with hexagonal wurtzite structure. From Hall measurement, all the films shown *n*- type conductivity with increased career concentration which confirms the direct proportionality of career concentration with sputter time. The resistivity is found to be decreased with increase in sputter time due to fewer mismatches from the reflectance spectrum, the reflectance value is found to be as less as possible (35%). So that the films can be used as anti reflection coating in solar cells. The Band gap energy of the films are found from Tauc's plot and it is found that (2.49eV) band gap value increases due to Burstein-moss effect.

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