ANALYSIS OF TEMPERATURE AND BIAS DEPENDENCE OF BARRIER HEIGHT IN Al/p-Sİ SCHOTTKY DIODES WITH INTERFACIAL INSULATOR LAYER

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Al/SiO$_2$/p-Si Şotki diodlarının baryer hündürlüklərinin (φ_B) temperatur asılılığı 295-440K intervalında tədqiq edilmişdir. Alınmış nəticələr göstərir ki, temperatur artdıqca ideallıq əmsalı (n) azalır və sıfırıncı mailin baryer hündürlüyü (ϕ_{B0}) artır. Nəzəri olaraq ϕ_{B0}=1,18 eV və σ_0=0,139 ən böyük qiymətlərində Qaus paylanmasından istifadə edərək bu qrafikdən baryer hündürlüyünün orta qiymətində və sıfırıncı maildə standart dönmə üçün alınmışdır. Beləliklə, modifikasiyalaşdırılmış $\ln\left(I_0/T^2\right)$ $-q^2 So^{2/2}(kT)^2$ q/kT-dən asılılıq qrafiki uyğun olaraq (ϕ_{B0}) və A^V üçün 1,82 eV və 33,27 A/cm^{2}K^2 verir. Bu A^V $\left(33{,}26\, A/cm^2K^2\right)$ qiymət p-tipli Si üçün nəzəri alınmiş 32 A/cm^{2}K^2 qiymətinə yaxındir.

Проведены исследования температурной зависимости высоты барьера (Φ_B) Al/SiO$_2$/p-Si диодов Шотки в температурном интервале 295-400K. Экспериментальные результаты показали, что с увеличением температуры уменьшается коэффициент идеальности (n) и увеличивается высота барьера нулевого наклона (Φ_{Bo}). Теоретически с использованием распределения Гаусса при наибольшем значении $\bar{\Phi}_{Bo}$ =1.18 eV и σ_o= 0.139 были получены из этого графика и для среднего значения высоты барьера и стандартного отклонения на нулевом уклоне соответственно. Таким образом, модифицированный график $\ln(I_o/T^2)-q^2$□$_o^2/2(kT)^2$ от q/kT дает Φ_{B0} и A^* 1.182 eV и 33.27 A/cm^{2}K^2 соответственно и это значение A^* (33.26 A/cm^{2}K^2) очень близок к теоретическому значению 32 A/cm^{2}K^2 для Si p-типа.

The temperature and bias dependence of the barrier height (Φ_B) of Al/SiO$_2$/p-Si Schottky diodes (SDs) have been investigated in the temperature range of 295-400K. Experimental results show that a decrease of the ideality factor (*n*) and increase of the zero-bias barrier height (Φ_{Bo}) with the increase of temperature. We attempted to draw a Φ_{B0} vs q/2kT plot to obtain evidence of a Gaussian distribution of the BHs , and the values of $\bar{\Phi}_{Bo}$ = 1.18 eV and σ_o= 0.139 V for the mean barrier height and standard deviation at zero bias, respectively, have been obtained from this plot. Thus, a modified $\ln(I_o/T^2)-q^2\sigma_o^2/2(kT)^2$ vs q/kT plot gives Φ_{B0} and A^* as 1.182 eV and 33.27 A/cm^{2}K^2, respectively and this value of the A* (33.26 A/cm^{2}K^2) is very close to the theoretical value of 32 A/cm^{2}K^2 for p-type Si.

1. INTRODUCTION:

Due the technical importance of the metal-semiconductor (MS) and metal-insulator-semiconductor (MIS) Schottky diodes, they have been thoroughly investigated [1-7] for a long time. However, their conduction mechanisms are not fully understood yet. The presence of the interfacial insulator layer and interface states strongly influence the electrical characteristics of a MIS device. There are several reasons, which cause the device to deviate from the ideal behavior, and must be taken into account. These include the effects of interfacial insulator layer, interface states and carrier transport mechanism. In this study, temperature dependent *I-V* characteristics of Al/SiO$_2$/p-Si Schottky diodes with interfacial insulator layer in the temperature range 295-400 K are reported. The aim of this study is to investigate temperature dependence of Φ_B and it's Gaussian distribution.

2. EXPERIMENTAL PROCEDURE

The Al/SiO$_2$/p-Si Schottky diodes were fabricated on B doped single Si crystal wafer having thickness of 350 µm with ~1 Ω-cm resistivity. For the fabrication process, Si wafer was decreased in different organic solvents and finally quenched in de-ionized water. The Al back contact was thermally evaporated by means of a tungsten filament onto the whole back side of Si and at 600 ^{o}C for 60 minutes in flowing dry nitrogen (N$_2$) ambient at a rate of 2 liter/min. After the thermal treatment Al circular dots having area of about 0.02 cm^2 and 2500 Å thick aluminum rectifying contacts were deposited at a rate of about 4 Å/s onto the SiO$_2$ surface of the wafer through a metal shadow mask in liquid nitrogen trapped oil-free vacuum system in the pressure of 2x10^{-6} Torr. The I-V-T measurements were performed by the use of a Keithley 220 programmable constant current source together with a Keithley 614 electrometer in a Janes vpf-475 cryostat.

3. RESULTS AND DISCUSSION

When MIS contact with R$_s$ is considered, the relation I-V, can be written as [1,2].

$$I = I_0 \exp\left(\frac{q(V-IR_s)}{nkT}\right)\left[1-\exp\left(\frac{-q(V-IR_s)}{kT}\right)\right] \quad (1)$$

where I$_o$ is the reverse saturation current and is equal to

$$I_o = AA*T^2 exp\left(-\frac{qЦ_{Bo}}{kT}\right)$$

where the quantities R_s, A, A*, T, q, k and Φ_{Bo} are well known parameters of diode[2]. The values of n and Φ_B are calculated from the eqs. (1) and (2), respectively, and given in Table 1.

Table1

Temperature dependent some diode parameters obtained from forward bias I-V data.

T (K)	Io(A)	n	nT (K)	Φ_B(eV)
295	7,50E-09	1,81	534	0,801
310	1,20E-08	1,74	539	0,832
320	3,99E-08	1,72	550	0,827
330	5,79E-08	1,68	554	0,844
340	1,09E-07	1,66	564	0,853
350	1,95E-07	1,64	574	0,862
375	8,30E-07	1,62	608	0,881
400	2,58E-06	1,58	632	0,905

As shown in Table 1, the values of Φ_{Bo} and n ranged from 0.801 eV and 1.81 (at 295 K) to 0.905 eV and 1.58 (at 400 K), respectively. This high value of n has been attributed to particular distribution of N_{ss} and the presence of a thick interfacial oxide layer [1-4]. These behaviors show an unusual behavior that it increases with the increase of temperature. Such temperature dependence is an obvious disagreement with the reported in ideal diodes.

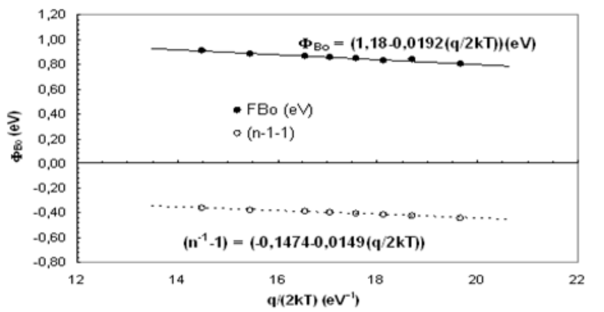

Fig. 1. The Φ_{Bo} and $((n^{-1}-1))$ versus q/2kT plot for Al/SiO_2/p-Si Schottky diode.

A conventional activation energy $\ln(I_o/T^2)$ versus 1/T plot gives a straight line(not here). However, the A* value was found as 3.3×10^{-3} $Acm^{-2}K^{-2}$. This value is 9697 times lower than the known value of 32 $Acm^{-2}K^{-2}$ for holes in p-type Si. This deviation may be due to the spatial inhomogeneous barrier height and potential fluctuations at the interface. As was explained by Horvath [8] the A^* value obtained from the temperature dependence of the I-V characteristics may be affected by the lateral inhomogenity of the barrier. The above abnormal behaviours can be explained using an analytically potential fluctuation model based on spatially inhomogeneous barrier heights at the interface [6-10].

We draw a Φ_{B0} vs q/2kT and $(n^{-1}$-1) vs q/2kT plots to obtain evidence of a Gaussian distribution of the BHs and they given in Fig 1. The values of $\overline{\Phi}_{Bo}$ = 1.18 eV and σ_o= 0.139 V for the mean barrier height and standard deviation at zero bias, respectively, according fallows eqs.:

$$\Phi_{ap} = \overline{\Phi}_{B0}(T=0) - \frac{q\sigma_o^2}{2kT} \qquad \left(\frac{1}{n_{ap}}-1\right) = \rho_2 - \frac{q\rho_3}{2kT} \tag{3}$$

$$\ln\left(\frac{I_0}{T^2}\right) - \left(\frac{q^2\sigma_o^2}{2k^2T^2}\right) = \ln(AA^*) - \frac{q\overline{\Phi}_{B0}}{kT} \tag{4}$$

where ρ_2 and ρ_3 are voltage coefficients which may depend on temperature and the values of ρ_2=-0.147 V and ρ_3 =-0.015 V, respectively. Thus, a modified $\ln(I_o/T^2)-q^2\sigma_o^2/2(kT)^2$ vs q/kT plot gives Φ_{B0} and A^* as 1.182 eV and 33.27 A/cm^2K^2, respectively and this value of the A* (33.26 $Acm^{-2}K^{-2}$) is very close to the theoretical value of 32 A/cm^2K^2 for p-type Si.

4. CONCLUSION

The I-V characteristics of Al/SiO_2/p-Si Schottky diode have been measured in the temperature range of 295-400 K. The data (I-V) analysis based on the Thermionic Emission (TE) theory has revealed the zero-bias barrier height Φ_{B0} decrease, the ideality factor n increases as the temperature decreases, respectively.These behaviors are attributed to Schottky barrier inhomogeneties by assuming a Gaussian distribution of barrier heights (BHs) due to barrier height inhomogeneties that prevails at interface. The Φ_{B0} vs q/2kT plot, and the values of Φ_{Bo}=1.18 eV and σ_o=0.139 V for the mean barrier height and standard deviation at zero bias, respectively. Thus, a modified $\ln(I_o/T^2)-q^2\sigma_o^2/2(kT)^2$ vs q/kT plot gives Φ_{B0} and A^* as 1.182 eV and 33.27 A/cm^2K^2, respectively and this value of the A* (33.27 $Acm^{-2}K^{-2}$) is very close to the theoretical value of 32 A/cm^2K^2 for p-type Si.

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