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The Annealing Effects of ZnO Thin Films on Characteristic Parameters of Au/ZnO Schottky Contacts on n-Si

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200 nm ZnO thin films have been grown on n type Silicon substrates by DC sputtering technique. One of the thin films has been annealed at 300 °C for 45 minutes. The Au front contacts on ZnO thin films have been formed by evaporation of Au metal by means of shadow mask. It has been seen that the rectification ratio of Au/ZnO device obtained using annealed ZnO thin film is higher than the one obtained using unannealed ZnO thin film. The characteristic parameters of Au/ZnO junctions such as ideality factor, barrier height and series resistance obtained by current-voltage (*I-V*) measurements of the structures at room temperature and in dark have been compared with each others.

Keywords: ZnO, Schottky contact, DC sputtering, Electrical properties.

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1. INTRODUCTION

Zinc oxide (ZnO) is one of the most important semiconductor materials with direct wide band gap (3.37 eV) and good transparency [1]. Recently, ZnO has attracted substantial attention due to its excellent physical properties and potential technological applications [2]. To obtain high-quality ZnO thin films various deposition methods have been used including such as spray pyrolysis process [3], molecular beam epitaxy (MBE) [4], rf magnetron sputtering [5], dc sputtering [6] and pulse laser deposition (PLD) [7].

In this study we obtained 200 nm ZnO thin films on n-Si substrate by dc sputtering technique. After annealing one of the films at 300 °C for 45 minutes, Au front contacts have been formed. The annealing effects of ZnO thin films on Au/ZnO contacts have been analyzed using the current voltage (*I-V*) measurements of the devices.

2. METHODS OF SAMPLE MANUFACTURING AND ANALYSIS

An n-type Si wafer with (100) orientation and 1-10 Ωcm resistivity has been used in the experiment. The wafer has been cleaned using tricholoroethylene, acetone and isopropanol. The wafer has been etched using 0.4 % HF solution. To make an ohmic back contact Au has been sputtered on the wafer and the wafer has been annealed at 450 °C for 15 minutes. The wafer has been cut into 2 pieces. 200 nm ZnO thin films have been formed by DC sputtering technique with about 1Å/s speed at 5×10^{-3} Torr in Argon atmosphere using ZnO target. One of the samples has been annealed at 300 °C for 45 minutes in N_2 atmosphere. The Au front contacts on ZnO thin films have been formed by evaporation of Au metal by means of a shadow mask. The obtained structures have been shown in figure 1. The electrical properties of Au/ZnO contacts formed on n-Si substrate have been analyzed using Keithley 2400 sourcemeter.

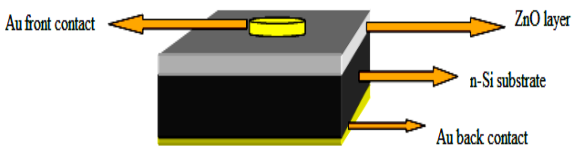

Fig. 1 – A scheme of Au/ZnO contacts on n-Si substrate

3. RESULTS AND DISCUSSION

Figure 2 shows ln *I-V* plots of Au/ZnO contacts on n-Si substrate. As seen from figure rectification ratio (RR) of the contact obtained using annealed ZnO thin film is higher than the one obtained using unannealed ZnO thin film. The rectification ratio results are shown in Table 1. The characteristic parameters of the contacts can be determined using well known

$$I = I_0\left(\frac{q(V - IR_S)}{nkT}\right) \quad (1)$$

equation [8] where I_0 is the saturation current and written as

$$I_0 = AA^{**}T^2 \exp\left(-\frac{q\varphi_b}{kT}\right) \quad (2)$$

ϕ_b is the barrier height at zero bias, A is the diode area, A^* the effective Richardson constant equals

Table 1 – Characteristic parameters of Au/ZnO contacts fabricated on n-Si

Method	ln*I-V*			Norde	
Parameters	RR	n	ϕ_b (eV)	R_s (kΩ)	ϕ_b (eV)
Au/ZnO as grown	11	2.66	0.776	144	0.778
Au/ZnO annealed at 300 °C	580	2.67	0.826	139	0.841

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to 36 Acm^{-2} K^{-2} for ZnO [9] and n the ideality factor. The ideality factors of Au/ZnO contacts have been determined from the slopes of the linear regions in Figure 2 by the help of using the equation 1. The barrier heights of the contacts have been determined using equation 2 by means of saturation current values. As seen from Table 1, although the ideality factor values are nearly same, the barrier height value of the contact obtained using annealed film is 0.05 eV higher than the one fabricated using unannealed film.

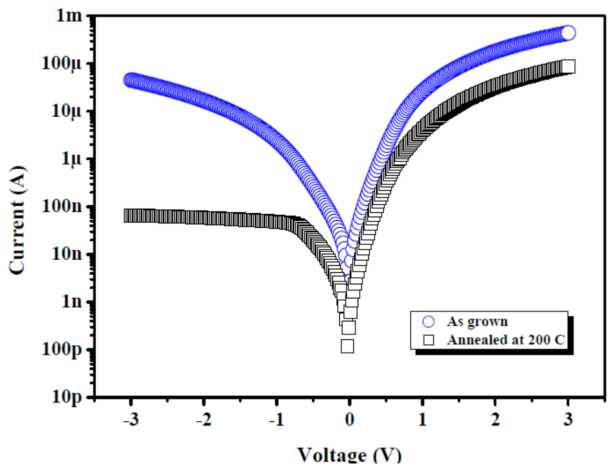

Fig. 2 – Current-voltage plots of Au/ZnO contacts

The forward bias *I-V* plots of the structures deviate from linearity at high voltages because of the series resistance. Norde functions can be used to determine the series resistance of the device using forward bias *I-V* data. Norde's method is defined by following relation [10]

$$F(V) = \frac{V_0}{\gamma} - \frac{kT}{q}\left(\frac{I(V)}{AA^*T^2}\right) \quad (3)$$

where γ is the first integer greater than ideality factor and $I(V)$ the current obtained from *I-V* characteristics. In this study, γ is taken as 3 for Au/ZnO diodes. The $F(V)$ vs V plots for the diodes are given in Figure 3. The barrier height of the device can be expressed as

$$\varphi_b = F(V_0) + V_0/\gamma - kT/q \quad (4)$$

where $F(V_0)$ is the minimum value of $F(V)$. The R_s of the diode is calculated through the relation

$$R_S = kT(\gamma - n)/qI_0 \quad (5)$$

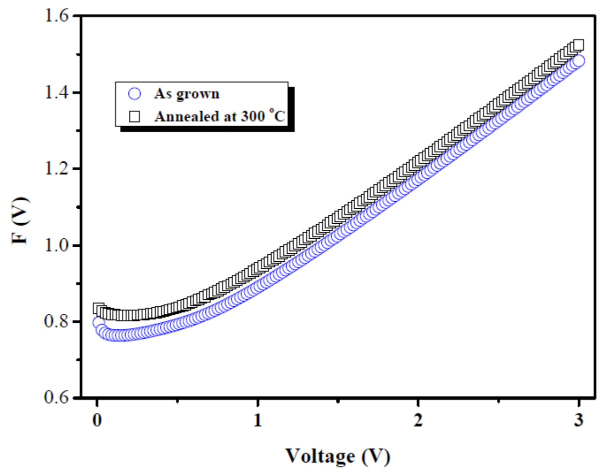

Fig. 3 – $F(V)$-V plots of Au/ZnO contacts

The barrier height values of the junctions very similar to the results obtained using ln *I-V* plots. The series resistance value of annealed film is lower than the one fabricated using unannealed film. Aydogan et al. [11] have obtained 7 identical Au/ZnO/n-Si diodes by electrodeposition of 0.33 μm ZnO thin film on n-Si and calculated their ideality factors ranged from 0.55 to 0.59 eV, and the ideality factor from 1.21 to 1.53. They have also calculated the series resistance of the diodes 1.8 kΩ using Norde's functions. In addition, Yakuphanoglu [12] calculated the barrier height, the ideality factor and series resistance values of Au/ZnO:Co/n-Si structure fabricated using cobalt doped zinc oxide nanofiber as 0.76 eV, 2.79 and 3.35 kΩ, respectively.

4. CONCLUSIONS

Au/ZnO contacts have been fabricated using both annealed and unannealed ZnO thin films formed on n-Si by DC sputtering technique. The electrical properties have been analyzed using *I-V* measurements in dark. It has been seen that the rectification ratio of the contact formed using annealed ZnO thin film is about 50 times higher than the contact formed using unannealed ZnO thin film. Furthermore, the barrier height value of Au/ZnO diode fabricated annealed ZnO thin film is higher than the one formed using unannealed ZnO thin film.

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