Photoluminescence study of ZnO:Al thin films with different power plasma

by Budi Astuti

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Abstract. ZnO doped Al (ZnO:Al) thin film was deposited on corning glass substrate using DC magnetron sputtering method. Depositon process of the ZnO:Al thin films was kept constant at Argon pressure, deposition temperature and deposition time are 500 mTorr, 400°C and 2 hours, respectivelly. Furthermore, for deposition process has been done on the variation of power plasma are 33, 43, and 50 watt. For the optical properties of the ZnO:Al thin films using Photoluminescence spectroscopy. Different plasma power will affecting on ion energy and momentum pounder. It's effect on the quality of thin films that influence to photoluminescence intensity was obtained.

1. Introduction

ZnO is an alternative Transparent Conductors Oxide (TCO) for window layer of solar cells [1]. The use of ZnO material because it is a high direct-bandgap type-n transparent semiconductor material with 3.37 eV at room temperature [2-5], has a large excitation binding energy of 60 meV [6,7], has high stability in plasma hydrogen, and heat cycle, and is resistant to radiation [8]. The value of electron mobility of ZnO thin films is also high at 200 $cm^2V^{-1}s^{-1}$ [9], and high optical transmittance of around 90% [1]. Furthermore, ZnO thin films also have advantage such as low prices, non-toxic, relatively low deposition temperatures, environmentally friendly, and easy to growth [10]. In addition to its advantages, ZnO thin films also have disadvantages such as less stable in the corrosive environment and low conductivity values around 10^{-8} $(\Omega)^{-1}cm^{-1}$ [11]. To increase the electrical conductivity of ZnO thin films can be doped aluminum (Al) material [12], Al doping on ZnO was able to increase the transmittance value at visible light region in the range of 64% - 96%, and also can increase the optical band gap energy [1].

The Optical properties likes transparency nature of the material was applied on the window layer are important properties to study. Many researcher was studied on the luminescence properties of ZnO:Al thin films such as Li *et al.* [13] reported that luminescence ZnO nanostructures using sol-gel method with thermal treatment shows reducing the yellow emission but retaining the green luminescence. Furthermore, Rodnyi and Khodyuk [14] its reported that optical and luminescence characteristics of ZnO largely depend on the impurity and parameter growth of the thin films. Furthermore, was explained that ZnO film exhibit two luminescence band. They are a short wavelength band which is located near the absorption edge of the crystal, i.e., the edge luminescence (3.35 eV), and a broad long-wavelength band, the maximum of which usually is in the green spectral range (2.45 eV).

In this paper, ZnO: Al thin film research will be carried out with different of plasma power to determine the luminescence and structural properties using home made dc magnetron sputtering. This method was used because it is easier to operate, high deposition rate, more stable, and cheaper [15].

2. Methods

In this experiment, the ZnO:Al target maked from compound of ZnO (MW09023 USA with purity 99.99%) and Al_2O_3 powder (MA01950 USA with piruty 99.999%) in total mass of 10 gram. The complete pellet-making mechanism can be seen in the previous paper [16]. The ZnO:Al thin film deposition process is performed on a corning glass substrate. Corning glass substrate is cut to the size of approximately (1 x 1) cm^2. After that the substrate was immersed in the methanol to remove the oil impurities were attached on the substrate surface for 15 minutes in ultrasonic bath. Subsequently substrate was immersed in acetone for 10 min in ultrasonic bath. Finally the substrate ware rinsed and sprayed with nitrogen gas to keep the substrate dry and clean. Parameter of ZnO: Al thin films grown as shown in Table 1.

Table 1. Deposition parameters of ZnO:Al thin films.

Parameter Deposition	Description
Deposition temperature	400^oC
Argon Pressure	500 mTorr
Plasma Power	33, 43, 50 watt
Time	120 menit

Furthermore, the characterization process of the ZnO:Al thin films was obtained has been done using Photoluminescence to determine the emission of the samples. Photoluminescence spectroscopy was taken at room temperature using excitation wavelength of 323 nm.

3. Result and Discussion

Optical properties of the ZnO:Al thin films was characterized using photoluminescence spectroscopy. Photoluminescence is a process in which a molecule absorbs a photon in the visible region, exciting one of its electrons to a higher electronic excited state, and then radiates a photon as the electron returns to a lower energy state. The light of the shorter wavelength which has greater energy is preferable for the excitation of the material. The electrons inside the materials move from the valence band to the excited states due due to photoexcitation. When the electron return to the valence band with the emitting light, this process as known as radiative process. Otherwise, if there is no light emission which is known as the nonradiative process. Generally, semiconductor materials has the radiative transition is between the energy states in the conduction band and the valence band.

Photoluminescence spectrum of ZnO:Al thin film with different plasma power are shown in Figure 1.

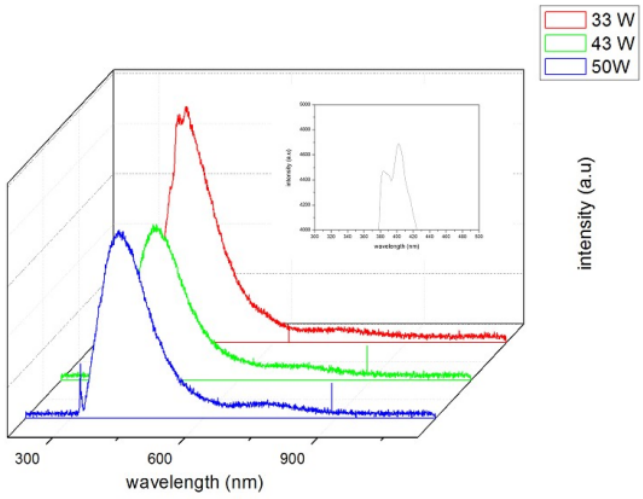

Figure 1. The result of Photoluminiscence characterization of ZnO:Al thin film samples with variation on power plasma

From Fig 1. shows the photoluminescence of the ZnO:Al thin films on corning glass substrat obtained by home made DC Magnetron Sputtering with different plasma power are 33 W, 43 W, and 50 W, respectively in the wavelength area of 200 nm - 1100 nm. A broad peak near UV emission band centered at 408.3 nm and 411.7 nm is due to the recombination of free exciton through an exciton-exciton collision process [17,18]. For the ZnO:Al thin film deposited with plasma power of 43 W and 50 W has a different peak intensity of emission at visible light centering 411.7 nm and 408.3 nm corresponding to energy photons of about 3.00 eV and 3.02 eV. Intensity increases at the increasing of plasma power. It is shows that with increases plasma power will increasing the possibility of atoms deposited on the substrate [19].

For thin films deposited with plasma power of 33 W, the photoluminescence spectra appear to have two peaks; one peak is in the UV region centered 385.8 nm corresponds photon energy of about 3.2 eV and the other peak is in the visible light region centered 404.2 nm and corresponds photon energy of about 3.05 eV. Based on Figure 1, shows that ZnO: Al thin films deposited with low plasma power (33 W) have a higher intensity. It is because in the deposition process, there are certain elements of oil in the vacuum pump rises into the chamber.

Furthermore, according to a broad peak of photoluminescence spectrum we can be determined FWHM value as shown on Table 2.

Table 2. FWHM of ZnO:Al Thin Films at Different Plasma Power

Plasma Power (W)	FWHM (eV)
33	8,70
43	9,28
50	9,55

From Table 1, it can be seen that the FWHM value increases at the increasing of plasma power. This is likely caused by a shift in wavelength in the thin film. It has suggested that the interstitial Zn defect at increasing plasma power [20]. The broad visible emission might be attributed to electronic transitions from the near-conduction band edge to deep level acceptors and to transitions from deep donor levels to the valence band [21].

Figure 2 shows the XRD of the ZnO:Al thin film at 33 W. these reflections were indexed by matching the pattern with standard JCPDS powder diffraction file of zinc oxides (Card no. 01-1136). The structure was found to be hexagonal with wurtzite arrangement. Two main diffraction peaks of ZnO thin films appear at 2θ = 34.4 Å and 2θ = 36.3 Å, which are corresponding to the (002) plane and the (101) plane of ZnO thin films, according to previous studies [22]. Its dominance peak (002) shows that the growth of grains is oriented towards the c-axis and perpendicular to the surface of the substrate [23].

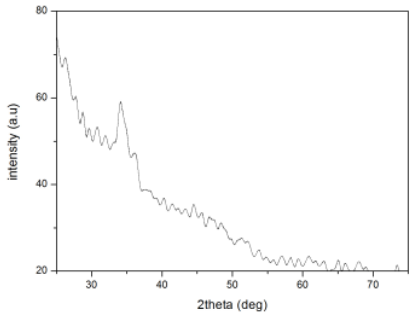

Figure 2. XRD Spectrum of ZnO:Al Thin Films at 33W

4. Conclusions

The increases of plasma power on the ZnO:Al thin film growth was affected to the greater of the intensity produced of photoluminescence, and the FWHM value also increases because there is a shift in the wavelength of emissions with the increasing of plasma power.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6