Noise Power Spectral Density Analysis for Silicon Carbide Substrate MESFET

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Abstract: This paper mainly concentrates on the transistors working functions, electrical characteristics and noise analysis at various operating voltages and temperatures. For this improvement authors are developed simulation methods for better results. The high frequency transistors are exposed with bunch of silicon carbide crystalline substances like 3C, 4H and 6H-SiC MESFETs. Because of the good researchers work, now a day's all are compared the parameter in between of cubic and hexagonal crystalline structure of silicon carbide MESFETs. Silicon carbide material is having wide band gap because of this reason it's useful for high energy and high frequency applications. The silicon carbide transistors are having large operating voltage in channel region because of this reason in channel region flows large current and also very less noise is produced. In wide band gap semiconductor transistors are produced very less noise compared to the various categories of substrates.

Keywords: MESFET, Silicon Carbide, Noise,etc.

I. INTRODUCTION

The Silicon carbide transistors are one of the most important components in analog and mixed signal IC design world; this is useful for both high frequency and low frequency applications. In wide band gap material is have large value of mobility with large drain current effects on gate voltage and vice versa and large intrinsic speed in transistor. The high cut-off frequency transistors are demand in microwave, military and radar applications.The gate to drain working operation is observed at the gate length and width is designed with 1000µm and 1µm [1]. Based on primary analysis to see the transistor minimum to maximum operating voltage characteristics and also simulated various models of Silicon Carbide MESFET drain region operating behaviour. Compare to silicon and GaAs materials SiC substrate MESFETS gives large efficiency and bandwidth [2][3]. The large energy width semiconductor materials are maintains for large carrier density states and large frequency usages [4]. The documentation is utilized for one of more polymorphic crystal structures of silicon carbide structures are depends upon the quality of the structures, one of the most commonly used structure is 3C-SiC and in here 3 represents character of being 3 bilayer periodic and C represents cubic symmetry. exactly In this same manner 4H-SiC and 6H-SiC structures are represents H represents symmetry of hexagonal and 4,6 represents character of being 4,6 bilayer periodic.

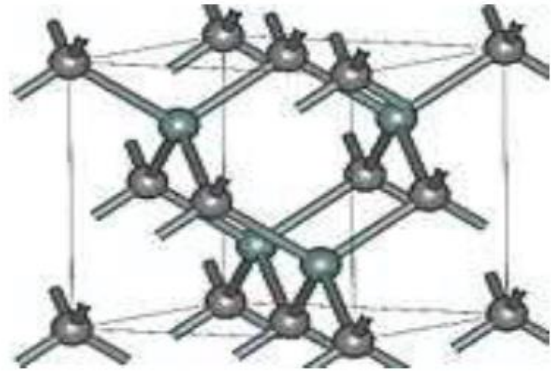The below shown structures are indicates the polytypic of silicon carbide [5].

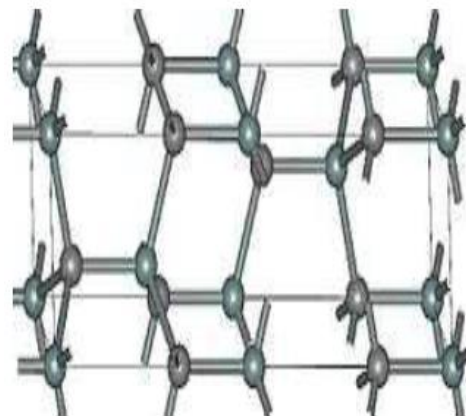**Fig.1. 3Dimentional periodic cell representation of 3C-SiC.**

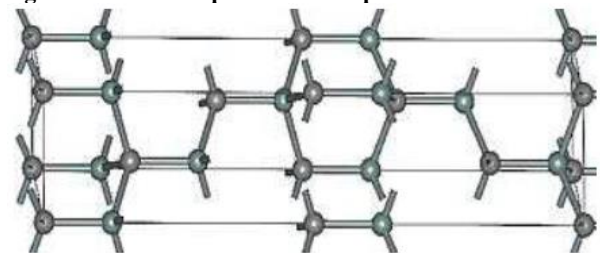**Fig.2. 3Dimentional periodic cell representation of 4H-SiC.**

Fig.3. 3Dimentional periodic cell representation of 6H-SiC.

In present situation silicon carbide material is most of the researchers are interest on to developed the high speed and large power application oriented components because of its very good material, compare to Si and GaAs, the silicon carbide material is having very good electrical and chemical properties[6].

The researchers are most commonly preferred silicon carbide substrate and it's have more usages and advantages, and also its have large energy width, large break down voltage and large conductivity [1]. The speed of the electron is more over other materials, minority carrier concentration life spam also more. In silicon carbide semiconductor material is having carrier bonding is too stable [3] when temperature is increases the temperature co efficient of silicon carbide is very less, because of this reason there is no phase distortion [5].

II. MESFET

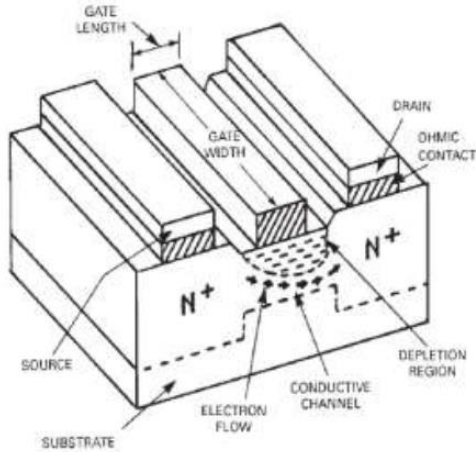The MESFET cross sectional representation fig.4. As shown in below.

Fig.4. cross sectional diagram of MESFET.

In here to analyse the simple noise density of Silicon carbide transistor, because of these drain carrier current hesitations is occurred. The drain carrier current hesitations are identified in between the regions of linear and saturation region due to the carrier concentration and assuming mobility is constant. Thickness of the channel reduces gradually from source to drain [8].

Drain characteristics:

Linear region:

Drain to source current (Ids) and drain to source voltage (Vds) both are dependent on linearity. The doping of the carriers are increased linearly in space channel region and also gradually increases the drain current [9].

$$Vds \leq Vgs - Vp \quad \text{...... (1)}$$

In saturation region the drain current is varies very less and drain voltage is varies high. When the channel region and doping concentrations are both are equal the drain current is operates constantly [9].

$$Vds \geq Vgs - Vp \quad \text{....... (2)}$$

Vp = pinch off voltage.

Noise:

The simple noise density is verified based on Hooge's equation and the fluctuation of the drain current is calculated using this equation [8].

The clamor level in the wide band gap materials are portrayed by this present Hooge's steady. The clamor spectra uncover the type of flicker noise [8].

III. RESULTS

The transistor devices output responses are observed and analysed the drain region operational result, transistor input

to output responses' and simple noise density at different frequencies. The transistor device operating and constant values are given below table 1 and these values are used for device response calculations [10].

TABLE 1: TRANSISTOR STANDARD VALUES

Parameter with symbol	Different Parameter values for the polymorphs of SiC		
	Value with unit 3C-SiC	*Value with unit 4H-SiC*	*Value with unit 6H-SiC*
Mobility (μ_n)	800×10^{-4} m²/V-s	600×10^{-4} m²/V-s	420×10^{-4} m²/V-s
Band-gap energy(E_g)	2.36eV	3.23eV	3.0eV
N_c	1.5×10^{17}/m³	1.7×10^{17}/m³	6.89×10^{17}/m³
N_v	1.2×10^{17}/m³	2.5×10^{17}/m³	2.5×10^{17}/m³
Hooge's Parameter (α_H)	0.33	0.1027	0.0529
Relative Permittivity(ε_r)	9.72	9.7	9.66
Drift Saturation velocity of electrons (v_{sat})	1.3×10^5m/s	8×10^4m/s	2×10^5m/s

Already discussed the operation of the transistor models like 4H,6H and 3C silicon carbide MESFETs in equations 1 & 2. The transistor drain region responses are plotted in fig.5,6 and 7. These analysis is taken at small frequencies because of the trap capacitance effect is not taken in to the response of the result.
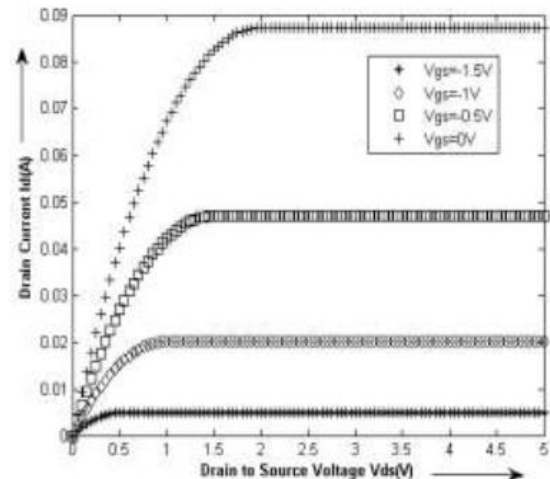

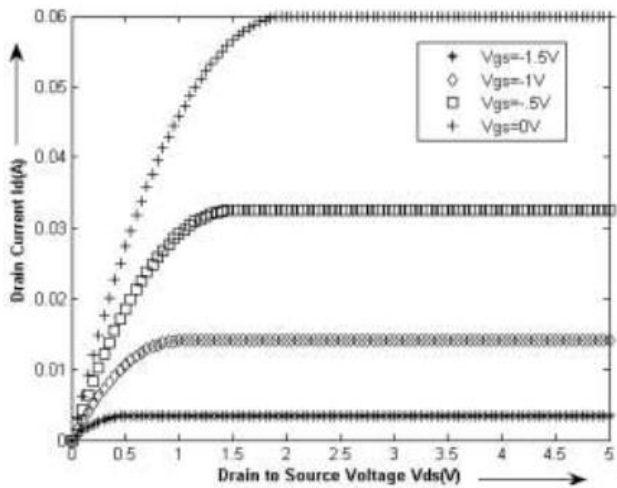**Fig.5. Ids Vs Vds simulation response of 3C-SiC MESFET.**

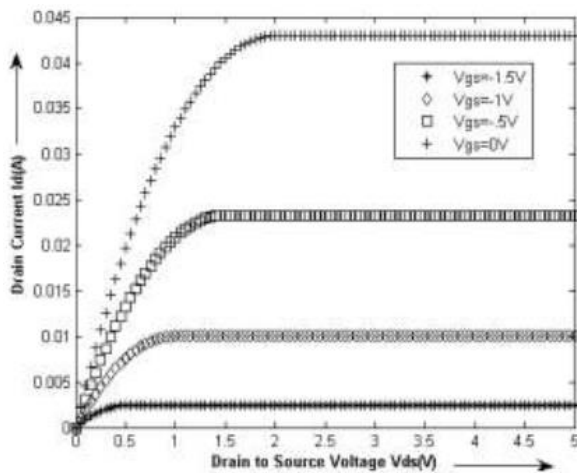**Fig.6. Ids Vs Vds simulation response of 4H-SiC MESFET**

Fig.7. Ids vs Vds simulation response of 6H-SiC MESFET.

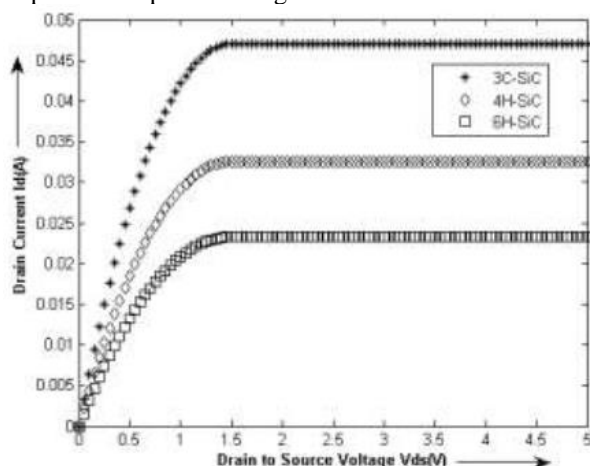All the silicon carbide models of the transistors drain region responses are plotted in figure.8.

Fig.8. comparative analysis on different silicon carbide MESFETs.

The silicon carbide drain current plots are almost comparable nature true to form. The large current conveying ability to have WGB semiconductors for that reason this materials implemented in the examination. The 3C silicon carbide transistor provides large currents compare to the remaining silicon carbide transistors.

In this relative investigation of different silicon carbide transistor exchange attributes are appeared in fig.9 utilizing various substrate material equations (3). The various models of the silicon carbide transistor substrates are having various drift saturation speeds using those values and used substrates referenced from table 1.
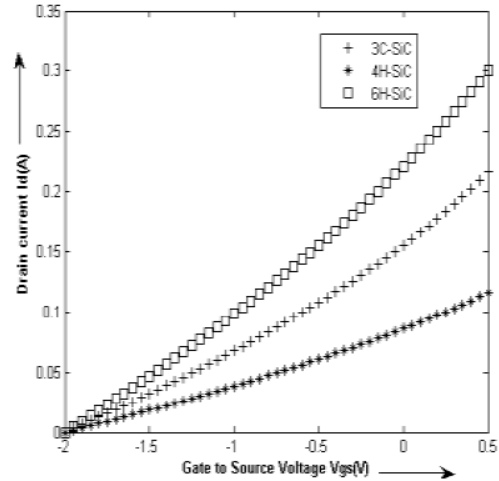

Fig.9. The silicon carbide semiconductors comparative analysis for transfer characteristics.

The different high speed semiconductor material transfer characteristics are plotted in fig.9. based on the various polytypes of the materials and in this analysis drain region current is improved gradually to all silicon carbide substrate materials with large drift velocity and mobility.

In fig.10 the simulation results are represents the simple power density on SiC transistor operating voltage from drain to source and vice versa and frequency and also fig.11 and fig.12 respectively. In here the operating voltage drain to source is varies from 0 to 5V and this same space charge region gate to source varies -1.5 to 0V. The noise response is plotted at small frequencies.
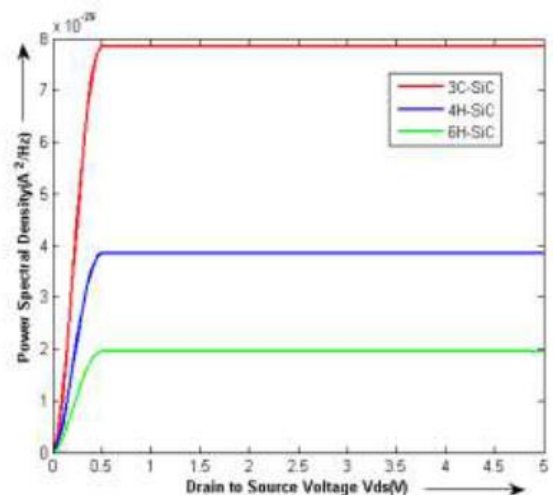

Fig.10. simple noise power density characteristics in different SiC materials.
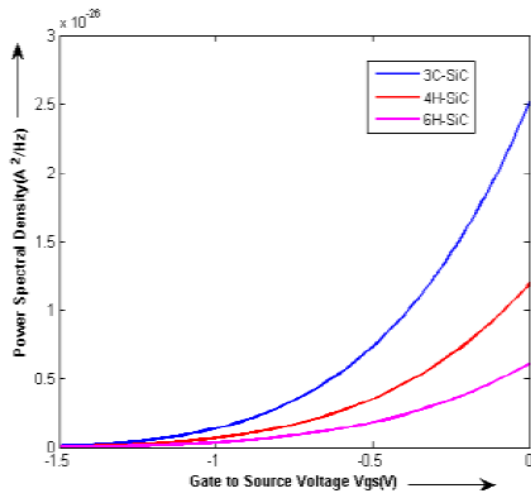
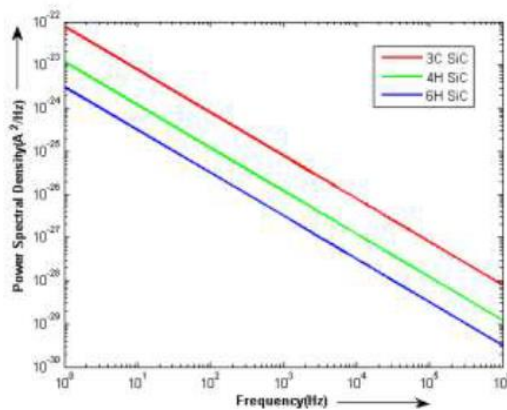**Fig.11. comparative analysis on noise power density with respect to Vgs .**

Fig.12. noise power density at operating voltages Vds= 5v and Vgs = -0.5V.

IV. CONCLUSION

The space charge region drain region simulation results represents when the carrier mobility is large in channel region conducts large drain current because of drain to gate operating voltage and vice versa. The silicon carbide transistors transfer characteristics are represents in saturation region the speed of the carrier concentration is more and drain region current is also large. Only the reason of large mobility and large carrier concentration in saturation region the models of the silicon carbide transistors are delivers large drain region current.

The noise density simulated results are observed and analysed, what the semiconductor materials are improves drain region currents same materials are generates large noise . the space charge region gate to source operating voltage is changes to positive the drain region charge carrier current improved and also noise power density improved. When the space charge region gate to source is operates at reverse operating voltages the power noise density of transistors material efficiency is good. The low frequency operating noise has critical effect on operating circuit execution. It happens fundamentally because of the doping impurities are dissipating of charge carriers [11]. One of the most important properties are having this silicon carbide semiconductor materials are 3C, 4H and 6H-SiC using this substrate of the material the transistor MESFET is very

better responses' are provided for high speed and high power applications. The substrate material Silicon Carbide 3C, in simulation results its gives very good performance because of this chemical, thermal and electronic qualities. The 3C-SiC photon concentration is very less when the mobility of the carriers are more [10],[12] because of these reasons the drain region current is produces more compare to the all models of the Silicon Carbide transistors. And also the noise power density simulation results give a good application part of response compare to other models.

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AUTHORS PROFILE

Boggadi Nagarjuna Reddy was born in September 17 1988, in Kadapa. His technical journey started with Diploma in Electronics at 2003. His taken under graduate 2010 on electronics and communication engineering in JNTUniversity, Anatapur. The master degree completed 2013 on VLSI in Sathyabama university, Chennai. Currently his a Ph.D scholar and work with high speed and frequency SiC devices and integrated circuits, at Bharath Institute of Higher Education and Research, Chennai.