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Enhancement of ZnO nanostructures Properties Grown by Electrochemical deposition technique

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ABSTRACT

ZnO nanostructure has been successfully synthesized on n-type Si (111) by electrochemical deposition method. The (FESEM) Images Showed that the Seed-shaped ZnO nanostructures with 20 nm radius occurred by changing the annealing time. The x-ray diffraction (XRD) revealed that ZnO were hexagonal grown with very high (101) orientation. The Optical gap spectrum proves that the grown ZnO Seed-shaped nanostructures of a very high quality in the UV region from electromagnetic spectrum.

1- Introduction

ZnO had been the subject of many fundamental and applied researches due to its unique structures, novel optical properties, piezoelectric and magnetic characteristics [1-3]. ZnO nanostructure showed a great interest for applications in photodiodes and sensors, among others. The synthesis of a long and uniform ZnO nanostructure is still rather difficult[4-8].

Among the various methods have been used to synthesize ZnO nanostructure in different morphologies, such as tubes, rods and tetrapods, the simplest and low cost methods are physical vapor deposition process using vapor solid transport via high temperature.

This letter, report an approaches to synthesis ZnO by electrochemical deposition. Significantly uniform seeds of ZnO revealed by the Images taken by field emission scanning electron microscopy (FESEM). High crystalline, c-oriented crystallographic structure investigated by X-ray diffraction (XRD). Optical gap spectra of the fabricated ZnO nanostructures showed optical gap from band emissions are in the UV region which confirming the high quality of ZnO.

2 - Experimental procedure

This study used a simple home-made Teflon cell with two electrodes for ECD (Fig. 1). A platinum spiral wire was used as an anode. Si (111) substrates were used as cathodes. 0.5 cm was the distance between the Pt wire (anode) and the Si substrate (cathode). This deposition setup was used in this study. The back contact at which the substrate is placed consists of aluminum. A sealing O-ring was placed on top of the substrate, particularly between the substrate and the cell.

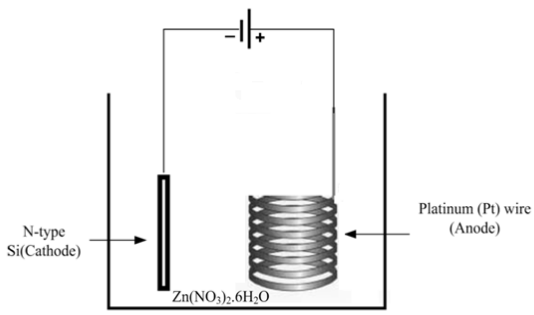

Fig. 1: Schematic diagram of a conventional ECD cell.

About 0.1 M of zinc nitrate powder was dissolved in distilled water the solution was then in the cell, current density is one of the main factors that affect ECD. ZnO was deposited under 2 mA/cm2 current density at supplied by a programmable current source for a constant duration time (60 min) on Si (111) substrates. The solution of zinc nitrate powder (99.999% Sigma-Aldrich) dissolved in distilled water. In ECD, $Zn(NO_3)_2$ was used as the electrolyte to cause the deposition of ZnO. Which is dissolved in deionized water. The number of moles in this study, 0.1 M (number of moles) = 29.748148 g from Zn (NO3)2·6H2O (powder). To obtain a number of moles equivalent to 0.1 M, 1.487 g of Zn

$(NO3)2·6H2O$ powder was dissolved in 50 mL of water.

The produced samples then annealed under furnace temperature was gradually increased from room temperature to 600. The temperature was then fixed at 30, 60,120 and 180 min. The Oven temperature was allowed to reach room temperature under natural conditions.

The morphology of the synthesized ZnO hexagonal tetrapods was observed with Field emission scanning electron microscope (FESEM) X-ray diffract meter was used for the structural measurements. Reflectance spectra of the samples were measured by spectrophotometer and the optical energy gap were calculated at room temperature.

3- Results and discussion

Fig. 2 a shows a typical FESEM image of a large scale ZnO crystal synthesized on n-type Si (111)grown at 60 min. Fig. 2 a , the hexagonal ZnO seeds image grown with annealing temperature 600°C for 30 min. Note the formation of uniform, seeds with equal diameters and hexagonal shapes of 40.nm in three dimensions of ZnO grown at 600°C for 60 min. as shown in fig 2b. The formation of these structures take parts into two steps: nucleation and growth Fig. 2 c. The ZnO on the first grains of the extended solid crystal occurred on the crystals layer forming the agglomeration of atoms or molecules as nucleation process and the growth of ZnO nanostructure will be grown from these nucleus successively. A change in the ZnO nanostructure shape as a function of the annealing temperature was observed. A significant change in the 3D ZnO shapes and an increase in the diameter with increased reaction temperature were also observed.

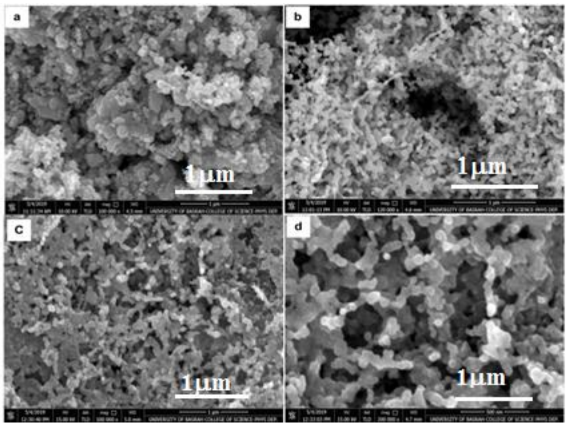

Fig. 2: FESEM images of the grown structures of on Si(111) and annealed with 600 °C for (a) 30min., (b) 60 min. ,(c) 120 min. and (d) 180 min. annealing temperature.

The ZnO XRD pattern is shown in Fig. 3.Revealing that ZnO are of the typical wurtzite structures. Three pronounced ZnO diffraction peaks with different intensities (100), (002) and (101) were observed for the ZnO grown at 600 oC for (a) 30min., (b) 60 min. ,(c) 120 min. and (d) 180 min. annealing temperature, as shown in Fig. 2.a,b,c and d successively. The scattering data are in agreement with the JCPDS file of ZnO (JCPDS 36-1451)[9-12]. c-axis oriented (002) plane growth are observed through the peaks at 34 °, . It can be seen also that the ZnO have (101) peak is dominant because the ZnO seeds have a larger radius 20 nm. Three different intensities of ZnO peaks with (100), (002), and (101) other peaks corresponding to the (102), (110), and (103) reflection planes, respectively from the diffraction patterns of the samples.

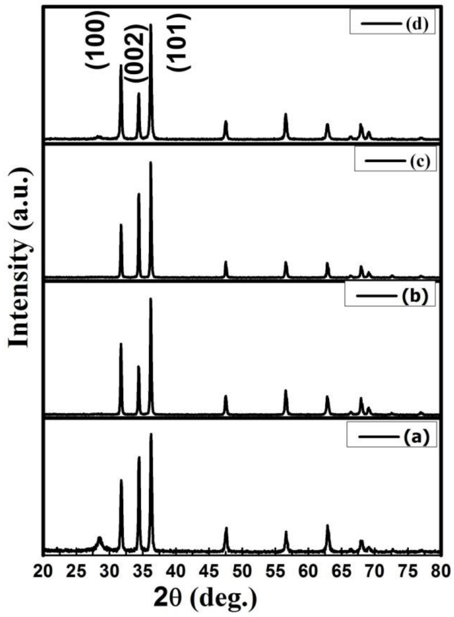

Fig. 3: XRD of the grown structures of on Si(111) and annealed with 600 °C for (a) 30min., (b) 60 min. ,(c) 120 min. and (d) 180 min. annealing temperature.

All the prepared samples showing higher diffraction intensity at (101) plane indicated which is mean the growth material was hexagonal. Notably, the crystallinity of the resulted nanostructures was changed with the annealing time for the same temperature, which was enhanced by increasing annealing time.

Figure 4: Showed the optical band gap which are plotted according to the equation of reflectance depending on the changes in the annealing time [13, 14].

$(\alpha h\upsilon)^2 = [h\upsilon\{\ln(R_{max.}-R_{min.}/R-R_{min.})\}]^2$

R, $R_{max.}$ and $R_{min.}$ are reflectivity of the sample ,maximum reflectivity and minimum reflectivity respectively. Optical band gap the ZnO nanostructures grown at (a) 30min., (b) 60min., and (c) 120 min. (d) 180 min. annealing time on Si(111) optical band gap 4.1, 3.85 , 3.1 and 3.15 eV for the ZnO nanostructure grown at (a) 30min., (b) 60min., and (c) 120 min. (d) 180 min. annealing time. respectively can be observed on the spectrum. As the resulting ZnO nanostructure grown with 120 min. annealing time has a nearest UV emission .The optical gap position of the UV emission is dependent on the diameter of the Nano seeds.

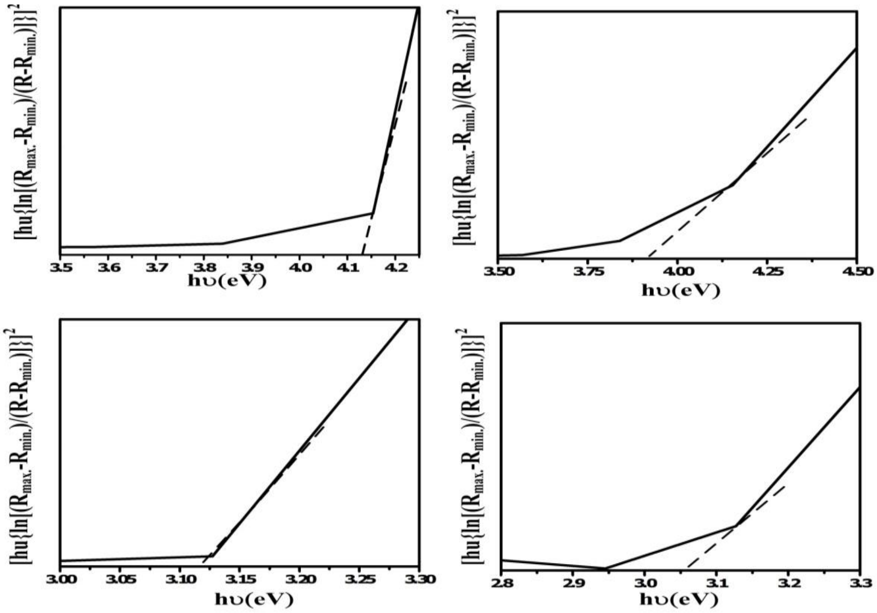

Fig. 4: Optical band gap of the ZnO seeds structures grown at (a) 30min., (b) 60min., and (c) 120 min. (d) 180 min. annealing time.

4 - Conclusion

Morphological images showed that ZnO nanostructures with different shapes and diameters were grown. Growth mechanisms for the formation of different seeds diameter were proposed. The XRD characterizations showed that the formed ZnO seeds were hexagonal phases with well crystalline, depending on the annealing time with constant temperature. The reduces in the optical energy gap which all are in the UV region of electromagnetic spectrum with increasing the annealing time under the same temperature by control defects led to lower optical gap in the UV emission.

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TJPS

تحسين خصائص اوكسيد الخارصين النانوي المنمى بتقنية الترسيب الكهروكيمياوي

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الملخص

تم في هذا البحث ترسيب اوكسيد الخارصين على ارضيات من السليكون نوع (111) n بطريقة الترسيب الكهروكيميائي وقد اثبتت فحوصات المجهر الضوئي الماسح ذو الانبعاث المجال ان اوكسيد الخارصين المرسب يتكون من حبيبات نوى بنصف قطر 20 نانو متر. فحوصات حيود الاشعة السينية اثبتت ان اوكسيد الزنك المرسب هو سداسي الشكل وذو طور (101) عالي جدا. تم ايضا حساب قيمة فجوة الطاقة البصرية واختلافها مع زمن تلدين العينات وقد بينت انها في المنطقة الفوق بنفسجية من الطيف الكهرومغناطيسي