ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 9, March 2013

Design of High Breakdown Voltage and Power Dissipation of 6H –SIC DIMOSFET using with Gaussian Profile in the Drift Region

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***Abstract*-In this paper novel approach for designing of high Breakdown voltage and power dissipation of 6H-SiC DIMOSFET using Gaussian profile has been presented. All calculation and graphs for power dissipation, on resistance and drain to source voltage at different level of doping for different values of current density have been observed using analytical method).**

***IndexTerms*- DIMOSFET, Power Dissipation,On Resistance, Drain to source Voltage,Current Density,Doping.**

I. INTRODUCTION

Silicon Carbide semiconductor has gained momentum in recent years. There has been various factor contributing to its increasing development and it is being viewed with keen interest because of its high thermal stability, high energy band gap, high break down voltage and lower specific on resistances.

The above properties of silicon carbide have caused its application in high power high voltage switching, high temperature electronics and high power microwave applications. The Silicon Carbide region called the P well that is adjacent to the gate oxide film created by heat treatment at temperature above 1600 C following doping with aluminum ions. During this process Si evaporates from Silicon Carbide surface which is smooth before treatment and the surface becomes rough and irregularities grow in size. The electron flowing on the surface collides with these irregularities and are scattered. The channel mobility becomes smaller and the overall resistance increases

It is fabricated using the process of diffusion using silicon as substrate. The p base and N drift region gives the forward blocking capability. The P base and N+ source regions are formed by ion implantation. The specific on resistance is sum of substrate, accumulation layer channel resistance and drift resistance. The drift region using Gaussian profile shows that with increase in energy and dose of implanted phosphorous ions results in an increase in projected range, longitudinal straggle and effective doping.

The silicon carbide semiconductors that are used in PCs Are adequate for controlling large amount of power but are widely used in products such as diode rectifiers and inverter controllers despite inadequacy, if silicon carbide semiconductors are used then it would be possible to control more electrical power with smaller power loss. The silicon carbide power MOSFET, a switching device that has a small resistance in operating mode and fast switching speed. The applicable criteria that follow.

II. GAUSSIAN DOPING PROFILE IN DIMOSFET

In this section the basic device equations and a derivation to evaluate effective carrier concentration of Gaussian profile are given .Considering the depletion region between the p –base and n drift region as one dimensional abrupt p-n junction.

A. Basic Equation Used In To Evaluate Effective Carrier Concentration of Gaussian Profile

The width of depletion region is given by

- . $W_d=\{2\varepsilon_s V_{DS}\}^{1/2}/\{qN_B\}^{1/2}$. (1)

Where q is electronic charge
N_B is drift region doping
V_{DS} is drain to source voltage

The total resistance is given sum of resistances

- $R_{onsp} = R_{n+} + R_c + R_A + R_J + R_D + R_{S\,(2)}$ (2)

R_{n+} is the contribution from the N+ source region,

R_c is the channel resistance,

R_A is the accumulation layer resistance,

R_J is the resistance of the JFET pinch off region,

R_D is the drift region resistance and,

R_S is the substrate resistance

Power dissipation is given by

- $P_D=1/2(j_{on}{}^2R_{on\text{-}sp}+J_LV_B)$ (3)

Where j_{on} is on state current density
J_L is reverse saturation current
V_{B} is breakdown voltage

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Theoretical Analysis

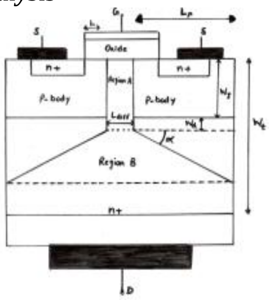

Fig 1 Basic Structure of Dimosfet

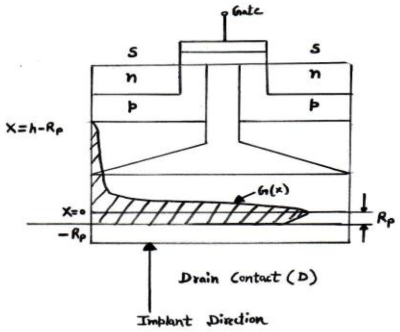

Fig 2 The Effective Carrier Concentration (Neff) of a Gaussian profile in the drift region

Calculation of the drop across channel regions which gives the total voltage from source to drain IDS $=I_{ch}$,that is about 15% of V_{DS} .The magnitude of Ich is given by

$I_{CH}=W\mu_{eff}\ V_{CH}\ [C_{OX}(2V_{GS}-V_{CH})]\ /2L[1+(\mu_{eff}/2v_{sat}L)]$ (4)

Where

L =5µm

h =65µm

a =15µm

W =300µm $=300\text{x}10^{-4}$cm

A =w x length=(300x15) $\mu m^2=4500\text{x}10^{-8}cm^2$

$Cox=8.59\text{x}10^{-8}\ F/cm^2$

$V_G=40V$

$V_D=$ (5 to 40) V

Vch=15% of V_{DS}

$V_T=1V$

Wt=40x10-^{4}cm

Wj=10x10-^{4}cm

Lp=25x10-^{4}cm

α =25°

For $N_B=10^{15}$, µo =530 cm^2/V.sec

For $N_B=10^{16}$,µo =500 cm^2/V.sec

For $N_B=10^{17}$,µo =280 cm^2/V.sec

Effective impurity concentration in the drift region is given by

$Neff = N_d/\ A_{oh}$ (5)

Gaussian profile that is generated is shown as the function G(x) in the drift region and is expressed as:

G(x) =(S/ (2Π)1/2σp)exp[-(x-Rp)2/2σp2] (6)

Where S is the ion dose per unit area and σp is the longitudinal or projected straggle. Consider an element dx at a distance x from the origin with cross-sectional area Aoequal to the area of the drift region. This gives the total impurity content in the element dx as AoG(x)dx from –Rp to h-Rp(Reference [2])

Calculation & related Graph

The drift region of the 6H-SiC DIMOSFET using a Gaussian profile shows that with increase in energy and dose of implanted Phosphorous ions results in an increase in the projected range, longitudinal straggle and the effective doping(N_{eff}). This is shown in Table 4.1.it is also seen that the effective doping level of the drift region using a Gaussian profile can be easily raised to 10^{16} atoms/cc or above the effective mobility(μ_{eff}) of carriers in the channel region is field dependent and depends both on the doping level of the p-body taken to be equal to Neff or NB of the drift region When operating the device, the p-base region is connected to the source metal by a break in the N+ source region and a fixed potential is given to the p-base region. The gate and source are short circuited and a positive bias is applied to the drain. The p-base and N-drift region form a reverse biased p-n junction and this junction supports the drain voltage across the junction depletion region. Since the p-region is more heavily doped than the N-drift region, the depletion region is wider in the drift region than the p-base region. Then for a positive bias applied to the gate, an inversion channel is generated on top of p-region which allows an electron current to flow from N+ source. At the edge of the p-base region and N-drift region near the surface and beneath the gate an accumulation layer is forward. This provides a second conducting path for the electron current which then enters the N-drift region and eventually flows to the drain. Between the accumulation and drift regions there exists an in-built n-channel JFET which has its own channel resistance. If we write down the total resistance or basically the specific on resistance of the device (or resistance area product) $R_{on\text{-}sp}$,(Reference[3])

Energy	Dose	Projected Range	Longitudnal Straggle	N(eff)/cc
K eV	cm-2	Rp(µm)	σp(µm)	
50	3.4x 10^{14}	0.059	0.027	5.2 x10^{16}
100	6.0x10^{14}	0.097	0.039	9.3 x10^{16}
250	1.2 x 10^{15}	0.249	0.073	1.9 x10^{17}
500	1.8 x 10^{15}	0.47	0.109	3.9 x10^{17}
750	2.2 x 10^{15}	0.616	0.119	3.4 x10^{17}
1.0Mev	2.4 x 10^{15}	0.764	0.131	3.7 x10^{17}
2Mev	2.8 x 10^{15}	1.28	0.157	4.3x10^{17}
3Mev	3.0 x 10^{15}	1.67	0.163	4.6 x10^{17}
4Mev	3.2 x 10^{15}	2.00	0.168	4.9x10^{17}

Table 1

ISSN: 2277-3754
ISO 9001:2008 Certified
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Volume 2, Issue 9, March 2013

EC(V/CM)	V_{DS}=5	V_{DS}=15	V_{DS}=25	V_{DS}=35
Electric field x10[6]	$V_{B(VOLTS)}$	$V_{B(VOLTS)}$	$V_{B(VOLTS)}$	$V_{B(VOLTS)}$
(N_{eff}=5 x10[16]) E_C=3	48.48	83.98	108.42	128.28
(N_{eff}=9.2 x10[16]) E_C=3.3	39.63	68.64	88.62	104.85
(N_{eff}=1.85.2 x10[16]) E_C=3.6	30.32	52.52	67.8	80.22
(N_{eff}=3.85.2x 10[16]) E_C=3.9	23.04	39.89	51.51	60.95
(N_{eff}=3.39 x10[16]) E_C=3.8	23.31	42.09	54.36	64.33

Table 2. Breakdown Voltage Vs Effective Doping at Gaussian distribution

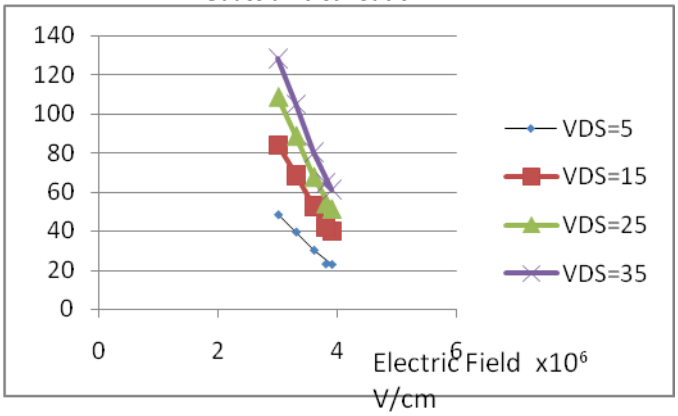

Fig 3. Plot of B/D voltage vs Electric field at Different Effective Doping

V_{DS}	N_{eff}=5 .2x10[1 6]/CC	N_{eff}=9.2 x10[16]/CC	N_{eff}=18. 5x10[17]/CC	N_{eff}=38.5x .5x10[17]/CC	N_{eff}=33.9x .5x10[17]/CC
$V_{DS(Volts)}$	$P_{D(mw)}$	$P_{D(mw)}$	$P_{D(mw)}$	$P_{D(mw)}$	$P_{D(mw)}$
5	19.13	3.19	3.48	1.67	1.9
15	104.81	2016	21.85	10.55	11.98
25	201.44	42.42	45.75	22.06	25.11
35	296.66	65.87	70.76	34.3	38.87

Table 3. Power Dissipation at different values of Neffective levels (Neff/cc) for different V_{DS} (Volts) level at Gaussian distribution

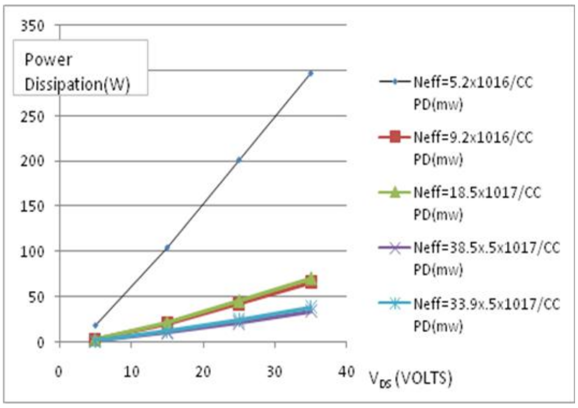

Fig 4.Plot of Power Dissipation (w) at different values of Doping for different V_{DS}(volts) levels of Gaussian distribution

III. RESULT

The magnitude of effective doping depends upon the ion doze and ion energy and will be affected in magnitude of Projected Range (Rp) and Longitudinal Straggle (σp).As effective doping increase the power dissipation decrease an breakdown voltage increases. This makes Silicon Carbide best suited for power devices applications. Drain current and power dissipation analysis has been made for various values of $V_{DS<}$ 40 and V_{GS} <40.

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