GROWTH AND CHARACTERISATION OF GaP/ZnO HETEROJUNCTION PROPERTIES

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1. Introduction

Zinc oxide (ZnO) is emerging as a multifunctional material for broad applications in blue and ultraviolet optoelectronic devices because of its direct and wide band gap of 3.4 eV and large exciton binding energy ~ 60 meV [1,2]. Conductive and transparent *n*-type ZnO thin films have significant commercial impact due to their use as transparent electrodes for flat panel displays, organic light emitting devices and in solar cells. ZnO n-type conductivity is relatively easy to realize via excess Zn or with Al or Ga doping. The next improvement will be obtained by the preparation of a GaP-ZnO heterojunction and its application will allow the designer to shift the absorption edge more to the blue part of the solar spectrum

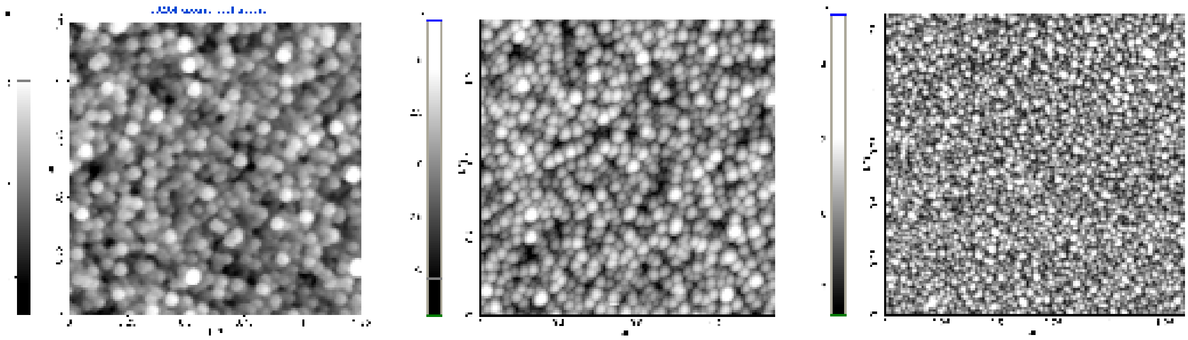
In this paper, we discuss the effect of deposition of ZnO thin layers on GaP substrate by magnetron sputtering, RF diode sputtering and PLD and their influence on the structural, electrical and optical properties. The main goal of this work is to find the technology for deposition very thin ZnO layers with defined electrical parameters to cover round GaP nanowires surface prepared by MO VPE technology.

2. Experimental

Polycrystalline zinc oxide layers, from ZnO targets were grown on GaP(1 1 1)B substrates by pulsed laser deposition (PLD), RF diode sputtering (RF DS) and RF reactive magnetron sputtering (RF RMS) . The ZnO thin layers prepared by PLD utilized a standard equipment including pulsed laser source (Nd:YAG laser, 355 nm), ZnO target and subsequent ambient oxygen pressure of 5 Pa for deposition of ZnO films at 400 °C. The planar RF diode sputtering diode system was employed for deposition of polycrystalline ZnO layers using a ceramic $ZnO:Ga_2O_3$ target in Ar atmosphere at room temperature. The next applicable technology for ZnO layer deposition is the RF reactive magnetron sputtering technique. The method has advantage in low temperature flow from magnetron discharge. The disk of Zn-Al alloy was used as the target. High-purity Ar and O2 were introduced as sputtering gas and reactive species, respectively. The Ar/O2 partial pressure ratio was set to the desired value equal to 100:1 during the deposition of ZnO layer at substrate temperature 30, 400°C and 125 W RF power. The surface morphology of deposited ZnO layers on GaP substrate was investigated by AFM system PARK XE-100. The I-V characteristics were measured using Agilent 4155C parameter analyzer in dark and under illumination by halogen lamp. The optical reflectance of GaP/ZnO structures was measured by the spectroscopic ellipsometer PHE 120 at 30° incidence angle. For photocurrent measurements the standard halogen lamp, monochromator and photocurrent measurement system were utilized.

3. Structural and electrical properties of deposited ZnO thin layers

The surface morphology of ZnO layers shows strong dependence on deposition conditions and technique. In Fig. 1a,b,c are shown the AFM surface morphology images of ZnO thin layers (~100 nm) prepared by different deposition techniques.



a) *b)* *c)*

Fig.1: *AFM surface morphology images of ZnO layers deposited by a) RF DS b) RF RMS and c) PLD*

In Tab.1 are summarized the related measured surface roughness and peak to valley high parameters of ZnO surface and Hall electrical parameters. The grain area of deposited ZnO layers is different for different techniques and the minimal grain area were reached by PLD, while the surface roughness R_a shows the minimal value for RF DS where the largest grain area was found. The RF RMS prepared ZnO layers shows the highest surface roughness but the best homogeneity of the grains ordering. The ZnO layers show n- type conductivity with concentration in the range of 6x 10^{16} – 1 x10^{18} cm^{-3} and resistivity 0.46 –19 Ωcm.

Tab.1 *Properties of ZnO layer deposited on insulating substrates.*

Technology	Substrate temperature [°C]	Roughness R_a/R_{pv} [nm]	Carrier concentration [cm^{-3}]	Carrier mobility [cm^2/Vs]	Resistivity [Ωcm]	Carrier type
RF RMS	RT	2.39/15.6	$1.6x10^{17}$	15	2.6	n
RF RMS	400	2.27/11.7	$1.2x10^{18}$	12	0.46	n
RF DS	RT	0.72/3.23	$2x10^{17}$	6	6.8	n
PLD	400	0.9/5.5	$6.2x10^{16}$	5	19	n

4. Electrical and optical properties of GaP/ZnO heterostructures

The spectral reflectance measurements of different ZnO structures in Fig.2 shows maxima and minima reflectivity in correspondence with refractive index and thickness of GaP/ZnO structures. The spectral characteristisc of pGaP/nZnO heterojunction photodiodes prepared by PLD, RF DS and RF RMS depicted in Fig.3 shows typical heterojunction photoresponse with expressive band gap absorption edge of ZnO layer near 370 nm and decay at GaP absorption edge near 500 nm. Electrical behavior of the samples was measured in the dark and by applying the illumination. As shown in Fig.4 the heterojunction p^+GaP/n-ZnO devices show rectifying properties in dependence of deposition method. The forward bias characteristics shows weak turn-in voltage in the range of 2-5V due to high resistivity of the contacts prepared without annealing. The forward bias characteristics can be improved by annealing of the contacts. The reverse breakdown voltage is more than 10V for RF DS and RF RMS method while PLD samples show higher dark reverse current due to defects formations at GaP/ZnO interface. High photosensitivity was reached under white light illumination for reverse bias over 0.5 V mainly for RF DS and RF RMS ZnO samples. The first deposition of 100 nm n-ZnO layer by RF DS on GaP nanowires is documented by the SEM image in Fig.5.

5. Summary

We have investigated n-ZnO polycrystalline thin films prepared on p-GaP substrate using PLD, RF DS and RF MRS techniques. The structural, electrical and optical properties of these structures revealed the ability to utilize n-ZnO/p-GaP heterostructure for application

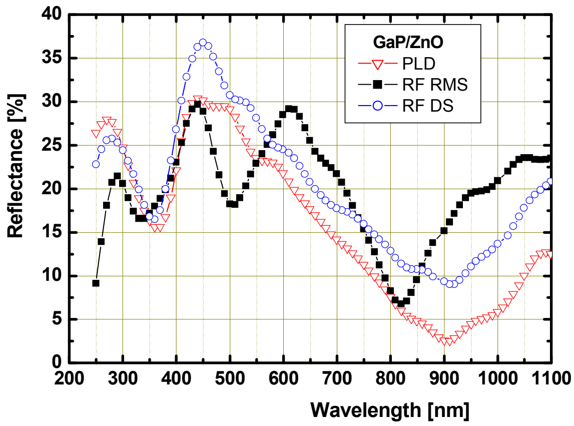


Fig.2 *Spectral reflectivity of ZnO layers*

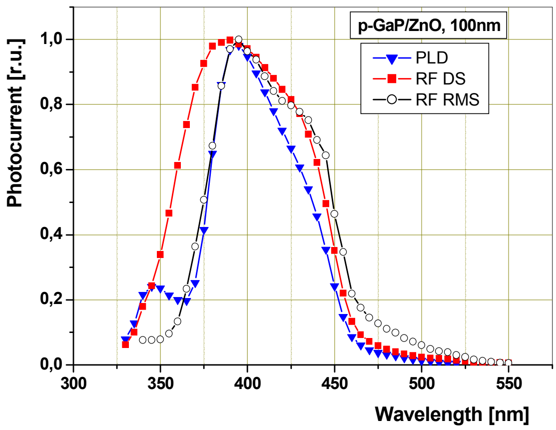


Fig.3 *Spectral responsivity of GaP/ZnO structures*

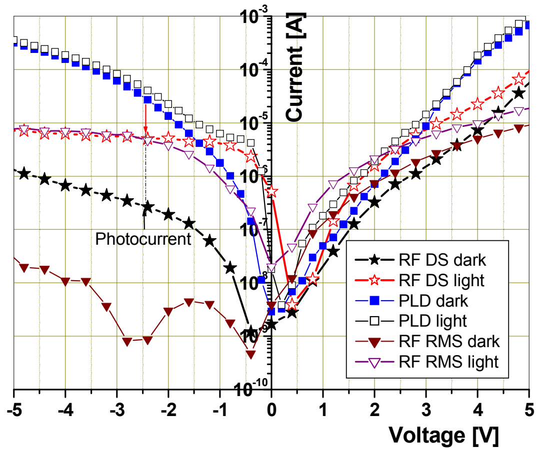


Fig.4 *I-V characteristics of GaP/ ZnO heterostructure photodiodes*

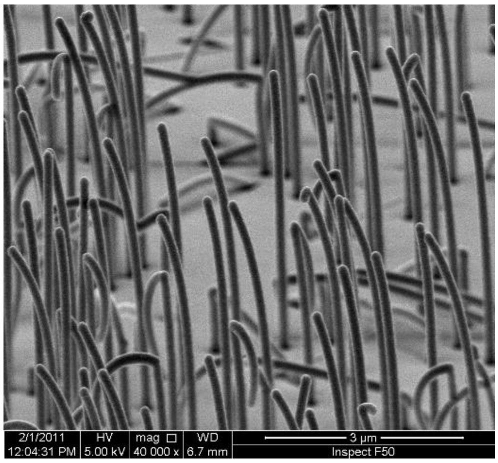


Fig.5 *SEM image of GaP nanowires covered by 100 nm thick ZnO layer by RF DS*

in the solar cells development mainly in the field of nanostructures while the optimization will be subjected for future investigation.

6. References

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