Digest Journal of Nanomaterials and Biostructures Vol. 7, No. 2, April - June 2012, p. 487 - 491

FABRICATION AND CHARACTERIZATION OF TETRALEG ZINC OXIDE NANOSTRUTURE USING EVAPORATION METHODE

A. J. HASHIM*, M. S. JAAFAR, ALAA J. GHAZAI, N.M.AHMED
Nano-Optoelectronics Research and Technology Laboratory,
[1]School of Physics, Universiti Sains Malaysia, 11800 Pinang, Malaysia

In the current work, tetraleg zinc oxide (ZnO) nanostructure has been fabricated using evaporation method, the structural and optical properties investigated using high resolution X-ray diffraction (HRXRD) which confirmed that ZnO film is successfully deposited on silicon (Si) substrate. This result is line with scanning electron microscopy (SEM) and atomic force microscopy (AFM) result which used to imaging the morphology of the film and it indicate that the roughly surface film was obtained. Photoluminescence (PL) emission employed to study the optical properties of ZnO film that showed two PL peaks have been observed; one in UV region at 371 nm (3.34 eV) and the other in visible region at 530 nm (2.34 eV). The visible emission of PL spectrum which attributed to the yellow defects inside the films has high intensity. This is expected to provide a suitable antireflection coating (ARC) for enhancing the efficiency of the photovoltaic devices such as solar cells and photodetectors.

(Received March 2, 2012; Accepted March 24, 2012)

Keywords: ZnO, Thermal Evapouration, PL, UV emission, ARC ,yellow defect.

1. Introduction

Zinc oxide (ZnO) is an important material in many optoelectronic devices and applications such as varistors, biosensors, gas sensors, transparent electrodes, etc. [1]. ZnO is a promising material due to the wide direct band gap of 3.37 eV at room temperature (RT) and high exciton binding energy of 60 meV which allow it to use in ultraviolet region with harsh condition [2].

The surface of one dimensional ZnO is very sensitive to the changes in surface chemistry and hence can be utilized to fabricate highly sensitive ZnO electrochemical sensors.

Many industrial and Commercial activities involve the monitoring and control of the environment, with applications ranging from domestic gas alarms and medical diagnostic apparatus to safety , environmental and chemical plant instrumentation , The largest barrier to achieve improved process or environmental control often lies at the interface between the system and the environment to be monitored , i.e. the sensor without significant advances in control and instrumentation will not be possible [3]. Furthermore Semiconductor biosensors is an electronic device designed to monitor the content of particles of a certain material in surrounding medium [4-5]

Various techniques have been employed to prepare ZnO films including the sol-gel process, chemical deposition, direct current (DC) and radio frequency (RF) sputtering, and pulsed laser deposition [6]. The evaporation method has drawn considerable attention since the resulting films properties can be controlled by changing the evaporation condition [7] .

In the present work the evaporated tetraleg zinc oxide nanostruture was reported which has been deposited on silicon Si (n type) (110) using furnace high temperature technique. Metallic zinc of purity (99.98 %) was employed. The films thickness of 420 nm is deposited at 900 C

*Corresponding author: abduljalelphys@gmail.com

temperatures which has a significant role in the sensing applications [8]. The high intensity of PL peak at 530 nm (2.34 eV) has been observed due to yellow defect which useful in ARC for solar cell is observed.

2. Experimental Part

Tetraleg ZnO nanostructure is deposited on Si substrate using thermal evaporation process of free-catalyst Zn powder (99.99%) and the process carried out in a quartz tube. Si (110) substrate was cleaned thoroughly by using the standard RCA method, and then substrate placed on an alumina boat used to this purpose, and set in front of Zn powder surrounded by the quartz tube. The furnace was heated from 400 to 850 ºC with flow argon and oxygen gases at rate flow 5 L min^{-1} for 1 h.

Thickness of the structure is measured by using optical reflectometry system Filmetric F20-VIS. The crystalline structure of the film was studied using high resolution X-ray diffraction (HRXRD) Model; PANalytical X'pert Pro MRD with a Cu-$K_{\alpha1}$ radiation source of λ = 1.5406 Å. The morphology of the structure, length and width of tetraleg is showed using scanning electron microscopy (SEM) and atomic force microscopy (AFM). The band gap energy of the structure have been evaluated using the photoluminescence spectra (PL) were recorded using photoluminescence spectroscopy system Model: Jobin Yvon HR 800 UV with He-Cd laser of 325 nm excitation sources.

3. Results and disscussion

Fig. 1 shows the XRD pattern of the tetraleg ZnO nanostructure deposited on Si substrate which is confirmed that the formation of polycrystalline ZnO. The XRD spectrum of ZnO film revealed that the diffraction peaks of the structure are (110), (002), (101), (102), and (103) at 2θ of 31.75º, 34.42°, 36.24º, 47.54º, and 62.82º respectively. This indicates that the film preferentially grew along c-axis orientation, perpendicular to the substrate.

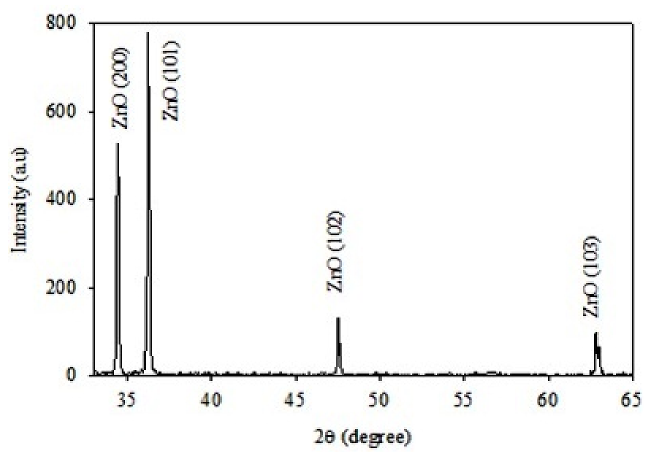

Fig. 1. The XRD pattern of ZnO thin film on silicon substrate

In order to attain the detailed structure information, the grain size along the c-axis has been calculated according to the Scherrer formula:

$$D = \frac{0.9\lambda}{B\cos\theta} \quad (1)$$

where λ is the X-ray wavelength, θ is Bragg angle, and *B* is FWHM value.

The average uniform strain e_{zz} for the lattice along the c-axis in the randomly oriented ZnO film deposited on Si substrate has been estimated from the lattice parameters using the Eqn. below.

$$\varepsilon_{zz} = \frac{c - c_o}{c_o} \times 100\% \tag{2}$$

where c_o is the lattice constant for the unstrained ZnO. The numerical value of c is calculated from XRD data according to the following equations:

$$2d_{hkl} \sin\theta = \lambda \tag{3}$$

where d_{hkl} is the lattice spacing of (*hkl*), λ is the X-Ray wavelength and θ is Bragg angle. At the same time, ZnO is a hexagonal structure which follows the formula [9]:

$$d_{hkl} = \frac{1}{\sqrt{4/3(h^2 + hk + k^2)/a^2 + l^2/c^2}} \tag{4}$$

where a and c are the lattice constants. The calculated c and corresponding, the strain of ZnO nanostructure are listed in Table 1 .Using c_o for ZnO of 0.52 nm [6]. Positive value of the strain in the film means that the sample is in a tensile condition . In spite of, the low strain was at (102) ZnO, however, still the (002) ZnO have prefable orientation for ZnO film.

The diffraction peak orientations, FWHM, c lattice constant, grain size and the strain of ZnO nanostructure on Si are summarized in table 1.

Table 1: Diffraction peak orientations, FWHM, c lattice constant and grain size of ZnO nanostructure on Si

Orientation	2θ (degree)	FWHM (2θº)	Grain size (d)	Lattice constant (*c*)	Strain
(002)	34.428	0.1968	27	5.21	0.00192
(101)	36.248	029.52	18	5.2045	0.00865
(102)	47.54	0.1968	27	5.2096	0.00184
(103)	62.824	0.1968	27	5.2137	0.00263

The surface morphology of deposited ZnO thin film onto Si substrate has been investigated, using SEM and AFM. ZnO film look like tetraleg nanostructure have been observed by SEM image as shown in figure 2 , the ZnO tetraleg is uniform and have a length of 2.5 nm and width 0.12 Mm which revealed this standard method provided nanostructure ZnO compared with high sophisticated methods

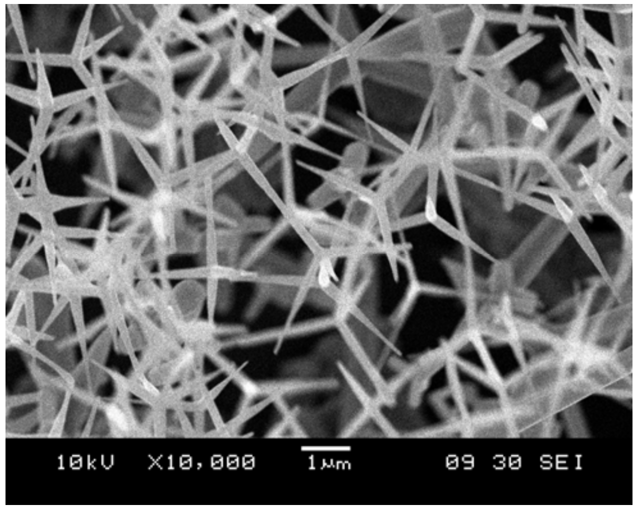

Fig. 2: The SEM image of tetraleg ZnO thin film on Si substrate

Fig.3 shows the AFM image of ZnO tetraleg nanostructure ZnO with high RMS which indicates that the surface roughness of the film on Si is very high.

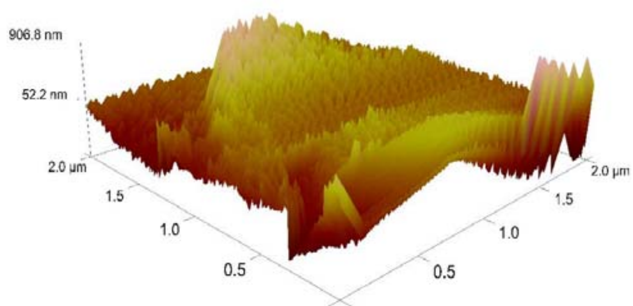

Fig.3 AFM image of ZnO film surface deposited using Evaporation technique.

However, the rough surface morphology of the nanostructure surface may be useful in the absorption of the UV light when it is used as a UV detector.

The PL spectrum of the prepared ZnO thin film on Si is shown in Fig. 4. Two luminescence peaks can be observed in the sample, the first peak is the UV emission at 371 nm (3034eV) which slightiy close to the bulk ZnO band gap energy of 3.37 eV corresponding to the near band edge emission (NBE) due to the electronic transition from near conduction band to valence band. The other one is in the visible region at 530 nm (2.34 ev) which may be due to the defect related deep level emission.

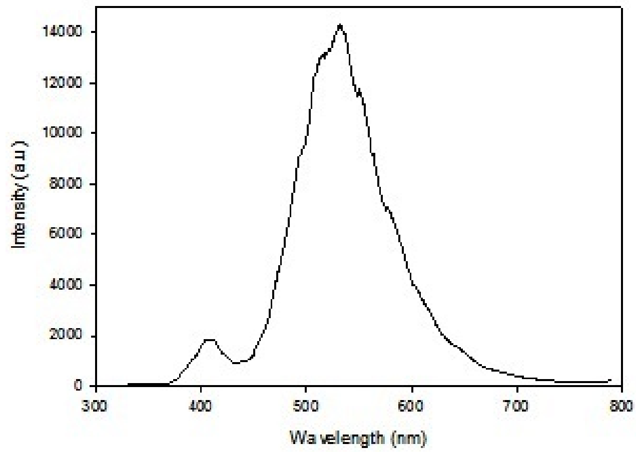

Fig. 4. PL peaks of ZnO thin film on si substrate

A broad green-yellow band peaked with high intensity at 530.0 nm was observed for the sample and make ZnO tetraleg nanostruture is promising material for many applications such as biosensor,photodetector and solar cell in both UV and VIS regions .

In summary, the tetraleg ZnO nanostructure on Si substrate was fabricated. For preferly (002)ZnO,The high grain size, and smoothly surface and relatively low strain observed in the ZnO sample. ZnO film has two PL peaks one at 371 nm in UV region and the other at 530 nm in green-yellow region with high intensity make it promising to use in both UV and VIS optoelectronic devices.

Refrences

[1] W. J. E. Beek, M. M. Wienk, R. A. Janssen, Adv. Mater. **16**, 1009 (2004).

[2] X.W. Sun and H.S.kwork: J. Appl. phys. **86**, 408 (1999).

[3] M. Rajalakshmim, A. K. Arora, B. S. Bendre, S. Mahamuni, J. Appl. phys. **87**, 2445 (2000).

[4] K. Vanheusden, C. H. Seager, W. L. Warren, D. R. Tallant, J. A. Voigt, J. Appl. Phys. **79,** 7983 (1996).

[5] N. Al-Hardan, M. J. Abdullah, A. Abdul Aziz, H. Ahmad, M. Rashid, Physica B : Phys. Condens. Matter **405**, 1081 (2010).

[6] Chennupati, Jagadish and Stephen J. Pearton, Zinc Oxide Bulk, Thin film and Nanostructures (2006) 14.

[7] M. Miyao, I. Tsunoda, T. Sadoh, A. Kenjo, Thin Solid Films **383**, 104 (2001).

[8] F. Zhang, X.Wang, S. Ai, Analytica Chimica Acta **519**, 155 (2004).

[9] Ghosh, R. Basak, D. Fujihara, S. J. of Appl. Phys. **96**, 2689 (2004).