Penerbit Akademia Baru

Journal of Advanced Research in Materials Science
ISSN (online): 2289-7992 I Vol. 20, No.1. Pages 6-13, 2016

RF Power Dependence of ZnO Thin Film Deposited by RF Powered Magnetron Sputtering System

K. Miandal[*,1,a], *M. L. Lam*[1,b], *F. L. Shain*[1,c], *A. Manie*[1,d], *K. A. Mohamad*[2,d] *and A. Alias*[1,f]

[1]Faculty of Science and Natural Resources
University Malaysia Sabah (UMS), 88999, Kota Kinabalu, Sabah, Malaysia
[2]Faculty of Engineering
University Malaysia Sabah (UMS), 88999, Kota Kinabalu, Sabah, Malaysia
[a*]kelliemiandal@gmail.com, [b]lammuili89@gmail.com, [c]farahlyanashian@gmail.com, [d]azmizamanie@gmail.com, [e]khairul77@gmail.com, [f]afishah78@gmail.com

Abstract - *This paper investigates the influence of RF power onto structural and optical properties of Zinc Oxide (ZnO) thin films. A series of ZnO thin films was prepared on the glass substrate by RF magnetron sputtering. ZnO is well known for various applications such as varistors, light emitting diode, gas sensor and much more. These applications are attributed to interesting material properties of a wide and direct band gap (3.37 eV) and high exciton binding energy (60 meV). X-ray diffraction (XRD), UV-Vis spectrophotometer and profilometer were used to check the effect of the different RF power on the structural and optical thin films. The increased of RF power resulted in the increase of the growth rate, where the film deposited at 175 W shows higher growth rate at 6.6 nm/m. All films are polycrystalline with (002) preferential orientation with high optical transparency approximately >80% in visible range. The intensity of film increase as the RF power increase but decrease for the film deposited at 175 W because the reaction rate at this power is very fast and cause the severe surface damage, resulting in the poor crystalline quality. The estimated band gap ≃ 3.25 eV was obtained.*

Keywords: - ZnO thin films, RF power, Structural properties, Optical properties, Morphology properties.

1.0 INTRODUCTION

ZnO may be great known to different applications, for example, a varistors, gas sensors and transparent conductors for thin film transistors and solar cells. Alternative rising applications incorporate light emitting diode (LEDs), laser diodes (LDs) and light detectors. These applications are credited to fascinating material properties of a wide and direct band gap (3.37 eV) , high exciton binding energy [1-2], high thermal and mechanical stability at room temperature make it attractive for potential use in electronics, optoelectronics and laser technology [3]. Different deposition techniques were utilized for the preparation of ZnO thin film such as magnetron sputtering, spray pyrolysis, pulsed laser deposition, electron beam evaporation, and sol-gel method [4-7]. Among these processes, the sputtering process is the most encouraging technique for depositing ZnO thin film. Those favorable circumstances for sputtering are the basic mechanical assembly, good surface flatness, high deposition rate, dense layer formation, transparency, and its potential for

Journal of Advanced Research in Materials Science
ISSN (online): 2289-7992 I Vol. 20, No.1. Pages 6-13, 2016

low-temperature processing [8-9]. The qualities of ZnO thin films are for the most part influenced toward preparation condition, for example, working pressure, type of substrate, the thickness of the films and deposition methods [8, 10]. In this study, the ZnO thin film was set up by a sputtering method and considered the impact of RF sputtering power on structural and optical properties. ZnO films were deposited by RF magnetron sputtering from a zinc oxide target under pure Ar atmosphere. The direct influence of RF sputtering power on the structural and optical properties of ZnO film is investigated in this study. The properties of the ZnO films were studied employing x-ray diffraction (XRD), UV-Vis spectrophotometer and profilometer. This research was done in order to determine the optimum RF sputtering power which will be used for our further research on hybrid device.

2.0 EXPERIMENTAL PROCEDURES

ZnO film was deposited on microscope slide glass by RF powered magnetron sputtering equipped with 3 inches diameter ZnO target of 99.99% purity. The substrate was initially cleaned with distilled water, ethanol and acetone in an ultrasonic bath for 3 minutes, 3 times for each solution. After that, the substrates were rinsed with distilled water and dried it with nitrogen gas before deposition. The substrate cleaned process was to remove grease and organic contaminations. The sputtering process is carried out with argon gas that flows from 10 to 30 sccm. The substrate rotation, deposition time and working pressure were fixed at 5 rpm, 25 minutes and 3 x 10 -3 torr, respectively. The sputtering was carried out at room temperature and the RF sputtering power was varied from 75 to 175 watt. The thickness of the film was measured by a NanoMap LS500 Profilometer. The structural and crystalline properties of thin films was analyzed using X-Ray Diffraction Philips Expert Pro. The UV-Vis Spectrometer Lambada EZ210 was used to evaluate optical properties of ZnO thin films.

3.0 RESULTS AND DISCUSSIONS

3.1 Growth characteristics

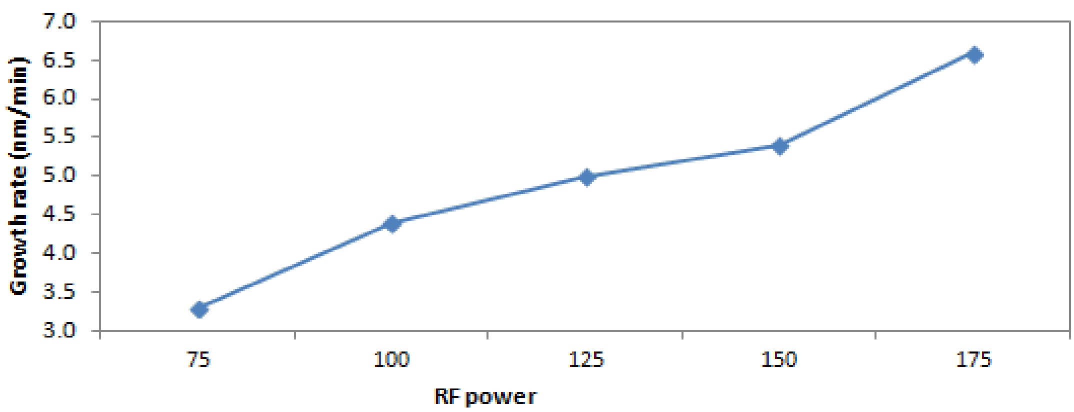


Figure 1: Dependence of the growth rate on the sputtering power for ZnO films

Penerbit Akademia Baru

Journal of Advanced Research in Materials Science
ISSN (online): 2289-7992 I Vol. 20, No.1. Pages 6-13, 2016

Figure 1 shows the growth rate are influenced by the sputtering power where the growth rate increase from 33 nm/m to 56 nm/m when the RF power increase from 75 W to 175 W. This situation occur due to higher number of the argon ion in the plasma at higher RF power so that more ions accelerated and hit the target hence there will be more sputtered atoms [1]. Other than that, at the higher RF power, the bombarding ions have higher kinetic energy due to momentum transfer, so that more atoms will be sputtered out [11]. The sputtered atom get higher energy at higher RF power and resulted the higher ZnO molecules arriving at substrate compare at lower RF power deposition and its contributes to the film growth [12].

3.2 Structural Properties

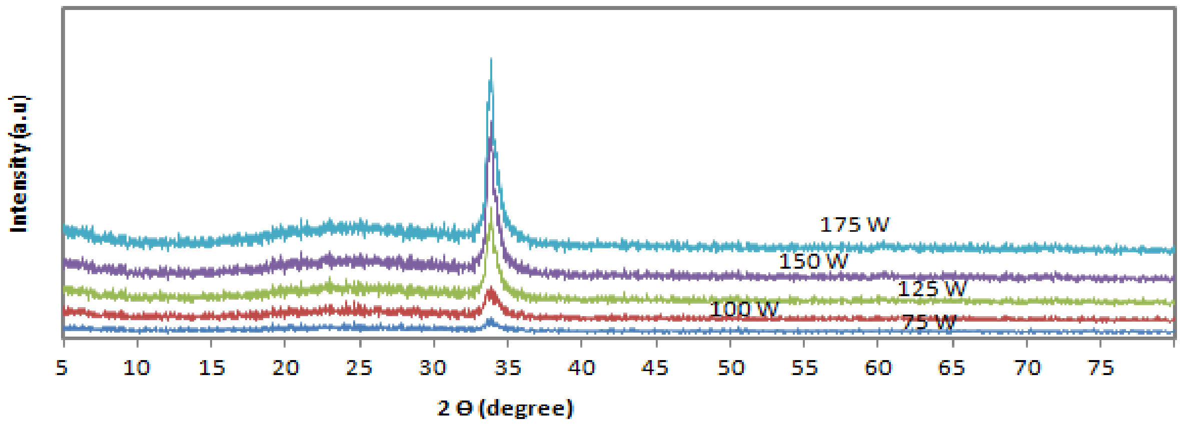


Figure 2: XRD diffraction pattern of the ZnO thin films deposited at different RF powers

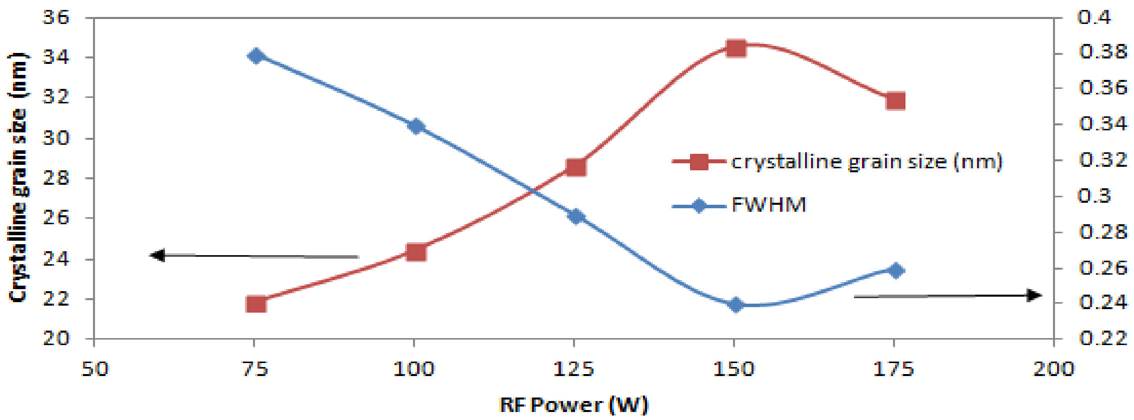


Figure 3: The estimated grain size and the variation of full-width half maximum (FWHM) of ZnO (002) diffraction peak at different RF power

Figure 2 shows the XRD spectra of the prepared ZnO thin films as the RF power change from 75 W to 175 W. ZnO thin films with different RF power were successfully deposited onto the glass substrate with strong (002) preferential orientation along c-axis due to the lowest surface free energy of (002) plane in ZnO. Figure 3 shows the crystalline grain size and fully width half

Penerbit Akademia Baru

Journal of Advanced Research in Materials Science
ISSN (online): 2289-7992 I Vol. 20, No.1. Pages 6-13, 2016

maximum values (FWHM) for the prepared ZnO thin films at different RF power. With the increase of the RF power, an increase in the intensity together with a slight decrease in FWHM of (002) peak observed. However, FWHM for the film deposited at 175 W is slightly increased. The increase of FWHM at 175 W has happened when high RF power induced the faster reaction rate and the severe surface damage, resulting in the poor crystalline quality. Peak full width at half maximum β is related to the mean crystallite size of the films that can be calculated through the Scherrer's formula [13]:

$$D = \frac{k\lambda}{\beta \cos\theta} \quad (1)$$

Where k is a shape factor with the value of k = 0.94 for cubic crystallites. λ, β, and ϴ are 1.54056 Å, observed FWHM and Bragg diffraction angle, respectively. The result is shown ZnO film deposited at 150W exhibit the highest value of the crystalline size of 34.6 nm which consistent with the value shown in Figure 2, with films deposited at 150 W shows the FWHM 0.24, have better crystalline quality.

3.3 Optical Properties

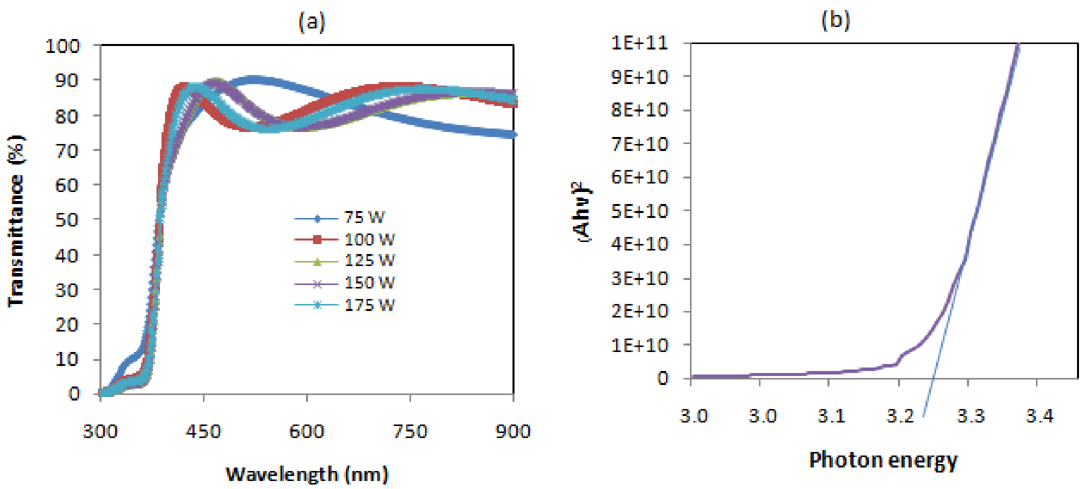


Figure 4: (a) optical transmittance spectra of ZnO thin films (b) plots (αhV)2 vs photon energy for ZnO thin films deposited on glass substrate at RF power of 75 W- 175 W

Figure 4(a) shows the transmittance spectra as a function of wavelength in the visible spectrum for the samples deposited at different sputtering power. The optical transmittance was measured using a UV-Vis spectrophotometer in the frequency range of 300-900 nm. The samples thickness ranged between 150 nm to 350 nm measured by a profilometer. All the thin films exhibited approximately 80% transmittance, and better transmittance was obtained in the blue range rather than the in the red range. The estimated energy band gap of ZnO can be obtained from Tauc plot using the Tauc relation [14]:

$$(\alpha h\nu)1/2 = (h\nu - Eg) \quad (2)$$

Here, A is a constant and hv are the quantum energy (eV). The absorption coefficient α can be calculated by using the transmittance (T) and the thickness (d) of the thin film.

$$T = \exp(-\alpha d) \quad (3)$$

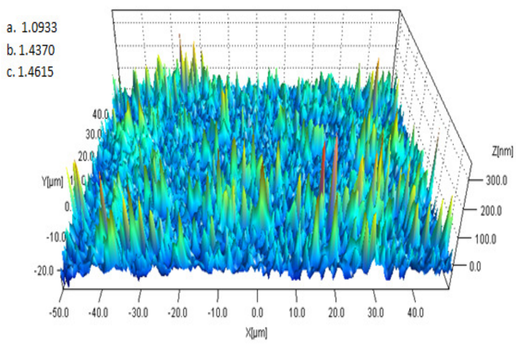
Figure 4(b) shows a graph of the quantum energy (hv) versus absorption coefficient (αhv)2 for the film at 150 W. Based on the tangent of each group, the value of the energy band gap (eV) was obtained, which satisfy the equation $(\alpha h\nu)^{1/2} = 0$. As fig. 4(b) shown, the energy band gap was 3.25 eV were obtained.

3.4 Surface Morphology

Figure 5: Comparison of surface morphology and RMS obtain from profilometer 3D image for ZnO thin films

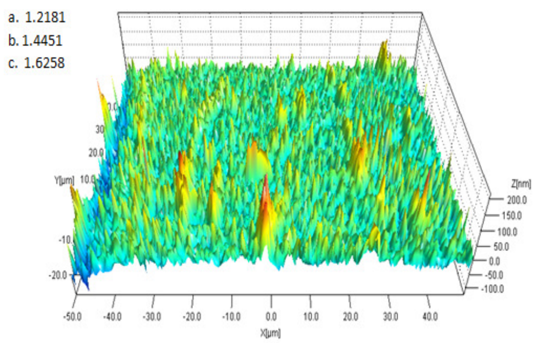
Thin films deposited at 75 W- 175 W

75 W



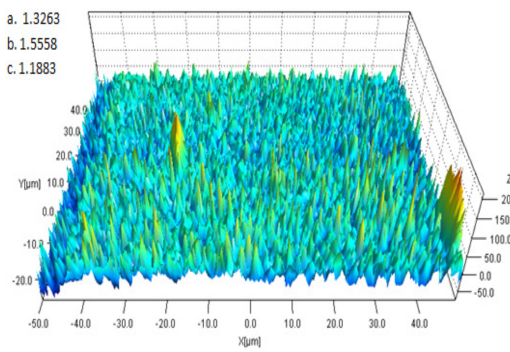
Average of RMS : 1.33

100 W



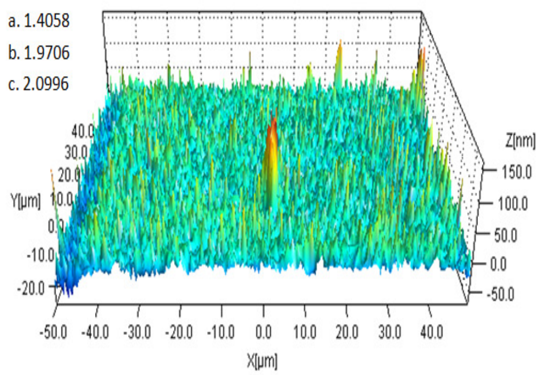
Average of RMS : 1.42

125W



Average of RMS : 1.53

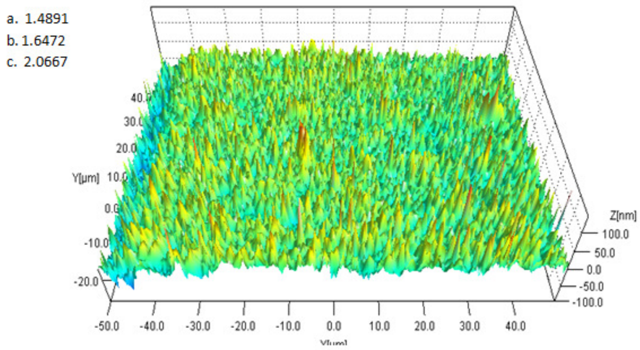
150W



Average of RMS : 1.83

Journal of Advanced Research in Materials Science
ISSN (online): 2289-7992 I Vol. 20, No.1. Pages 6-13, 2016

175W



Average of RMS : 1.73

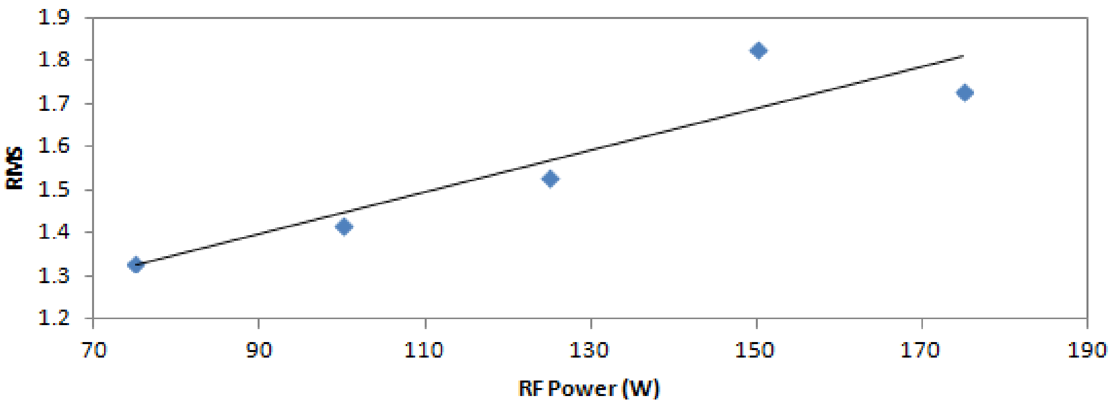


Figure 6: RMS of ZnO thin film with different RF power

Figure 5 shows the profilometer images of ZnO thin films deposited at different sputtering RF power. ZnO films show different surface roughness and root mean square (RMS) under different deposition conditions. The root mean square (RMS) of 1.33, 1.42, 1.53, 1.83 and 1.73 for films prepared at RF power of 75 W, 100 W, 125 W, 150 W and 175 W, respectively. Root mean square (RMS) increased with the increased RF power of the prepared films as shown in Figure 6. The increasing value of root mean square (RMS) were indicating that the grain size on the top of the ZnO films increased with increasing the RF power, agree with XRD measurement, show that larger grain size may induce the rougher surface [9].

4.0 CONCLUSIONS

The RF power for ZnO thin films has been studied. The result shows growth rate for ZnO thin film deposited on the glass substrate was influenced by the different RF power. Structural analysis of ZnO thin film revealed films are polycrystalline with (002) orientation with crystallite size increasing on high RF power while the optical transmission pattern shows the fully transparent film with high transparency achieve.

ACKNOWLEDGMENT

The author is grateful to University Malaysia Sabah for providing the instrument for conducting the research.

REFERENCES

[1] Lu, Yang-Ming, Weng-Sing Hwang, W. Y. Liu, and J. S. Yang. "Effect of RF power on optical and electrical properties of ZnO thin film by magnetron sputtering." Materials chemistry and physics 72, no. 2 (2001): 269-272.

[2] Zhang, Yangyang, Manoj K. Ram, Elias K. Stefanakos, and D. Yogi Goswami. "Synthesis, characterization, and applications of ZnO nanowires." Journal of Nanomaterials 2012 (2012): 20.

[3] Kołodziejczak-Radzimska, Agnieszka, and Teofil Jesionowski. "Zinc oxide—from synthesis to application: a review." Materials 7, no. 4 (2014): 2833-2881.

[4] Ayouchi, R., F. Martin, D. Leinen, and J. R. Ramos-Barrado. "Growth of pure ZnO thin films prepared by chemical spray pyrolysis on silicon." Journal of Crystal Growth 247, no. 3 (2003): 497-504.

[5] Nagayasamy, Nagarani, Saroja Gandhimathination, and Vasu Veerasamy. "The Effect of ZnO Thin Film and Its Structural and Optical Properties Prepared by Sol-Gel Spin Coating Method." Open Journal of Metal 2013 (2013).

[6] Musa, Mohamed Zahidi, Mohamad Hafiz Mamat, and Mohamad Rusop. "Electrical Characteristic of UV Sensor Using Nanostructured Al Doped ZnO Thin Film." In Advanced Materials Research, vol. 667, pp. 384-387. Trans Tech Publications, 2013.

[7] Ilican, S., Y. Caglar, and M. Caglar. "Preparation and characterization of ZnO thin films deposited by sol-gel spin coating method." Journal of optoelectronics and advanced materials 10, no. 10 (2008): 2578-2583.

[8] Lin, Su-Shia, and Jow-Lay Huang. "Effect of thickness on the structural and optical properties of ZnO films by rf magnetron sputtering." Surface and Coatings Technology 185, no. 2 (2004): 222-227.

Penerbit Akademia Baru
Journal of Advanced Research in Materials Science
ISSN (online): 2289-7992 I Vol. 20, No.1. Pages 6-13, 2016

[9] Kim, Hyoun Woo, and Nam Ho Kim. "Structural studies of room-temperature RF magnetron sputtered ZnO films under different RF powered conditions." Materials Science and Engineering: B 103, no. 3 (2003): 297-302.

[10] Lin, Su-Shia, Jow-Lay Huang, and Ding-Fwu Lii. "The effects of rf power and substrate temperature on the properties of ZnO films." Surface and Coatings Technology 176, no. 2 (2004): 173-181.

[11] Hwang, Deuk-Kyu, Kyu-Hyun Bang, Min-Chang Jeong, and Jae-Min Myoung. "Effects of RF power variation on properties of ZnO thin films and electrical properties of p–n homojunction." Journal of crystal growth 254, no. 3 (2003): 449-455.

[12] Yu, Xuhu, Jin Ma, Feng Ji, Yuheng Wang, Xijian Zhang, Chuanfu Cheng, and Honglei Ma. "Effects of sputtering power on the properties of ZnO: Ga films deposited by rf magnetron-sputtering at low temperature." Journal of Crystal Growth 274, no. 3 (2005): 474-479.

[13] Saad, M., and A. Kassis. "Effect of rf power on the properties of rf magnetron sputtered ZnO: Al thin films." Materials Chemistry and Physics 136, no. 1 (2012): 205-209.

[14] Junfei, Shi, Dong Chengyuan, Dai Wenjun, Wu Jie, Chen Yuting, and Zhan Runze. "The influence of RF power on the electrical properties of sputtered amorphous In—Ga—Zn—O thin films and devices." Journal of Semiconductors 34, no. 8 (2013): 084003.