STUDY OF SPUTTERED ZnO THIN FILMS ON SiO_2 AND GaP SUBSTRATES

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Received 30 April 2011; accepted 29 May 2011.

1. Introduction

Recently, Zinc oxide (ZnO) has been attracting particular interest because of its remarkable optical and electronic properties. Its significant optical transparency combined with an excellent electrical conductivity made ZnO a promising material for the fabrication of optoelectronic devices. It has a direct wide band gap of 3.37 eV, large exciton energy of 60 meV. ZnO exhibits the most splendid and abundant configuration of nanostructure that one material can form [1]. Compound semiconductors have also attracted much attention, because they are strong candidate materials for light-emitting diodes operating in the blue-to-ultraviolet region. Gallium phosphide, has potential for ultraviolet, blue, and blue-green detection application from 250 to 500 nm. It has much higher absorption coefficients at shorter wavelengths, which is necessary for many ultraviolet applications. So the GaP nanomaterials have stimulated a great deal of interest in scientific research and technology applications, such as the GaP quantum dots, nanorods, nanowires, and nanoparticles have been reported [2]. In this work, we studied the dependence of the properties of the prepared ZnO thin films on SiO_2 and GaP substrates according to deposition temperature. The structural and electrical properties of the prepared films are discussed.

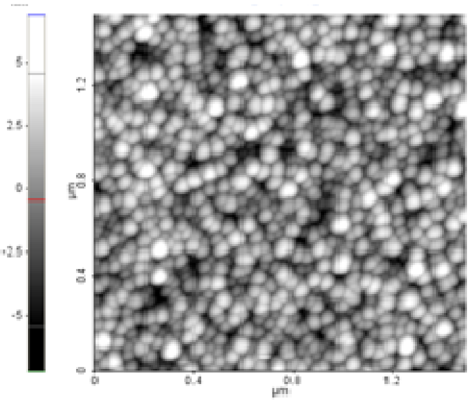
2. Experimental details

ZnO thin films were deposited on GaP and SiO_2 substrates using RF reactive magnetron sputtering at room temperature (RT) and at 400 °C. A disk of Zn-Al alloy (99.99% purity for both Zn and Al) with 2 % Al was used as the target. The diameter and the thickness of the target were 76 and 5 mm, respectively. The target-substrate distance was fixed at 60 mm. Before being fixed on the substrate holder, the substrates were rinsed in ethanol and pre-cleaned in ultrasonic bath. The substrate holder was parallel with respect to the target. The vacuum chamber was evacuated to a base pressure of $2x10^{-3}$ Pa using a rotary pump combined with a diffusion pump, and then high-purity Ar and O_2 (99.99% for both cases) were introduced as sputtering gas and reactive species, respectively. The total pressure was fixed at 0,3 Pa in the case of deposition at room temperature and at $8x10^{-2}$ Pa in the case of deposition at 400°C. The Ar/O_2 partial pressure ratio was set to the desired value equal to 100:1. Prior to film deposition, the target was pre-sputtered for about 10 minutes to remove the surface contaminants, while the substrate was blocked with a shutter. Once steady state was reached, the shutter was opened to start growth. ZnO films were deposited at room temperature and 400°C for 30 minutes using an RF power source of 125 W. During the deposition, the substrate temperature was monitored by a thermocouple. The surface morphologies of films were examined by a PARK XE-100 atomic force microscope (AFM) working in non-contact mode. The XRD pattern was measured using Philips PW1710. The measurement of electrical properties was carried out on the Hall-effect measurement using standard van der Pauw technique.

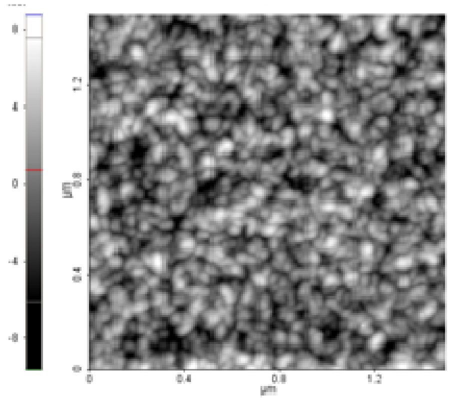
3. Results and discussion

3.1 Morphology

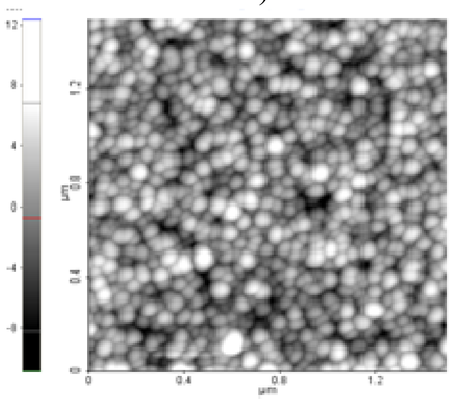
The thickness of the prepared film was 100nm. Fig. 1 shows the surface morphologies of ZnO films deposited at room temperature and at elevated temperature on SiO_2 and GaP substrates. One can see that the surface morphology of ZnO layers shows strong dependence on deposition conditions. The surface roughness shows the minimal value for RF sputtering at 400 °C (Ra = 1,867 nm) while at room temperature the surface roughness is higher (Ra = 2,391 nm), what is in good agreement with the literature [3]. The magnetron sputtered ZnO layers show high surface roughness but very good homogeneity of the grains ordering especially in the case of layers deposited on SiO_2 substrates. The peak to valley parameter is also dependent on the deposition temperature. While at room temperature the value of this parameter is equal to Rpv = 15,65 nm at 400 °C Rpv = 1,1,78 nm. This can be explained by higher atom mobility and with increased atom filling effect at the grain boundaries at higher growth temperature. Fig. 2 shows a SEM image of the layer prepared at high temperature. It can be seen that at higher temperatures some of the crystals are casted one into another.



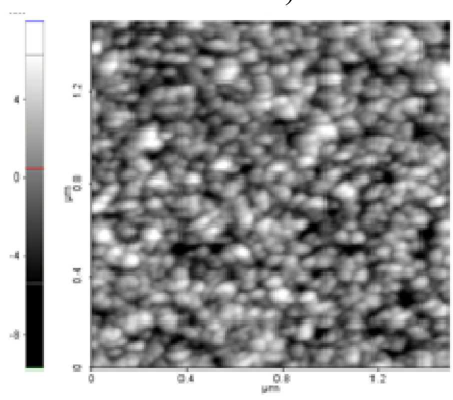
a)



b)



c)



d)

Fig.1: *Morphology of the prepared films on SiO_2 (a,b) and GaP (c,d) substrates at room temperature (a, c) and at 400°C (b, d).*

XRD pattern of the ZnO layer grown at RT is shown on Fig. 3. Similar peaks were identified by Zhao et al [4]. It can be seen that the (002) plane has the highest peak intensity suggesting that the layer has a *c*-axis-preferred orientation. Additional peaks along with (100), (101) and (103) planes are also observed.

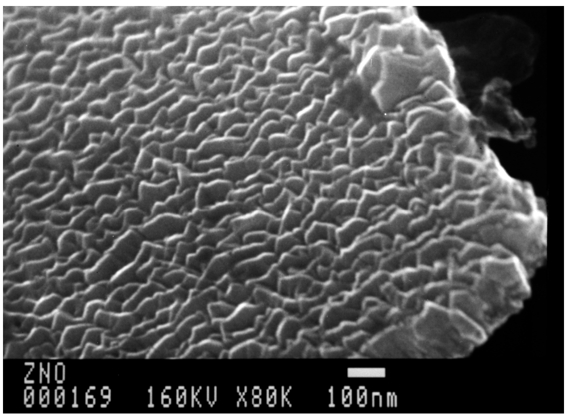


Fig.2: *SEM image of the surface of the ZnO: Al film grown at 400°C*

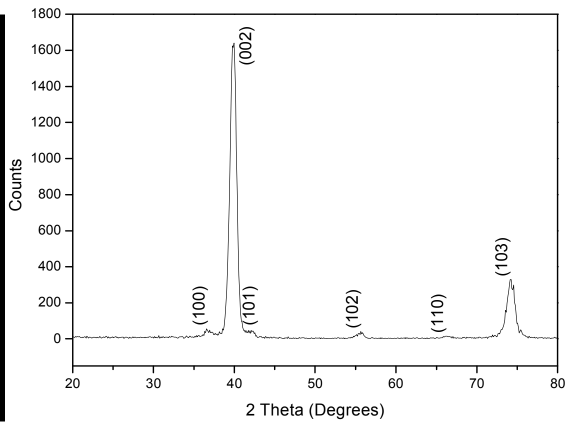


Fig. 3: *XRD spectra of the prepared ZnO film*

3.2 Electrical properties

The electrical properties of the prepared ZnO layers are summarized in Table 1. The ZnO layers show n- type conductivity with concentration in the range of $1x10^{17} – 1x10^{18}$ cm^{-3} and resistivity 0,6 –2,6 Ωcm with decreasing tendency with the increase of temperature. The carrier mobility is 15 cm^2/Vs for the samples prepared at room temperature and 12 cm^2/Vs for the samples prepared at 400 °C.

Tab.1 *Properties of ZnO layers deposited on GaP substrates at RT and at 400 °C*

Substarte temperature [°C]	Roughness R_a/R_{pv} [nm]	Carrier concentration [cm^{-3}]	Carrier mobility [cm^2/Vs]	Resistivity [Ωcm]	Carrier type
25	2,39/15,6	$1,6x10^{17}$	15	2,6	n
400	2,27/11,7	$1,2x10^{18}$	12	0,46	n

4. Conclusion

We have investigated n-ZnO polycrystalline thin films prepared on SiO_2 and p-GaP substrate using magnetron sputtering technique. The structural and electrical properties of these structures were studied. The measured parameters give promising results with a possibility to utilize n-ZnO/p-GaP heterostructure for application in the solar cells development especially in the field of nanostructures. The prepared structures will be a subject of further research.

Acknowledgements

This paper is supported by grant of Science and Technology Assistance Agency “GRONA”, no. APVV-0301-10, VEGA project 1/0689/09, 1/0553/09, 1/0114/10, CENTEM project reg. no. CZ.1.05/2.1.00/03.0088 within the project No. 1M06031 and CE for development and application of advanced diagnostic methods in processing of metallic and non-metallic materials, ITMS: 26220120048, supported by the Research & Development Operational Program funded by the ERDF.

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