Journal of Electron Devices, Vol. 6, 2008, pp. 194-196

© JED [ISSN: 1682 -3427]

Journal of Electron Devices
www.jeldev.org

Comparison of Power dissipation in Ni /4H SiC Schottky Barrier Diode with Uniform and Linear graded doping profiles.

Rajneesh Talwar & Dr. A.K. Chatterjee*
Department of Electronics & Communication Engineering
RIMT-IET, MandiGobindgarh, Punjab,INDIA
rajneesh_talwar@yahoo.com,
Department of Electronics & Communication Engineering
Thapar University, Patiala, Punjab,INDIA
akchatterjee@thapar.edu

Abstract:

Significant improvements in the performance of power devices are possible by the replacement of silicon with silicon carbide The current voltage characteristics of the Schottky Barrier Diode defined by the diode equation can be obtained by using a C++ Program. A set of values of current and voltage are generated using the C++ program. The device parameters i.e. the area, barrier height and doping levels being obtained from published work. This paper mainly analysis power dissipation using 4H silicon carbide diode with Nickel as contact metal with uniform and linear graded doping. It is further recommended to use Linear graded doping to reduce power dissipation in 4H-SiC Schottky barrier diode.

Keywords:
4H-SiC, Schottky barrier diode, Linear graded doping, Uniform doping

Introduction

The current voltage relationship of the Schottky barrier diodes have been obtained by Bethe[1], W.Schottky[2], Crowell and Sze[3]. These have been experimentally verified by Chang and Sze[4] with devices having pre-determined parameters and dimensions. However, it is sometimes useful to obtain a solution for the current density J_F in terms of forward drop directly from the diode equation for specific values of forward voltage V_F. Since the diode equation cannot be solved directly, the C++ program has been used which can give by iteration the equality of two functions into which the diode equation is split. The set of values of J_F & V_F obtained using the C++ program have been found to tally well with experimental results using contacts to Nickel by Saxena and Steckl[5], Sochacki[6]. The data obtained can further be used to find power dissipation with uniform and linear graded doping and slight changes in the program.

Theory:

The basic device structure using a partial metal overlap over the Schottky contact by Itoh et. al[7] is shown in figure 1 below:

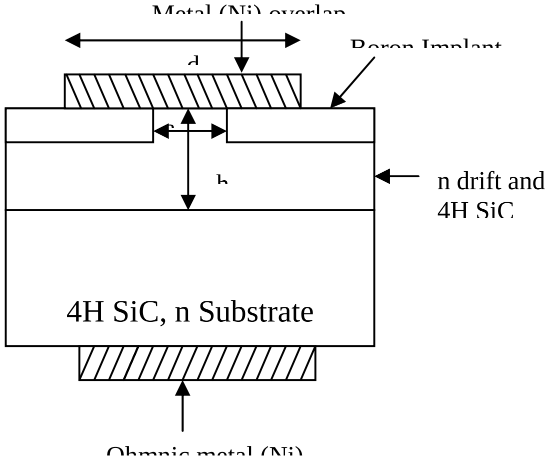


Figure 1

The device is made using an n-type 4H SiC substrate on top of which an n-type epilayer is grown. The thickness of the epilayer is ‘h’ and boron implant from the top of the epilayer is made with a gap in the centre over which a metal contact with finite diameter ‘d’ is made. The diameter of the Schottky contact is ‘a’.

The (V-I) equation of the Schottky diode using thermionic emission theory is given by[5]. This can be quoted as:

$$J_F = J_S \left[\exp\left(\frac{qV_D}{\eta KT} \right) - 1 \right], \qquad (1)$$

Where

$$J_S = A^* T^2 \exp\left(-\frac{q\phi_B}{\eta KT} \right), \qquad (2)$$

Where V_D is the voltage drop on the ideal diode i.e. at the Schottky contact, K is the Boltzman’s constant (CV/K), q is the electronic charge in Coulombs, A^* is the effective Richardson’s constant in $\left[\frac{A}{cm^2} K^2 \right]$ and ϕ_B is the Schottky barrier height in volts. The schottky barrier diode is shown in figure 1.

It has the series resistance, namely the specific on resistance R_{on-sp}

R_{on-sp} may be approximated at low and medium current levels to the resistance of the drift layer of thickness ‘h’. The basic current voltage equation for such a diode has been derived by Baliga[9] and Bhatnagar et. al.[10]. The forward drop V_F of the diode can be expressed as

$$V_F = V_D + J_F R_{on-sp} \qquad (3)$$

Combining with equation (3) with (1) and (2) above,

$$V_F = \frac{\eta KT}{q} \ln\left(\frac{J_F}{A^* T^2} \right) + \phi_B + J_F R_{on-sp} \quad (4)$$

The specific on-resistance of the device can be expressed as

$$R_{on-sp} = \rho_D \frac{L_G}{\tan\alpha} \ln\left[1 + \frac{2h}{a} \tan\alpha \right] \qquad (5)$$

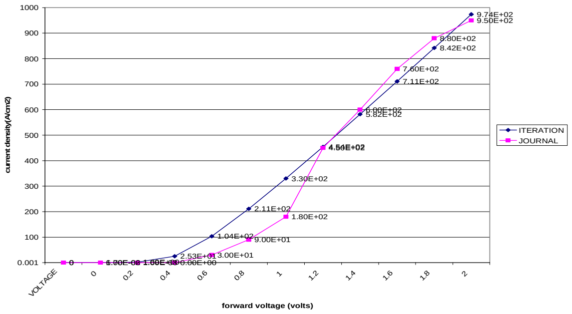
Where $\alpha = 26°$.

The equation (4) can be rewritten as

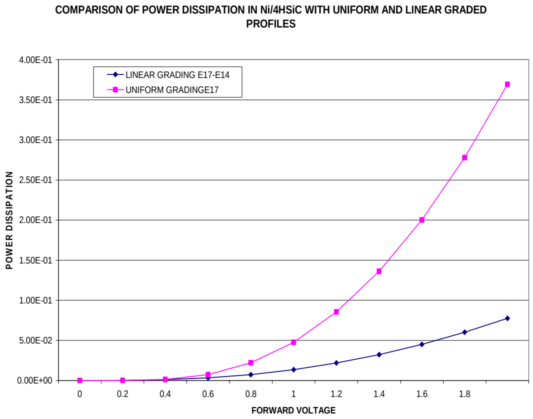
$$-\frac{\eta KT}{q} \ln\left(\frac{J_F}{A^* T^2} \right) = -V_F + \phi_B + J_F R_{on-sp} (6)$$

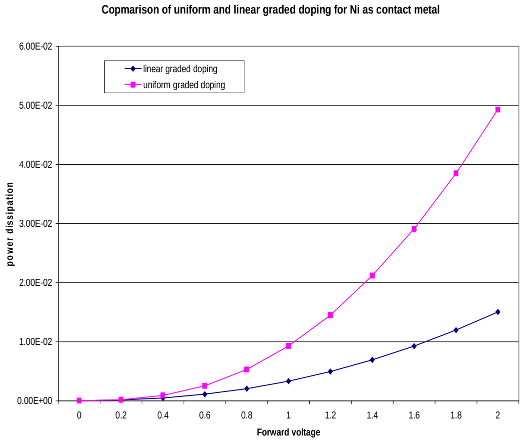
Results and Discussions:

The results of the C++ program for the Nickle contact metal are shown in figure & is seen to tally well with experimental results of Nickel by Saxena and Steckl[5]. The effective Richardson’s coefficient A^* was taken to the 146A/cm^2/K^2 for both theory and experimentation.



Thus it is possible to plot V-Jf characteristics and further we can compare the power dissipation in Ni/4H-SiC with different doping profiles i.e uniform doping and linear graded doping as shown below


COMPARISON OF POWER DISSIPATION IN Ni/4HSiC WITH UNIFORM AND LINEAR GRADED PROFILES


Copmarison of uniform and linear graded doping for Ni as contact metal

From the graphs it is clear that if one goes for Linear graded doping profile instead of uniform doping for 4H/SiC Schottky barrier diode the power dissipation can further be reduced.

CONCLUSION

The present work was undertaken with the aim to find power consumption in 4H/SiC & to prove that power dissipation can be reduced if we go for linear grading profile instead of uniform doping of the devices like the 4H-SiC schottky barrier diode and utilize it to generate such characteristics.

References

[1] H.A. Bethe, “Theory of the boundary layer of crystal rectifiers”, MIT Road Lab, Rep. 43-12 (1942).

[2] W.Schottky, Halblitertheoric der speerschicht”, Naturevissenschapter, 26, 843(1938).

[3] C.R. Crowell and S.M.Sze, “Current Transport in Metal-Semiconductor Barriers”, Solid State Electron, 9, 1035 (1966).

[4] C.Y. Chang and S.M. Sze, “Carrier Transport across metal semiconductor barriers”, Solid State Electron, 13, 727 (1970).

[5] V.K. Saxena, Jian NongSu and Andrew J. Steckl, “IEEE Transaction on Electron Devices”, 46(3), 456 (1999).

[6] Marinsz Sochacki, Jan Szmidt, Aleksander Werloowy and Mjetek Bokowski, “Current voltage characteristics of 4H-SiC diodes with nickel contacts”, Journal of Wideband gap materials, 9(4), 307(2002).

[7] Akira Itoh, Tsunenoleu Kimoto and Hiroyuki Matsunami, “IEEE Electronic Device Letter”, 17(3), 139(1996).

[8] Akira Itoh, Tsunenoleu Kimoto and Hiroyuki Matsunami, “IEEE Electronic Device Letter”, 16(6), 280(1995).

[9] B.J. Baliga, “Modern Power Devices, Chapter 4, Newyork, Wiley”, 1997.

[10] M. Bhatnagar, P.K. McLarty and B.J. Baliga, “IEEE Electronic Device Letters”, 13(10), 501(1992).