Application of Low Specific on Resistance and High Thermal Stability 6H –SIC DIMOSFET using with Uniform Distribution in the Drift Region

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Abstract- Silicon carbide(SiC) has lowest specific on resistance and high thermal stability as compared to silicon. This has made use of Silicon carbide in design of domestic electrical appliances to assist in energy saving. Silicon carbide power devices can operate at much higher junction temperature than those made of silicon. However, this does not mean that SiC devices can operate without a good cooling system

Index Terms- Silicon carbide, Power electronics, High temperature techniques

I. INTRODUCTION

While SiC's smaller on-resistance and faster switching helps minimize energy loss and heat generation, SiC's higher thermal conductivity enables more efficient removal of waste heat energy from the active device. Because heat energy radiation efficiency increases greatly with increasing temperature difference between the device and the cooling ambient, SiC's ability to operate at high junction temperatures permits much more efficient cooling to take place, so that heat sinks and other device-cooling hardware (i.e., fan cooling, liquid cooling, air conditioning, heat radiators, etc.) typically needed to keep high-power devices from overheating can be made much smaller or even eliminated. While the preceding discussion focused on high-power switching for power conversion, many of the same arguments can be applied to devices used to generate and amplify RF signals used in radar and communications applications. In particular, the high breakdown voltage and high thermal conductivity coupled with high carrier saturation velocity allow SiC microwave devices to handle much higher power densities than their silicon or GaAs RF counterparts, despite SiC's disadvantage in low-field carrier Uncooled operation of high-temperature and high-power SiC electronics would enable revolutionary improvements to aerospace systems. Replacement of hydraulic controls and auxiliary power units with distributed "smart" electromechanical controls capable of harsh ambient operation will enable substantial jet-aircraft weight savings, reduced maintenance, reduced pollution, higher fuel efficiency, and increased operational reliability. Performance gains from SiC electronics could enable the public power grid to provide increased consumer electricity demand without building additional generation plants, and improve power quality and operational reliability through "smart" power management.

More efficient electric motor drives enabled by SiC will also benefit industrial production systems as well as transportation systems such as diesel-electric railroad locomotives, electric mass-transit systems, nuclear-powered ships, and electric automobiles and buses.

Applications of high-temperature power devices include aircraft, space, oil and gas exploration [3], where power systems are expected to operate in an elevated ambient temperature. These devices are also interesting in milder environments, because they should require less cooling. This latter approach is described in [4]: using a power module designed for 250°Cin a 150°C environment allows for the use of a much smaller heatsink. Si-based devices indeed offer less headroom between the ambient and maximum junction temperatures, requiring very efficient cooling. This is of great importance, as the thermal management system is one of the bulkiest and heaviest parts of a converter.

II. UNIFORM DOPING PROFILE IN DIMOSFET

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

III. BASIC EQUATION USED IN TO EVALUATE SPECIFIC ON RESISTANCE OF UNIFORM DISTRIBUTION OF DRIFT LAYER

The width of depletion region is given by

- $R_{on\text{-}sp} = 1/ [\mu_{eff} q N_B (Wt-Wj-Wd-L_p \tan ά)$ (1)
- where
- Wt=40x10-4cm
- Wj=10x10-4cm
- Lp=25x10-4cm
- $\alpha = 25°$
- N_B is drift region doping
- μ_{eff} is effective mobility

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 pinchoff 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
$V_{B\text{ is}}$ breakdown voltage

Theoretical Analysis

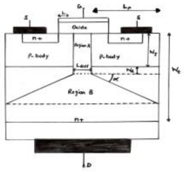


Figure 1 basic structure of dimosfet

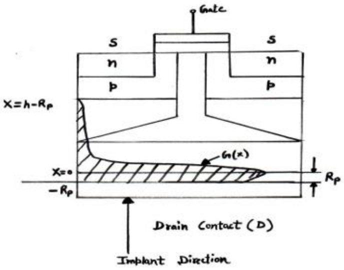


Figure 2 The Effective Carrier Concentration (Neff) of a Gaussian profile in the drift region

B Maximum Operating Temperature of Power Devices

Silicon Carbide remains solid up to 2730°C. However, the actual maximum operating temperature of a SiC device is One of the limits is the Semiconductor Thermal Runaway (STR) Above a certain temperature, the intrinsic carrier density becomes higher than the maximum doping level sustaining a given voltage. So at the STR, the material is no longer able to block its rated voltage. The device becomes more and more conductive as the temperature increases, and the temperature increases as more current flows through the device (runaway phenomenon). It can be seen from figure 1 that a 1200 V (4H-SiC) device has a maximum operating temperature of around 1500 K (1230°C). A device of with the capacity to capacity to carry currents of 10A level was created. The Silicon semiconductor was inadequate for handling large amount of power, but are widely used in products such as diode rectifiers and invertors controllers inspite of inadequacy.

TABLE I
TEMPERATURE LIMITS FOR VARIOUS ELEMENTS OF A SIC DIE.

	material	max. temp.	cause
Semiconductor	SiC	2730°C	sublimation
Schottky metal	Ti	1668°C	melting point
Top metallization	Al	660°C	melting point
secondary passivation	polyimide	500-620°C	decomposition
contact anneal. [8]	Ti/Ni	350-500°C	solid state reaction

Ref[4]

As stated by the first law of thermodynamics, the variation of the internal energy in the device (U) is

$$\frac{dU}{dt}=P-Q \quad (3)$$

Where P is the electrical power dissipated in the device and Q is the heat flux removed from the device. At the electrical steady state, in conduction mode, I _V , with V , the voltage across the device being a function of I and Tj , the junction temperature. I is the current flowing through the device . Therefore, P is itself a function of I and Tj only:

$$\frac{dU}{dt}=P(T_{j0})+\frac{\partial P}{\partial T_j}\varepsilon-\frac{T_{j0}-T_A}{R_{Th}}-\frac{\varepsilon}{R_{Th}} \quad (4)$$

In figure 3, this corresponds to the intersects between thedevice (dashes) and cooling (plain) characteristics. This figure represents the power P(Tj) dissipated by an imaginary device (at a constant current) depending on its junction temperature, and the cooling capability

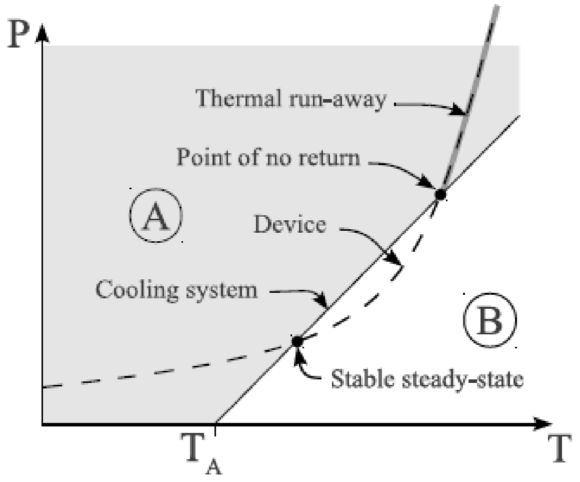


Figure 3 Conditions of thermal equilibrium: when the device is in region it tends to heat up (because its power dissipation is higher than the cooling capabilities). When in region B, it tends to cool down

IV. CALCULATION & RELATED GRAPH

The blocking voltage is supported across the drift layers and serves as minimum possible theoretical limit for the on resistance of power MOSFET. Finally, it must be noted that in this study, the thermal conductivity of SiC was considered constant. This is a coarse approximation, as this conductivity (hence the cooling performance) tends to decrease dramatically as the temperature rises

Values of Power Dissipation at different values of Breakdown Voltages(volts) for different Doping levels(N_B) level at Uniform Distribution					
$N_B=10^{15}$	$N_B=10^{15}$	$N_B=10^{16}$	$N_B=10^{16}$	$N_B=10^{17}$	$N_B=10^{17}$
$V_{B(VOLTS)}$	P_D(w)	$V_{B(VOLTS)}$	P_D(w)	$V_{B(VOLTS)}$	P_D(w)
208.5	0.92	89.09	0.097	38.11	0.0064
294.92	2.62	125.99	0.29	53.9	0.021
361.21	4.45	154.29	0.51	66.01	0.04
417.09	6.29	178.17	0.76	76.23	0.061
466.32	7.98	199.21	0.99	85.23	0.083
510.82	9.57	218.22	1.22	93.36	0.1
551.76	10.97	235.71	1.45	100.84	0.12
589.86	12.27	251.97	1.66	107.8	0.15

Table 2.

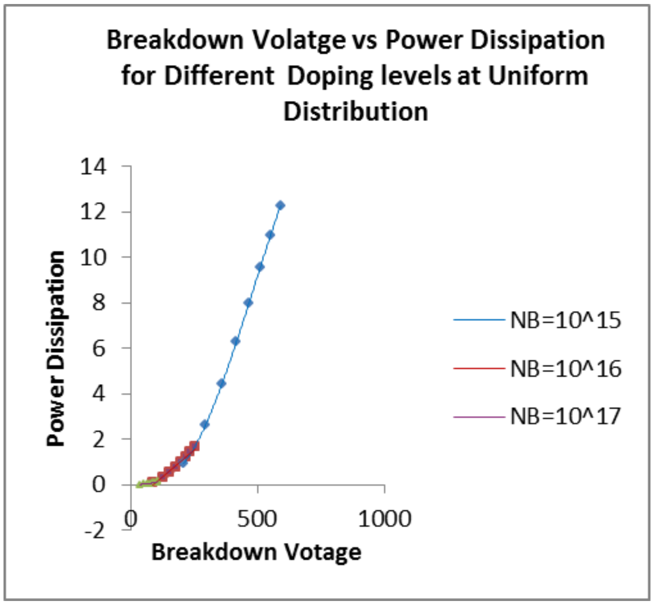


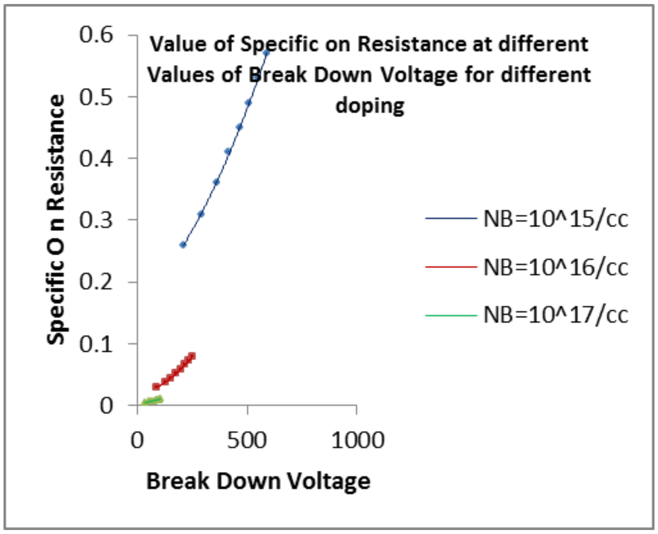
Figure4

Values of specific On-Resistance at different values of Breakdown voltages(volts) for different Doping levels(NB) of uniform Distribution					
$N_B=10^{15}$/CC	$N_B=10^{15}$/CC	$N_B=10^{16}$/CC	$N_B=10^{16}$/CC	$N_B=10^{17}$/CC	$N_B=10^{17}$/CC
$V_{B(VOLTS)}$	R_{ON-SP}X10^{-1}	$V_{B(VOLTS)}$	R_{ON-SP}X10^{-1}	$V_{B(VOLTS)}$	R_{ON-SP}X10^{-1}
208.5	0.26	89.09	0.03	38.11	0.0048

294.92	0.31	125.99	0.037	53.9	0.0056
361.21	0.36	154.29	0.044	66.01	0.0064
417.09	0.41	178.17	0.052	76.23	0.0072
466.32	0.45	199.21	0.059	85.23	0.008
510.82	0.49	218.21	0.066	93.36	0.0088
551.76	0.53	235	0.073	100.84	0.0096
589.86	0.57	251.97	0.079	107.8	0.0103

Table 3

$V_{DS(Volts)}$	$P_{D(mw)}$	$P_{D(mw)}$	$P_{D(mw)}$	$P_{D(mw)}$	$P_{D(mw)}$



V. RESULT

The increase in doping reduces power dissipation the shallower the doping more the power Dissipation The specific on resistance increase with decrease in doping.This is ideal for construction Power electronics device.

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