Abstract: We have investigated the current–voltage (I–V) characteristics of Aluminum (Al) Schottky contacts on undoped and platinum (Pt)-doped FZ n-Silicon(Si) in the temperature range of 300-420 K. The I–V analysis based on thermionic emission (TE) theory shows the value of the Schottky barrier height \( \Phi_B \) and ideality factor \( \eta \) were varied from 0.63 eV and 0.98 at 300 K to 0.56 eV and 0.75 at 420 K, respectively. It is observed that the decrease of \( \Phi_B \) and \( \eta \) with increase of temperatures. These parameters were correlated to the defect levels generated by the Pt in Si. This high value of the \( \Phi_B \) shows that Pt in Si creates donor levels in the energy gap that compensate electrons to reduce the conductivity of the material.

Key Words: Current–voltage–temperature/ Schottky barrier/ platinum-doped silicon/ deep level

1. INTRODUCTION

Doping Si with metals was initially carried out in order to reduce the switching time of electronic devices [1]. Pt was preferred mainly because in silicon it acts as a lifetime killer. In this work, Schottky barrier diodes were fabricated on undoped and Pt-doped FZ n-Si. The current–voltage–temperature (I–V–T) characteristics were used widely to study the behaviour of devices since they offer important parameters such as the saturation current \( I_s \), the ideality factor \( \eta \) and the Schottky barrier height \( \Phi_B \) [2]. In the present work, we report on the I–V characteristics of Al Schottky contacts on undoped and Pt-doped FZ n-Silicon(Si) in the temperature range of 300-420 K.

2. EXPERIMENTAL

The Schottky contacts diodes compatible with CMOS technology were fabricated on 6 inch in diameter of FZ n-Si. After thermal diffusion of the Pt into the bulk, Schottky diodes were fabricated on the substrates. In device characterization, I–V measurements of Al Schottky contacts on undoped and Pt-doped FZ n-Si were carried out using a Agilent B1500A semiconductor device analyzer with a voltage source. The measurements were performed in the temperature range of 300-420 K and in the dark. The data were taken from -2 to 2 V with a voltage step of 0.025 V.

3. RESULTS AND DISCUSSIONS

Fig. 1 shows the log. I–V characteristics both in reverse bias and in forward bias of the diodes that were fabricated on undoped and Pt-doped FZ n-Si. The reverse current of the Pt-doped diode shows a 1 order of magnitude reduction at room temperature. These significant reductions in reverse current are due to the significant increase in barrier height. These measurements are used widely to study the behaviour of devices since they offer important parameters such as the \( I_s \), the \( \eta \) and the \( \Phi_B \). From the thermionic I–V relationship of a Schottky barrier diode is given by[3]

\[
I = AA'T^2e^{-\frac{\Phi_B}{kT}}\left(\frac{qv}{ekT} - 1\right)
\]

\[
= I_s\left(e^{qV/kT} - 1\right)
\]  

(1)
Where $I_s$ is the saturation current, $A$ is the diode area, $A^*$ is the Richardson’s constant, $\Phi_B$ is the effective barrier height, and $\eta$ is the ideality factor where

$$\eta = \frac{q}{kT} \left[ \frac{dV}{d(lnI)} \right].$$  \hspace{1cm} (2)

Where $A$ is the area of the diode while $A^*$ is the Richardson constant given as 112 $\text{Acm}^{-2}\text{K}^{-2}$ for n-type silicon \cite{2}. Plotting $\log[I/(1 - \exp(-qV/kT))]$ versus $V$ is shown in Fig.2, and its value was used to determine the $\Phi_B$ for the contacts. The $\eta$ was obtained from the linear portions of the plot between natural log of current and voltage over two orders of magnitude. The value of the $\Phi_B$ and $\eta$ were varied from 0.63 eV and 0.98 at 300 K to 0.56 eV and 0.75 at 420 K, as shown in Fig. 3 and 4, respectively. It is observed that the $\Phi_B$ was decrease linearly with increase in temperature from 300–420 K.

![Diagram](image-url)

Fig. 1. The $I$-$V$ characteristics of Al/Pt-doped Si Schottky diode in the temperature range of 300–420 K.

![Diagram](image-url)

Fig. 2. Plot of $\log[I/(1 - \exp(-qV/kT))]$ against $V$ for Al/Pt-doped Si Schottky diode.

When plotting $\log[I/(1 - \exp(-qV/kT))]$ versus $V$, the data are linear all the way to $V = 0$, also shown in Fig. 2. The barrier height is most commonly calculated from the current $I_s$, determined by extrapolating the semilog $I$ versus $V$ curve to $V = 0$. The barrier height $\Phi_B$ is calculated from $I_s$ in Eq. (1) according to

$$\Phi_B = \frac{kT}{q} \ln \left( \frac{A^*}{I_s} \right)$$  \hspace{1cm} (3)

![Diagram](image-url)

Fig. 3. Schottky barrier height against temperature for Al/Pt-doped Si Schottky diode.

![Diagram](image-url)

Fig. 4 was the plot of $\eta$ versus temperature which shows the decrease of ideality factor with increase of temperature.
Fig. 4. Ideality factor versus temperature for Al/Pt-doped Si Schottky diode.

The Schottky barrier heights can be determined from a $\ln(I_F/T^2)$-$q/kT$ plot for a given forward bias $V_F$ by [2]

$$\ln\left(\frac{I_F}{T^2}\right) = \ln(AA^*) - \frac{q(\phi_B-V_F)}{n kT}$$  \hspace{1cm} (4)

Where $A$ is the diode area, $A^*$ is the Richardson’s constant, $\phi_B$ is the effective barrier height, and $n$ is the ideality factor. Fig. 5 shows the $\ln(I_F/T^2)$-$q/kT$ plot between 300 and 420 K for the diodes fabricated on undoped and Pt-doped n-type Si substrate, which gives an barrier height($\phi_B(T)$ ) of 0.65 and 0.71 eV, respectively.

Fig. 5. Richardson plot of $\ln(I_F/T^2)$ against $q/kT$ for Al/Pt-doped Si Schottky diode.

Temperature dependence of series resistance ($R_s$) affects the electrical properties of the Al/Pt-doped Si Schottky diodes and is measured in the temperature range of 300–420 K. The series resistance values are evaluated from the forward bias $I$-$V$ data using the method developed by Cheung [4]. The forward bias $I$-$V$ characteristics due to thermionic emission of a Schottky contact with the series resistance can be expressed as Cheung’s function given by

$$\frac{dV}{d(\ln I)} = I R_s + \eta \left(\frac{kT}{q}\right)$$  \hspace{1cm} (5)

The plots of experimental $dV/d(\ln I)$ versus $I$ for different temperatures are shown in Fig. 6. The series resistance value is obtained from the slope and $nkT/q$ value from the y-intercept. The series resistance decreases with increase in temperature. It is observed that the decrease in series resistance is more at low temperatures than at high temperatures since the slope of the curve is large at low temperatures as shown in Fig. 7.

Fig. 6. Plots of $dV/d(\ln I)$ versus current ($I$) for Al/Pt-doped Si Schottky contacts at various temperatures.

Fig. 7. Temperature dependence of the series resistance for Al/Pt-doped Si Schottky diode.
4. CONCLUSION

We report on the temperature-dependent $I-V$ characteristics of the $Al/Pt$-doped Si Schottky diodes in the temperature range of 300–420 K. The obtained $I-V$ barrier heights are in the range of 0.63–0.56 eV and that of ideality factor are 0.98–0.75. The obtained Schottky diode parameters such as ideality factor, barrier height and series resistance from forward $I-V$ characteristics shows strong dependence on temperature. The increase in ideality factor and decrease in barrier height with decrease in temperature have been explained based on the thermionic emission with the assumption of Gaussian distribution of the barrier heights at the interface. The variation of $R_S$ with temperature may be due to the factors responsible for the increase in ideality factor and lack of free carrier concentration at low temperatures. This high value of the $R_S$ shows that $Pt$ in Si creates donor levels in the energy gap that compensate electrons to reduce the conductivity of the material.

5. ACKNOWLEDGMENTS

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6. REFERENCES