Open Dual Gate AlGaN/GaN Heterostructure HEMT

Dr. T.Venish kumar[1], S.Jawahar Ramkumar[2], M.Selvapandi[3], E.Suriya[4]
[1, 2, 3, 4] Dept of Electronics and Communication Engineering
[1, 2, 3, 4] Nadar Saraswathi college of Engineering and Technology

Abstract- *A novel Aluminium Gallium Nitride/Gallium Nitride heterostructure high electron mobility transistor based on open-dual gate technology was analysed. To increase the threshold voltage of GaN high electron mobility transistor, a p-GaN/AlGaN/GaN/AlGaN double heterostructure device with gate field was analysed. This narrow bandgap GaN and wide bandgap AlGaN contributes its physical properties and forms Two Dimensional Electron Gas (2DEG) with high mobility. The dual channel controlled by top gates provide more drain current capability and in critical dimensions it enables further scaling conditions. . The presence of Two Dimensional Electron Gas (2DEG) at the interface of AlGaN/GaN heterostructure HEMTs intrinsically normally-on devices. To make it as a normally-off device HEMT p-GaN material is used under gate. The developed structures are all demonstrated with Silvaco TCAD simulator. Atlas tool in Silvaco is a physical based 2 and 3 dimensional device simulator. This Silvaco TCAD simulator is used study about I-V and C-V characteristics of the device.*

Keywords- GaN/AlGaN, dual channel, HEMT, 2DEG, p-GaN, Silvaco TCAD, characteristics.

I. INTRODUCTION

The HEMT stands for a High Electron Mobility Transistor. The device is a form of field effect transistor (FET) that utilises an unusual property of a very narrow channel enabling it to operate at exceedingly high frequencies. In addition to the very high frequency performance, the HEMT also offers a very attractive low noise performance. Essentially the device is a field-effect transistor that incorporates a junction between two materials with different band gaps as the channel instead of a doped region which is used in the standard MOSFET. As a result of its structure, the HEMT may also be referred to as a heterojunction FET, HFET or modulation doped FET, MODFET on same occasions. The key element within a HEMT is a specialised PN junction that it uses. It is known as hetero-junction and consists of a junction that uses different materials either side of the junction. The most common materials used is aluminium gallium arsenide (AlGaAs) and gallium arsenide (GaAs). Gallium arsenide is generally used because it provides a high level of basic electron mobility which is crucial to the operation of the device. Silicon is not used because it has much lower level of electron mobility. There is a variety of different structures that can be used within a HEMT, but all use basically the same manufacturing processes.

II. LITERATURE SURVEY

GaN-based transistors with p-GaN gate are generally considered to be promising devices for use in power converters, thanks to the positive and stable threshold voltage, the low On-resistance and the high breakdown field. This paper gives an overview of the latest results of this technology and reliability of these devices by submitting original data. The first part of the work describes the technological problems related to the development of a p-GaN gate and the most promising solutions to minimize gate leakage current. In the second part of the paper we describe the most relevant ones Mechanisms that limit the dynamic performance and reliability of GaN-based normally-off systems transistors.

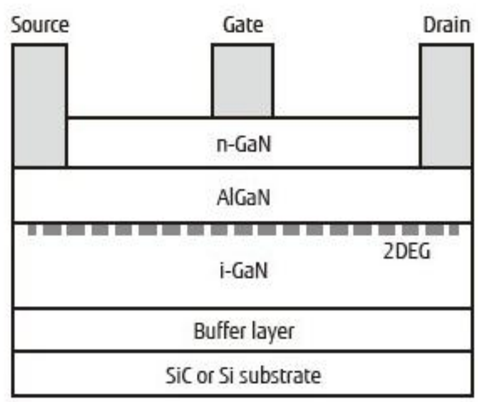


Fig.1 Basic GaN HEMT structure

Due to the high carrier density and high electron mobility of the two-dimensional electron gas (2DEG), high Electron mobility transistors (HEMTs) based on gallium nitride (GaN) are suitable devices for high power and high frequency applications. Clearly the presence of the 2DEG at the interface of AlGaN/GaN heterostructure makes HEMTs intrinsically normally-on devices. However, typically off for power electronics applications. The operation is desirable for safety reasons and to simplify the driver circuitry. In this context, although several. Approaches to obtain normally-off transistors have been described in the literature, normally-off GaN-based. HEMTs with a p-GaN gate are among the most promising and are the only ones commercially available today. This paper provides an overview of the most relevant technological issues for normally-off HEMTs with a p-GaN gate. First the functional principle and the influence of the heterostructure parameters are discussed. Then the possible effects of the dry etching process of p-GaN is briefly mentioned. After that, the role of the metal/p-GaN interface and the effects of the thermal processes on the electrical properties are widely discussed. Finally, recent alternative approaches that have been proposed to avoid using the p-GaN dry etch.

III. EXISTING WORK

The working principle of the self-locking HEMT with p-GaN Gate is schematically. Basically, the use of a standard Schottky contact as gate electrode on an AlGaN/GaN heterostructure results in normally-on operation of the devices since the AlGaN line. The band edge is below the Fermi level at the interface with GaN. On the other hand, after introducing a p-GaN cap layer on the AlGaN, the conduction band of the AlGaN is raised, which leads to the depletion of the 2DEG. In principle, the self-locking operation of the device can be achieved in this way. Adding any p-GaN cap layer on an AlGaN/ GaN heterostructure does not necessarily ensure normally-off operation. In the Indeed, an appropriate choice of all heterostructure parameters. Acceptor concentration of p-GaN, residual donor concentrations in the AlGaN and GaN, thickness (dAlGaN) and Al molar fraction (xAlGaN) of AlxGa1-xN junction, etc. Is essential to work efficiently exhaust the 2DEG channel and reach a reasonable threshold voltage Vt.

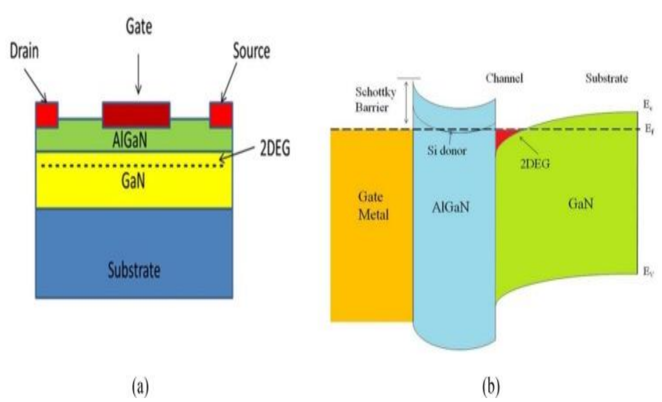


Fig.2 (a) 2D structure view 2DEG formation in the device. (b) 2DEG formation in the top view of device.

To facilitate 2DEG depletion in equilibrium Condition (at VG = 0), a high acceptor concentration of the p-type GaN top layer are used. However, there is an intrinsic n-type conductivity is typically observed even in nominally undoped GaN or AlGaN. It has been a long time since achieving p-type conductivity in GaN standing problem. Magnesium (Mg) is the p-type reference dopant B. for GaN or AlGaN, since it acts as an acceptor when incorporated into the Nitride lattice as a substitute for GaN. However, it is difficult to obtain a high hole concentration in p-GaN (or p-AlGaN), since ionization Energy of the Mg p-type dopant is relatively high, i. H. in that area 150–200 meV. Typically, p-type GaN cap layers with an acceptor concentration of about 3 × 1019 cm-3 are used, i.e. three orders of magnitude higher than the residual donor doping concentration of the AlGaN layer. A higher Mg content in the p-GaN does not recommended, as the incorporation could lead to a deterioration in quality the crystalline quality of the layer and a consequent decrease in the electrically active acceptors.

IV. PROPOSED WORK

The next decade of development in manufacturing technology and its thermo mechanical material properties, GaN seems to be the best choice for the development of future power electronic devices. The recent advances in high electron mobility transistors (HEMTs) have shown immense development because of their low noise, high carrier speed, high breakdown field, high switching speed, and high power applications in microwave frequencies. The development of wireless communication explicitly shows the demand for high-performance solid-state components. It mainly includes the attributes of high performance, high efficiency, linearity, manufacturability and low cost]. To meet these requirements, the High electron Mobility Transistor (HEMT) is analyzed in this article. In recent years, GaN HEMTs attracted attention due to their high performance. Since AlmGa1mN/GaN HEMTs have a Due to the greater potential of microwave ovens, they have received wider attention. Also high Power densities of more than 10 W/mm have been achieved for GaN-based HEMT on SiC substrate.

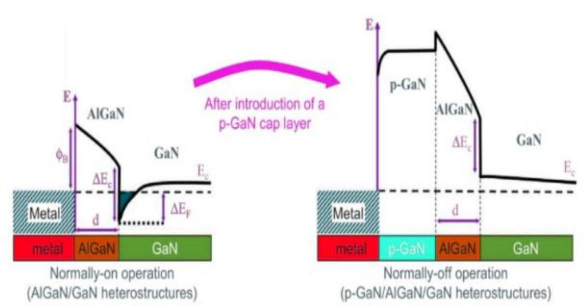


Fig.3 Bandgap energy diagram with 2DEG formation

In order to study the performance of AlGaN/GaN devices, it is necessary to conduct high-level studies voltage applications. The GaN has a three times higher breakdown field (Ec = 3 MV/cm) compared to silicon or GaAs. Even a GaN-based device has more than 100 times lower ON resistance (Ron) as a device fabricated using Si material. Compared to other group III-V semiconductors Devices GaN-based HEMT can achieve two-dimensional electron gas (2DEG) sheet carrier density (ns) well over.

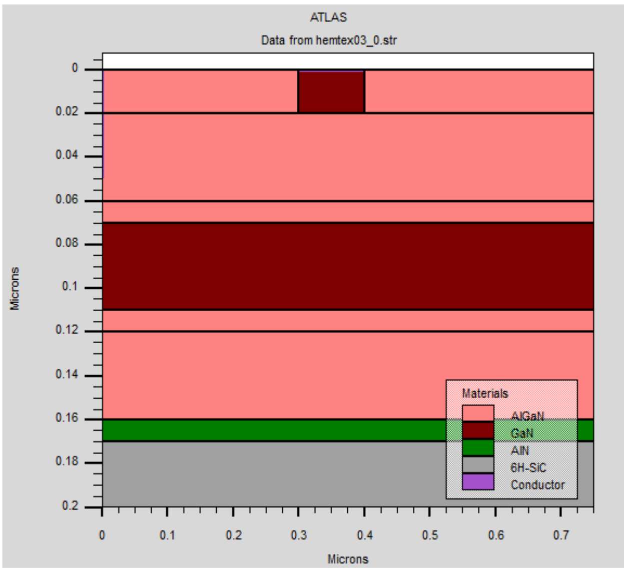
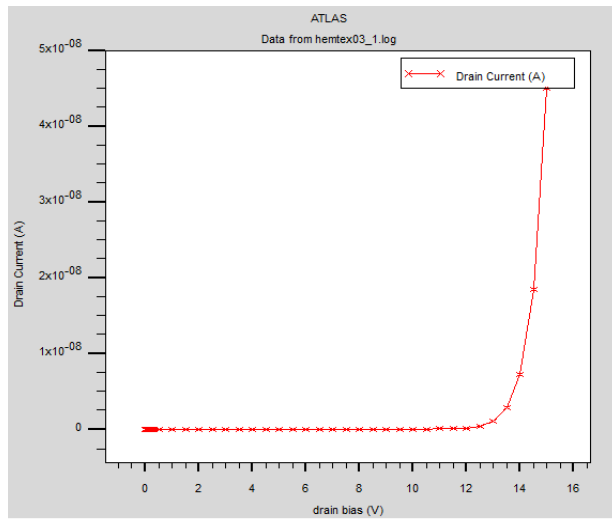


Fig.4 AlGaN/GaN HEMT with p-GaN material

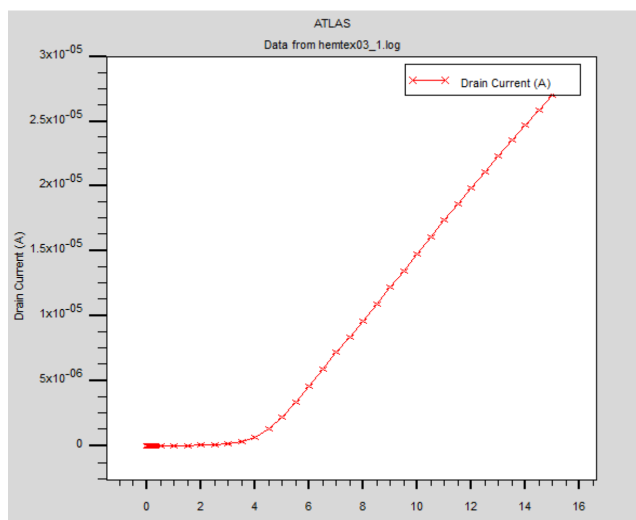
V. RESULTS AND DISCUSSION

The width of the bridge increases, *V*TH increases, because the resistance of the bridge and the source-to-p-GaN bridge contact decreases. However, there is a trade-off, since an increase in bridge width reduces the 2DEG channel area, which increases *R*ON. The normal device has two transconductance *(gm)* peaks—a first sharp peak near *V*TH and a second broad peak at a higher *V*GS. The second peak is possibly due to the gate injection effect in the p-GaN HEMT. The bridged device, on the other hand, has only one peak. A possible explanation is that the two peaks are overlapping as *V*TH increases. *G*m, max decreases as the bridge width increases. Pulsed *ID*–*V*GS characteristics were measured to determine the effect of the bridge on the dynamic properties of the device. For pulse widths from 200 ns to 1 ms (with a constant pulse period of 10 ms), there was no apparent change in *V*TH for the normal device. However, for the bridged device, *V*TH significantly decreased for pulse widths smaller than 1 μs. This is likely due to the RC delay of the holes that are depleted when a gate bias is applied. The capacitance between the gate and the p-GaN was measured to be 2 pF (not shown). From the TLM measurements, the p-GaN sheet resistance was 80 k_/_, and the p-GaN/source effective contact resistance was 1.5 k_· mm. Since the bridge width is 10 μm, and the gate-to-source distance is 2 μm, the resistance of the bridge structure is 166 k_. Therefore, the hole depletion has an RC delay of around 0.3 μs. The delay may increase due to the T shape of the bridge. The exact mechanism behind the frequency dispersion needs further study. Reducing the resistance of the bridge and the source contact, along with optimization of the structure considering capacitive coupling, is expected to result in an improvement in the high-frequency performance.

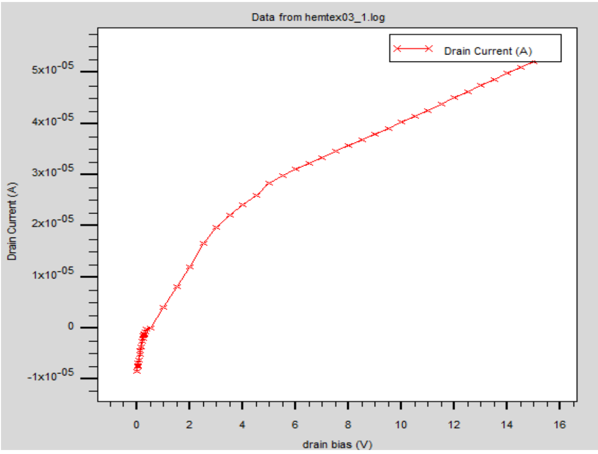
The drain characteristics of the device when the gate voltage vgate=0,



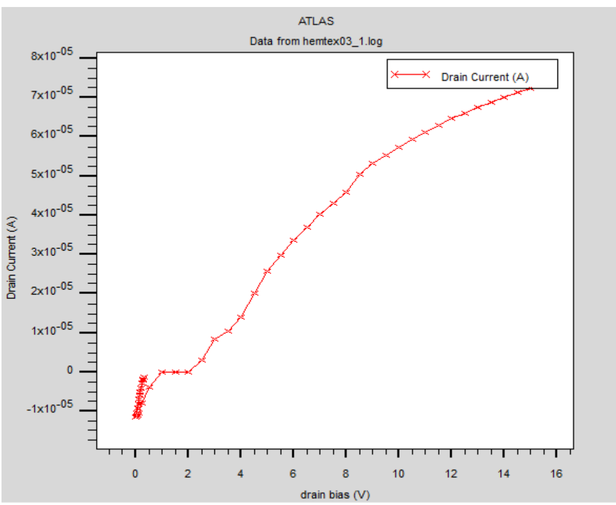
The drain characteristics of the device when the gate voltage vgate=1,



The drain characteristics of the device when the gate voltage vgate=2,



The drain characteristics of the device when the gate voltage vgate=3,



These are the drain characteristics of our device with different gate bias voltage and different materials.

VI. CONCLUSION

We analysed source-related p-GaN gate HEMTs with a p-GaN bridge. With this novel structure, VTH substantially improved from with inside the everyday structure without the bridge. This may be defined in terms of the boom with inside the depletion width of the p-GaN at the gate interface with the aid of using connecting the p-GaN below the gate to the source. More studies wishes to be achieved to absolutely understand the advantages and viable boundaries of this novel structure. We have effectively advanced a brand new normally-off AlGaN/ GaN transistor with an excessive drain contemporary. The transistor, which we name a GIT, makes use of hollow injection from the p-AlGaN formed over the AlGaN/GaN, ensuing in a dramatic boom of the drain contemporary at excessive gate voltages because of the conductivity modulation.

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