THE INTERSECTION BEHAVIOR OF REVERSE BIAS CURRENT -VOLTAGE (I-V) CHARACTERISTICS OF (Al-TiW+PtSi)/n-Si SCHOTTKY DIODES AT WIDE TEMPERATURE RANGE

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80-360K temperatur intervalında maqnitron tozlandırma metodu ilə hazırlanmış $\left(Al - TiW + \mathrm{PtSi}\right)$ Şotki diodlarının düzünə və əks mailləri I-V tədqiq edilmişdir. Əks deşilmə gərginliyində alınmış diodlarda mənfi temperatur əmsalı alınmış və temperatur artması ilə son gərginliyin azalması müşahidə edilmişdir. Eyni zamanda sıfırıncı mailin artdıqca $\varphi\left(I - V\right)$ baryer hündürlüyü azaldıqca n-ideallıq faktoru temperatur artdıqca azalır. Düz mailin I-V qeyri-ideal asılılığı bölğünün sərhəddinnin sərt halı asılılığı ilə əlaqədardır. Alınmış nəticələr göstərdi ki, müxtəlif temperatur üçün I-V əyriləri hətta sonuncu müqavimətdə müəyyən gərginlikdə adi xarakterə malikdir.

Исследованы особенности прямого и обратного хода уклона I-V (Al-TiW+PtSi) диодов Шоттки изготовленные методом магнетронного распыления в температурном интервале 80-360К. Полученные диоды при обратном напряжения пробоя показали отрицательный температурный коэффициент и уменьшение порогового напряжение с увеличением температуры. Одновременно при уменьшении высоты барьера нулевого уклона Fb (I-V), фактор идеальности n уменьшается с увеличением температуры. Неидеальное поведение прямого уклона I-V были приписаны зависимости поверхностного состояния границы раздела. Экспериментальные результаты показали, то обратный уклон кривые I-V для различных температур имеет обычный характер при определенном напряжении уклона даже при конечном сопротивлении.

The forward and reverse bias I-V characteristics of (Al-TiW+PtSi)-n-Si Schottky diodes (SDs) were fabricated by a magnetron sputtering method were measured in the temperature range of 80-360 K. The basics diode parameters were found strongly temperature dependent. In our diodes, while the reverse breakdown voltage shows a negative temperature coefficient, the forward threshold voltage decreases with increasing temperature. At same time, while the zero-bias barrier height Φ_b(I-V) increases, the n decreases with increasing temperature. The series resistance values decreased with increasing temperature; the changes being quite important at high voltages and at low temperature ranges. The non-ideal behaviour of forward bias *I-V* characteristics was attributed to interfaces states in equilibrium with semiconductor and series resistance. Experimental results show that all reverse bias semi-logarithmic I-V curves for the different temperatures have an almost common cross-point at a certain bias voltage even with finite series resistance.

1. INTRODUCTION

The main diode parameters such as the ideality factor n and barrier height (BH) in a great variety of metal-semiconductor (MS) Schottky diodes have been extensively studied and reported in the literature for more than four decades [1-8]. In generally, analysis of the I-V characteristics of SBDs based on TE theory usually reveal an abnormal decrease in the BH and increase in the n with decrease in the temperature[1-3]. R.Hackam and P.Harrop [9] proposed that the ideality factor n should be included in the expression for the reverse saturation current I_o. In this study, the forward and reverse bias I-V characteristics of (Al-TiW+PtSi)-n-Si SDs fabricated by a magnetron sputtering method were measured in the temperature range of 80-360 K. The validity of including n in the expression of I_o is demonstrated by the comparing the corrected values of the barrier height. In addition, Horvath et al studied its temperature dependence in Al/SiO_2/p-Si Schottky diodes [10]. They observed that the forward bias *I-V* curves intersection under room temperature. In our diodes, while the reverse breakdown voltage shows a negative temperature coefficient, the forward threshold voltage decreases with increasing temperature. In addition, In this study, we have investigated the intersection behavior of reverse bias current-voltage-temperature (I-V-T) characteristics of (Al-TiW+PtSi)-n-Si Schottky diodes (SDs) in the temperature range of 80-360 K.

2. EXPERIMENTAL PROCEDURE

The Al-TiW+PtSi-n-Si Schottky diodes were fabricated on float zone <111> n-type single crystal silicon wafer having 0.7 Ω.cm resistivity. The Si substrates were placed in the vacuum chamber after level-by-level clearing during 10 minutes in a mix of a peroxide-ammoniac solution and washing subsequent in de-ionized water during 15 minutes. The temperature of preliminary heating of the substrates plates was 250 ^oC, the heating time 5 minutes. The film was rendered at a mode: during 320 second the voltage submitted on a target was 350 V, current of the anode was 3 A. The plates after drawing a metal film have been annealed to achievement of more homogeneous contents of TiW alloy and for creation of homogeneous metal - semiconductor interface. The Al-TiW+PtSi-n-Si Schottky diodes obtained in a uniform work cycle were exposed to heat treatment at temperature 500^{o}C in an atmosphere N_2 within 20 minutes. I–V measurements were performed by the use of a Keithley 220 programmable constant current source, a Keithley 614 electrometer.

3. RESULTS AND DISCUSSIONS

Fig. 1 shows the reverse and forward bias semi-logarithmic experimental ln I-V characteristics of Al-TiW+PtSi-n-Si Schottky diode in the temperature range of 80-360 K. According to the thermionic emission theory (TE), the relation between the applied forward bias and the current can be written as [1-3]

$$I = I_o \exp\left(\frac{qV}{nkT}\right)\left[1-\exp\left(-\frac{qV}{kT}\right)\right] \qquad (1)$$

where Io is the reverse saturation current.

$$I_o = AA^{*}T^{2}\exp\left(-\frac{q\Phi_{bo}}{kT}\right) \qquad (2)$$

The n, Φ_{Bo} ,A, A*,k are well known other parameters of diodes. The value of n can be obtained from the slope of the straight line of the forward bias LnI-V plots as

$$n = \frac{q}{kT}\left(\frac{dV}{d\ln I}\right) \qquad (3)$$

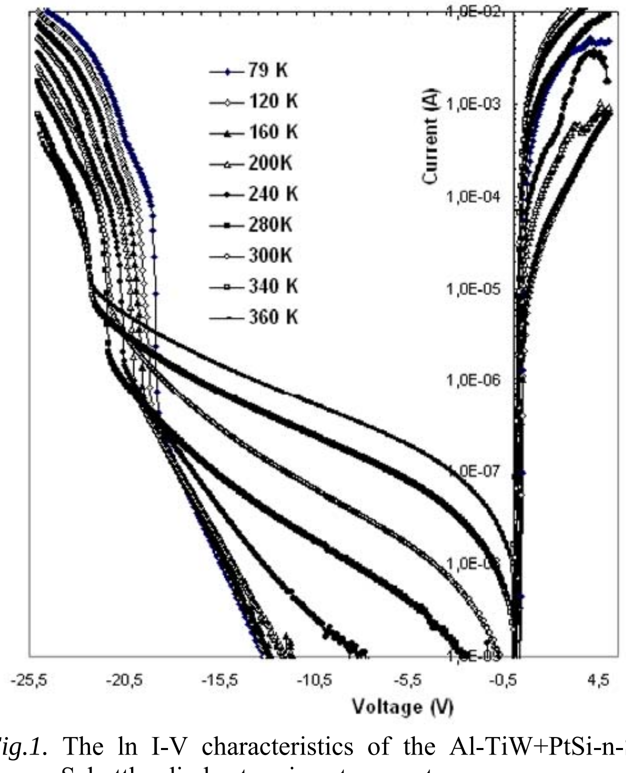

Fig.1. The ln I-V characteristics of the Al-TiW+PtSi-n-Si Schottky diode at various temperatures.

The n should also be included in the expression for the I_o. This is because the effects that causes deviation from to 1 especially at low temperature and high bias. Similar results have also been found by several authors [5,11] as

$$I_o = AA^{*}T^{2}\exp\left(-\frac{q\Phi_{bo}}{nkT}\right) \qquad (4)$$

Thus, the barrier height Φ_{bo} determined, at each temperature, from I_o according to

$$\Phi_{bo} = n(T)kT\ln\left(\frac{AA^{*}T^{2}}{I_o}\right)$$

The variation in n and Φ_{bo}(I-V) as a function of operating temperature are shown in Fig. 2. Fig. 2 shows an increase in the zero-bias barrier height Φ_{bo} and a decrease in the ideality factor n with increasing operating temperature. Since the current transport across the MS interface is a temperature activated process, electrons at low temperatures are able to surmount the lower barriers. The high values of n may be related to thermionic emission (TE) over a Gaussian barrier height distribution.

As can be seen in Fig .1, an interesting feature of the forward bias semi-logarithmic *I-V* curves is the almost common intersection point of all the curves at certain bias voltage and for this voltage point the current through the diode is temperature independent. Similar results have been obtained recently by simulation of forward bias *I-V* curves of Schottky diodes [10,12]. It was found that the presence of series resistance in diode causes bending due to current saturation and plays subtle role in the keeping this crossing hidden. It will be observed that such a plot of Φ_B(I-V) vs T (Fig.2) shows an unusual behavior that it increases with increasing temperature.

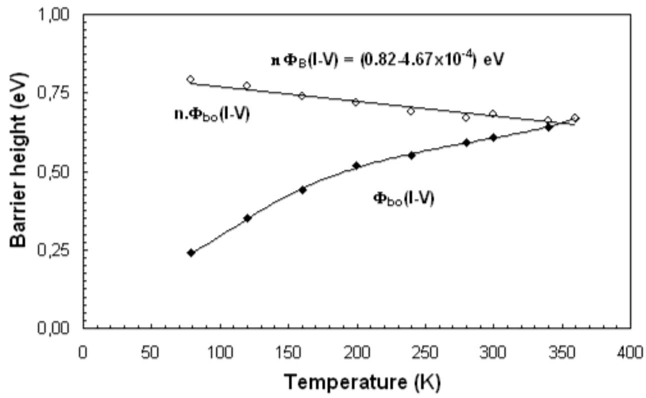

Fig. 2. Temperature dependence of the Φ_{bo} and (n*Φ_{bo}) for the Al-TiW+PtSi-n-Si Schottky diode.

Such positive temperature coefficient is an obvious disagreement with then negative temperature coefficient of reported negative temperature coefficient of the barrier height of Si Schottky diodes [2,5]. Therefore, the values of barrier height $\Phi_{Bn}(T)$ determined in accordance with Eq.(5) and is given in Table 1 and Fig.2. It will be observed that a plot of $\Phi_{Bn}(T)$ vs T has a negative temperature coefficient as $3x10^{-4}$ eV/K. This value of temperature coefficient is found to the barrier height was in very close agreement with the temperature coefficient of the Si band gap ($-4.73x10^{-4}$ eV/K).

3. CONCLUSION

The conduction mechanism of the Al-TiW+PtSi-n-Si Schottky diodes have been investigated using forward bias *I-V measured* in the temperature range of 80-360 K. It was seen that while the zero-bias barrier height Φ_b(I-V) increases, the ideality factor n decreases with increasing temperature.

Experimental results shows that the argument for inclusion of ideality factor n in the expression the Io statement. Also, the reverse bias *I-V* curves show the intersection behaviour. This behaviour of the crossing of *I-V* curves appears as an abnormality when seen with respect to the conventional behaviour of SBDs. This behaviour of the crossing of *I-V* curves appears as an abnormality when seen with respect to the conventional behaviour of SBDs.

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