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Analysis of temperature dependent I-V characteristics of Pd/ZnO/n-Si Schotky diode by Sol-gel method

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Abstract - *The ZnO thin film was deposited on n-Si (100) by sol-gel and spin coating technique. Pd/ZnO/n-Si/Ti/Al Schottky contact were fabricated by the thermal evaporation method using shadow mask technique. The ZnO thin film was annealed in Ar (argon) atmosphere at 450^{0}C to enhanced structural and surface morphology. The structure and surface morphology of ZnO thin film prepared were characterize by the XRD and SEM and it was found that the thin film is polycrystalline in nature with homogeneous surface. The I-V characteristics of the device were analyzed by the semiconductor parameter analyzer. The semiconductor parameters were determined at different operating temperature in air atmosphere.*

Keywords*: ZnO, Sol-gel, Thermal evaporation, Schottky****.***

I. INTRODUCTION

Recent research mainly focused on wide band gap semiconductor material. ZnO is one of most promising semiconductor material having wide band (3.37eV), large exciton binding energy (60 eV).[1] In addition to these ZnO has piezoelectric[2], ferromagnetic[3] properties and due to large exciton binding energy ZnO is used as the laser diode at room temperature[4]. ZnO is also used for different environmental gases detection because of its high sensitivity to surroundings gases [5]. It is very tough to obtain the p-type ZnO therefore it requires to fabricate different semiconductor devices such as UV photo detectors, gas sensors and solar cells by using Hetero junction or metal-semiconductor type contact. One advantage of metal semiconductor contact is speed of operation because of unipolar charge carriers. So there are many works performed on metal-ZnO schotky contact and in turn important properties of schottky contact variation with operating temperature were investigated [1, 6-7]. The ZnO thin film can be fabricated by different methods such as pulse laser deposition (PLD)[8], spray pyrolis [9], thermal evaporation[10] and sol-gel[11]. Among all of these method sol-gel is very effective method because of the large area deposition, easy doping low temperature process non toxic and cheap in cost. In this work ZnO thin film was fabricated by sol-gel method and structural and surface morphology are investigated by the XRD and SEM and it was found that film is polycrystalline in nature with homogeneous surface of particle size 60-100nm and with crystalline size 12nm. Pd/ZnO/n-Si/Ti/Al schottky contacts were realized by shadow masking technique [6, 10]. The temperature dependence characteristics of schottky contact were analyzed by the semiconductor parameter. The barrier height, saturation current and ideality factor were evaluated from I-V characteristics of schottky contact. The temperature range of the experiment varies from 292K-540K.

II . EXPERIMENT

A. ZnO Thin Film Preparation

ZnO thin film was deposited on n-Si(100) substrate using sol-gel and spin coating method. Zinc acetate dihydrate used as precursor material. The 4.9gm Zinc acetate dehydrated was dissolved in 150ml of isopropanol at room temperature for 30minutes stirred with stirrer to get a milky solution.[11] Drop wise was diethanolamine added to this milky solution by micropipette to get homogeneous transparent solution and stirring continue to 2 hr here diethanolamine was used as stabilizer. The sol was kept for 24 hr in air atmosphere to stabilize. The sol was spin coated on the n-Si for two different speed of spinner namely 1000rpm for 15second and 2000rpm for next 15 second. After deposition of the sol on substrate it was heated upto 250^{0}C in air atmosphere to remove the organic compound from the film. This step of deposition of sol on silicon repeated for 4-5 time to get approximately 250nm thick ZnO thin film on the n-Si(100) substrate. To improve surface and structural properties of ZnO thin film thermal annealing was performed in Ar atmosphere at 450^{0}C on film deposited by the sol-spinning method .The whole process of ZnO thin film shown in flowchart.1. The surface and crystal structure of the deposited film were investigated by the XRD and SEM.

B. Device Fabrication

The Pd/ZnO/n-Si/Ti/Al device was fabricated by the thermal evaporation using shadow mask technique [11]. For the top schottky contact a 200nm Pd deposited using shadow mask of area .785X10^{-2}cm^2 on the n-type ZnO film. The back ohmic contact was realized by the deposition of Ti and Al of thickness 100nm for each metal so that total back contact is 200nm and it is ohmic in nature. These metallization was performed in thermal deposition unit (HIND HIVAC India make). In the

thermal unit distance between source and substrate is 18cm and estimated time of deposition is 45 minutes at vacuum of 10^{-6}mbar. Finally the device is annealed at 450^0C in nitrogen atmosphere to improve the contact quality. The schematic of the device is shown in fig.1.

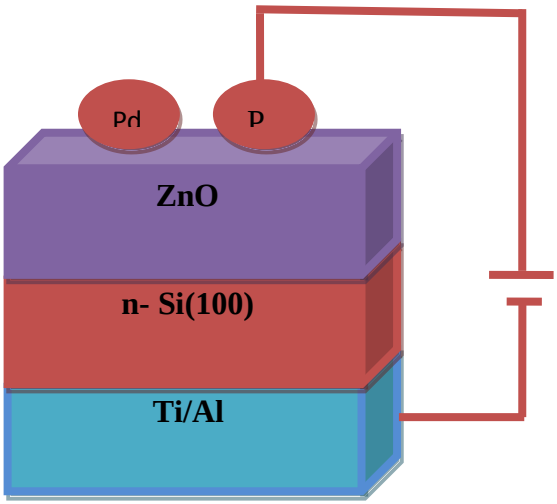

Fig.1. Schottky diode structure.

III. RESULT AND DISCUSSION

A. Thin Film Characterization

The crystal structure of the ZnO thin film was carried out by the X-ray diffraction. From X-ray diffraction pattern it was found that ZnO thin film is polycrystalline in nature with prominent peaks along 31.79 ^{0} (100), 34. 44^0 (002) 36.31^0 (101), 47.43 (102) 56.62 ^{0} (110) 62.91(103) and 67.83 ^{0} (112) standard data files (JCPDS file no.36-1451) were used to indexed all these peaks [11]. The crystallize size were determined by scherer formula [11].

$$D = \frac{c\,\lambda}{\beta \cos\theta}$$

where D is crystalline size, λ wavelength , c correction factor β-full width half maximum, and θ is diffraction angle. The value of crystalline is approximately 10.4nm. The surface morphology of ZnO thin film was measured by the SEM(scanning electron microscope) the SEM image shown in fig.2 reveals that the surface is homogeneous in nature with particles size 80-100nm.

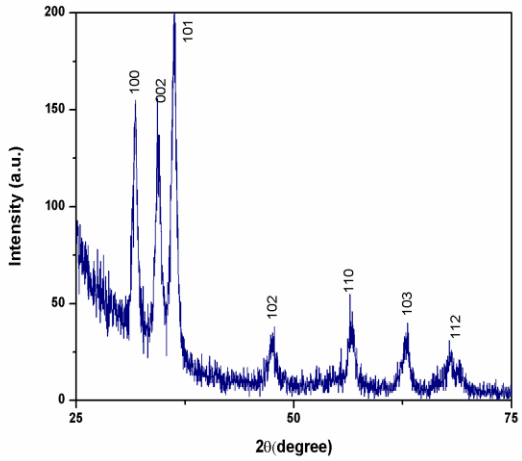

Fig.2. X-ray diffraction of ZnO thin film

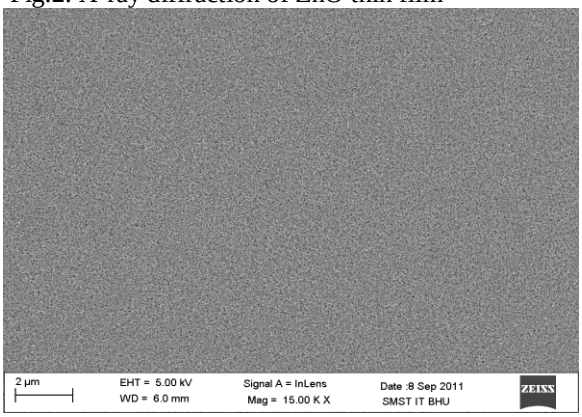

Fig.3. SEM image of ZnO thin film

B. Device Characterization

The Pd/ZnO/n-Si/Ti/Al schottky diode I-V characteristic was obtained by the semiconductor parameter analyzer. The I-V characteristics of device is shown in fig 2 (a & b). The work function of Pd (palladium) is larger than the electron affinity of n-ZnO so there is rectifying contact form between the Pd/ZnO, and barrier height is the difference between difference the electron affinity of ZnO and work function of the metal. The experimental value (0.70 eV) of the barrier height is deviated from the theoretical value (1.02 eV) because mechanism of current transport across barrier is not due to only thermionic emission [7]. Schottky diode parameters can be evaluated by the well known equation[6]

$$I = I_s \left\{ exp\left(\frac{qV}{nkT}\right) - 1 \right\}$$

where I_s is saturation current and given by the equation below

$$I_s = AA^{**}T^2\left\{exp\left(-\frac{q\varphi_b}{kT}\right)\right\}$$

with A contact area, T temperature in kelvin ,φ_b barrier height, k boltzmann constant , A^{**} Richardson constant . The above equation was written assuming the total thermionic emission. The value of the barrier height, saturation current and ideality factor were tabulated in table 1. From the table it was obtained that the barrier height increases with increase in temperature in turns increasing in saturation current. The decrease in barrier height with good agreement with reported work [12].

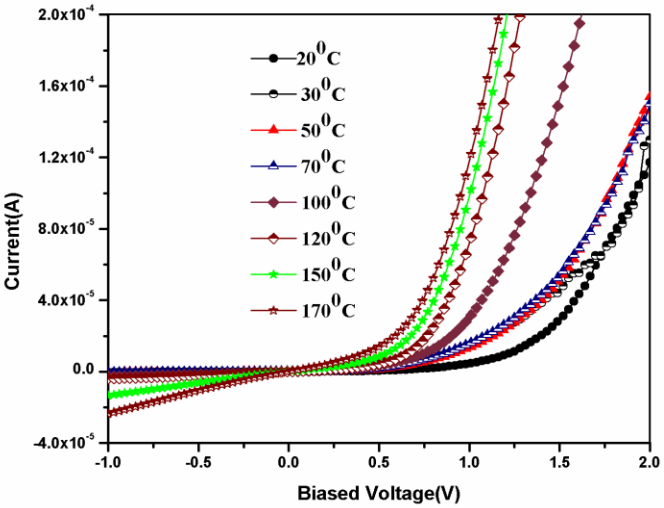

Fig.4. I-V characteristics of Pd/ZnO schottky contact at different operating temperature.

Table.1 Device parameters at different operating temperature

Temperature(K)	Barrier Height(φ_b)(eV)	Saturation Current (I_s) (A)	Ideality Factor(η)
293	.7023	$1.79X10^{-8}$	5.257
303	.7094	$3.65X10^{-8}$	4.825
323	.7774	$2.51X10^{-8}$	4.376
343	.8074	$4.09X10^{-6}$	4.311
373	.8139	$2.96X10^{-7}$	4.251
393	.8623	$3.38X10^{-7}$	5.620
403	.8529	$8.78X10^{-7}$	3.972
423	.9384	$8.87X10^{-7}$	3.963

CONCLUSION

The polycrystalline ZnO thin film was prepared by sol-gel spinning coating method. The crystal structure of ZnO thin film performed by the X-ray diffraction method and crystalline size of film was found to be 10.5nm from shrerer formula. The surface morphology of the SEM(scanning electronic microscopy) and it was found that the surface is homogeneous with particle size 80-100nm. Finally the device characterization was performed by the semiconductor parameter analyzer. It was found that the saturation current increases with temperature however zero bias barrier height increases with increase in temperature.

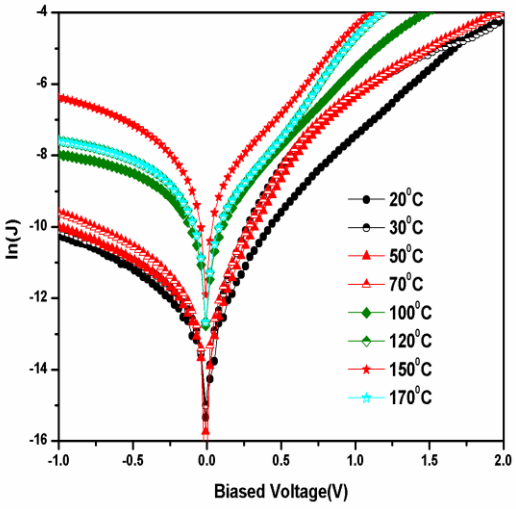

Fig.4. ln(J) - V characteristics of the device for different biased voltage.

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