Drain Characteristic Analysis of High Electron Mobility Transistors (MOSHEMT)

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Abstract*: A High-electron-mobility transistor, otherwise called a field-effect transistor consolidating an intersection between two materials with various band holes as the channel rather than a doped region. While lately, gallium nitride HEMTs have pulled in consideration because of their powerful execution. In this paper a MOSHEMT device is designed and afterward break down the device DC characteristic. MOSHEMT is a modified structure of HEMT. In MOSHEMT an oxide layer (Hf02) is embedded to the device. Characteristic dissect of device include the breaking down of channel current, gate leakage current and furthermore the Ioff/Ion proportion of the device. HEMT transistors can work at higher frequencies.

Index Terms*: HEMT, MOSHEMT, 2 DEG region, Gallium arsenide, Gallium nitride, oxide layer (HfO2)

I. INTRODUCTION

Transistors are mainly used as switch. It is made out of semiconductor material more often than not with somewhere around 3. A voltage given to the transistors can be controlled by other couple of transistor terminals. Today, a few transistors are showing exclusively, yet a lot more are revealed installed in coordinated circuits. Most transistors are produced using extremely unadulterated silicon or germanium, yet certain other semiconductor materials can likewise be utilized. A transistor may have just a single sort of charge transporter, in a field effect transistor, or may have two sorts of charge bearers in bipolar intersection transistor device. Contrasted and the vacuum tube, transistors are commonly littler, and require less capacity to work. Certain vacuum tubes have points of interest over transistors at high working frequencies or high working voltages. Numerous sorts of transistors are made to institutionalized details by different makers. In January 26, 1954, Morris Tanenbaum discovered the principal working of silicon transistor at bells lab. silicon transistor was created in 1954 by Texas Instruments. This was formed by Gordon Teal, a specialist in developing precious stones of high voltage, who had recently worked at Bell Labs. In 1960 at Bell Labs the first MOSFET was fabricated by Kahng and Atalla.

II. HISTORY OF HEMT

It has been located over a long time since the high electron mobility transistor (HEMT) was first proposed in 1979 [1]. The key knowledge of the HEMT is the field-impact balance of the high-mobility two-dimensional electron gas (2DEG) at the heterostructure [2]. HEMT structure was a outcome of an exploration with various purposes and there were a few components superimposed. The late 70s saw the growth of the atomic shaft epitaxy progress system and regulation doping together with a striking enthusiasm for the conduct of quantum well structures [3].

Around then T. Mimura and his partners at Fujitsu were taking a shot at GaAs MESFETs. Confronting issues with a high-thickness of the surface states close to the interface, they chose to utilize a regulation doped heterojunction superlattice and could deliver exhaustion type MOSFETs [4]. While those structures were still tormented by a few issues, the plan to control the electrons in the superlattice jumped out at him. He accomplished this by presenting a Schottky contact over a heterojunction. In this method, the AlGaAs/GaAs HEMT was designed. In this manner the primary HEMT based coordinated circuit was accounted. Close by Fujitsu a few other research offices joined on the further improvement of the new structures: Bell Labs, Thomson CSF, Honeywell, IBM [5]. So as to counter extraordinary issues, a few structures were proposed: AlGaAs/GaAs HEMTs, AlGaAs/InGaAs pseudomorphic-HEMTs(pHEMTs) AlInAs /InGaAs/InHEMTs(pHEMTs)AlInAs/InGaAs/InP-HEMTs.
P HEMTs. In any case, until the decade's end HEMTs for the most part discovered military and space applications [6]. Just during the 90s the innovation entered the shopper advertise in satellite and rising cell phone frameworks.

In the start of the most recent decade new strategies for affidavit of GaN on sapphire by MOCVD were created. In this method, the creation of AlGaN/GaN-based HEMTs was conceivable [7]. GaN has a wide band hole which brings the benefits of higher breakdown voltages and higher operational temperature. Since the extensive grid confound among AlN and GaN a strain in the AlGaN layer is initiated, which produces a piezoelectric field. Together with the extensive conduction band counterbalance and the unconstrained polarization this prompts extremely high qualities for the electron sheet charge thickness [8]. This extensive capability of AlGaN/GaN structures (and the roundabout favorable position of brilliant warm conductivity of the sapphire substrates) was acknowledged very soon and the examination concentrate halfway moved from AlGaAs/GaAs to AlGaN/GaN devices.All through further improvement and streamlining distinctive techniques were introduced. A technique as of late used in high-voltage p-n convergences [9] This method was furthermore refined to T-shaped and along these lines Y-framed entryway terminals. Another movement in upgrade of the structure is the development of a slim AlN prevention between the GaN channel and the AlGaN layer. It grows the conduction band balance and the two-dimensional electron gas (2DEG) thickness and

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decreases the blend issue scattering, as such extending the flexibility [10]. An additional choice to overcome the electron gas transport properties is the twofold heterojunction structure. The InGaN layer under the channel shows a negative polarization charge at the interface, and along these lines improves the conveyor control in the channel.

III. STRUCTURE OF MOSHEMT AND MATERIAL PROPERTIES

The MOSHEMT device structure is represented in the below figure. The materials used are AlGaN/GaN [11]. MOSHEMT is built on the silicon carbide substrate. The HEMT is somewhat extraordinary to different sorts of FET. The electrons from the n-type area travel through the precious stone grid and many stay near the Hetero-intersection. These electrons in a layer that is just a single layer thick, framing as a two-dimensional electron gas. Inside this area, the electrons can move uninhibitedly, in light of the fact that there are no other contributor electrons or different things with which electrons will impact and the portability of the electrons in the gas is high. The predisposition voltage connected to the gate framed as a Schottky obstruction diode is utilized to tweak the quantity of electrons in the channel shaped from the 2 D electron gas and successively this controls the conductivity of the device. The width of the channel can be changed by the gate predisposition voltage.

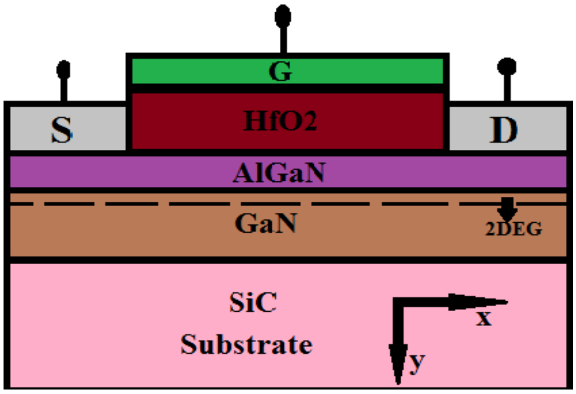

Fig 1: AlGaN/GaN MOSHEMT device with oxide layer (HfO2).

A.GALLIUM ARSENIDE:

Gallium arsenide (GaAs) is a composite of the components of gallium and arsenic.

PROPERTIES:

PROPERTY	Values at 300 k
Melting point (°C)	1240
Density (g/cm^3)	5.3176
Crystal structure	zinc blende
Refractive index^b	3.666
k (ohm^{-1}cm^{-1})	10^{-6} - 10^3
Band gap (eV)^c	1.424

Table 1: shows various properties of the gallium arsnide material

B. GALLIUM NITRIDE:

Since 1990s Gallium nitride (GaN) is generally utilized in light-discharging diodes because it is a parallel III/V direct bandgap semiconductor. At higher temperatures and higher voltages GaN is better than gallium arsenide (GaAs) transistors. GaN transistors are used for microwave frequency as power enhancer. For THz devices GaN shows better performance [12].

PROPERTIES:

PROPERTY	Values at 300 k
Melting point (°C)	1250
Density (g/cm^3)	ca. 6.1
Crystal structure	Würtzite
Refractive index^b	2.35
k (ohm^{-1}cm^{-1})	10^{-9} - 10^{-7}
Band gap (eV)^c	3.44

Table 2: shows various properties of the gallium nitride material.

IV. SIMULATION RESULT AND DISCUSSION

The AlGaN/GaN MOSHEMT device is created via TCAD tool and the structure is created via writing code in sprocess and then the structure is visualized by svisual. The structure is created in a step by step process. The steps include in the creation of this device are Declare initial grid, Gate oxidation, Extract tox, Polysilicon deposition, masking polysilicon, etching polysilicon, LDD implantation, Spacer formation, SD implantation, SD Annealing, Making SD contacts, Reflect, Save final structure.

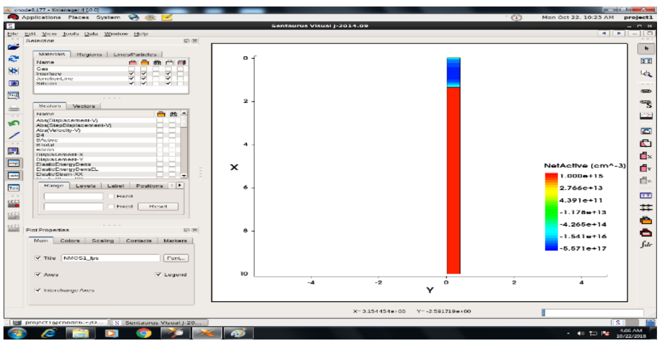

Fig 2: MOSHEMT structure is created by step by step process. In the first step the substrate is created and the declare all the initial grid values

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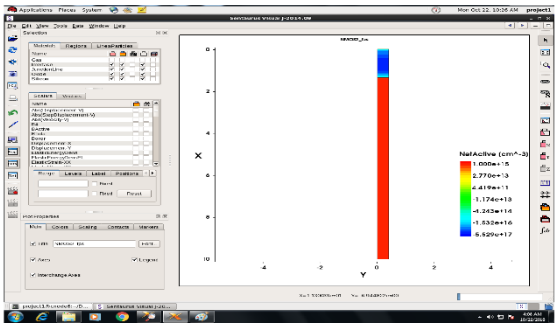

Fig 3: This figure demonstrates the inclusion of gate oxidation process. Gate oxide is generally a silicon di oxide material. This is to ensure that there is no leakage from gate to body.

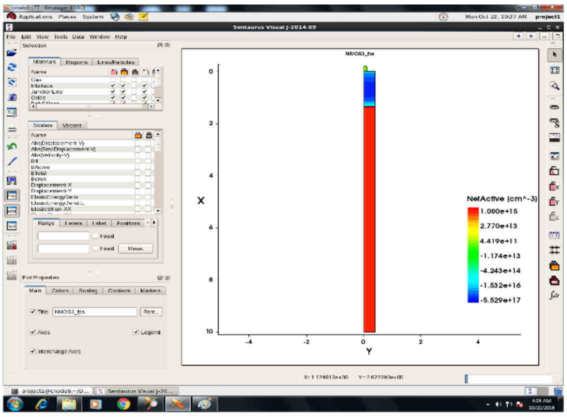

Fig 4: In 3rd step the oxide layer deposited is extracted and also above the oxide layer the polysilicon is deposited.

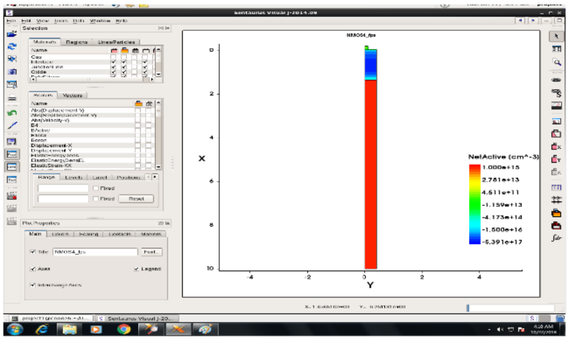

Fig 5: This step implies the removal of polysilicon material that is called etching process.

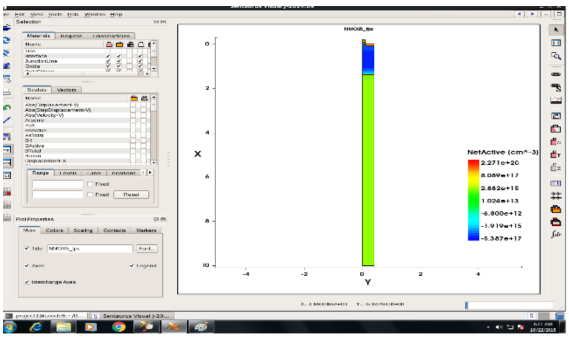

Fig 6: After the etching process, the LDD implantation is done.

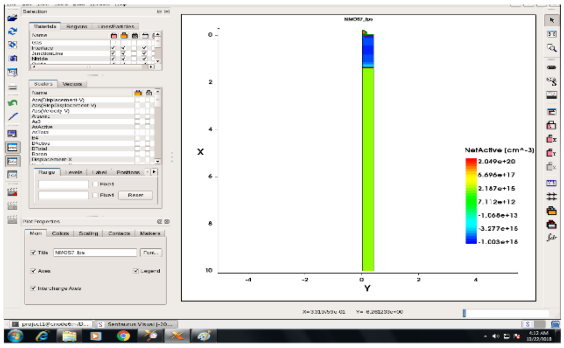

Fig 7: Then the gate, source and drain are formed and also nitride spacer formation is carried out.

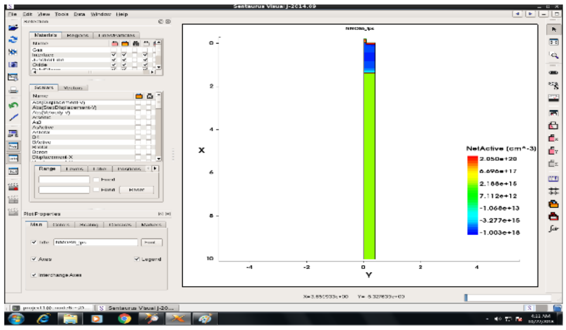

Fig 8: This figure implies the SD implantation. Here contacts are given between the source and drain region.

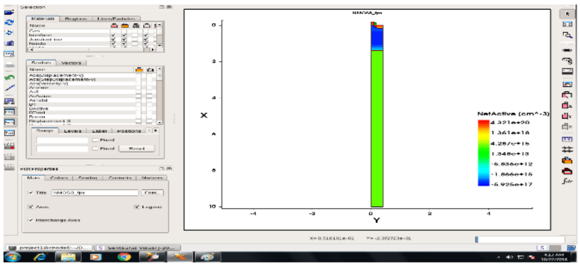

Fig 9: This is the final step where the structure is fully developed and we have to reflect the one side to the opposite side to get the full MOSHEMT structure.

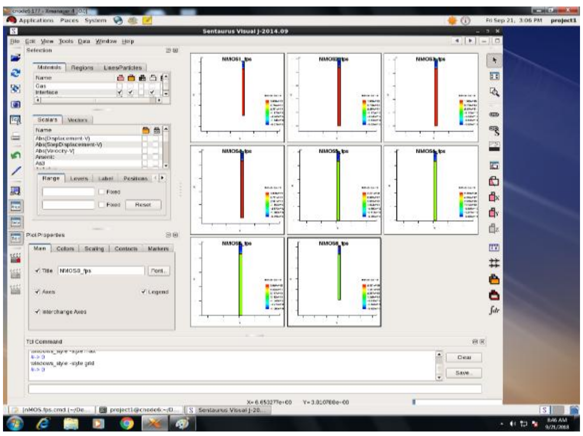

Fig 10: This figure shows the step by step creation of MOSHEMT device with the mentioned parameters.

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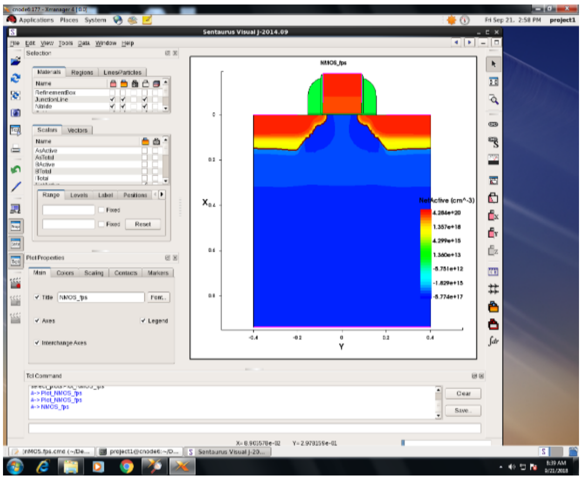

Fig 11: This image shows the complete MOSHEMT structure created using the TCAD tool. Both the source and drain regions are n-doped and the oxide layer material used is HfO2.

Hence for the created MOSHEMT device, we are analyzing the DC characteristic curves. In TCAD tool Sdevice is used to for analyzing the characteristic of the device.

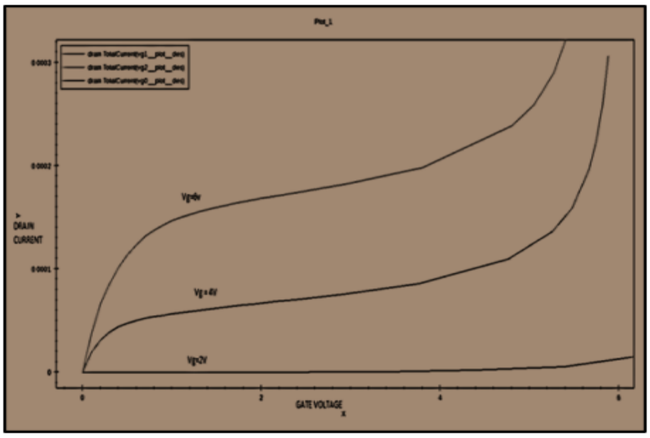

Fig12: This figure demonstrated the Id-Vg characteristic curve of the MOSHEMT device. The gate voltage is given as 2V,4V and 6V and the corresponding drain current curve is noticed.

Table 3: This shows the Ioff / Ion ratio and the gate leakage current for the MOSHEMT device.

V. CONCLUSION

In this work, the structure of MOSHEMT is created and also analyzed the DC characteristic curve of the device. MOSHEMT is a modified structure of HEMT. The characteristic of drain current in HEMT transistor is not linear when the applied gate voltage is above 2V.When the gate voltage is higher than 2V in MOSHEMT device the drain current is linear. This shows that MOSHEMT device is more suitable for the application where the gate voltage is higher. And also, the gate leakage current is 5.8 mA/mm and the current ON/OFF ratio is 1.28 in MOSHEMT device. In spite of all these, more negative gate voltage is required to off the device. There is a scope that this gate voltage can be reduced by using different materials as the oxide layer. The future work is focused on replacing the oxide layer with other high K- dielectric materials for further reduction of gate voltage.

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PARAMETER	OUTPUT VALUES
drain current	the drain current is linear above 2v of gate voltage
Ioff / Ion	1.28
Gate leakage current	5.8mA/mm

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