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SIMULATION OF NANOSCALE SYMMETRIC DOUBLE GATE $Al_{0.83}In_{0.17}N/GaN/Al_{0.83}In_{0.17}N$ USING HEMT

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Abstract:
In these present work, I have proposed and perform the extensive simulation of the device structure having p-GaN as back barrier layer inserted in the conventional AlInN/GaN/AlInN, for reducing the short channel effects, gate leakage and enhancing the frequency performance. By using the p-GaN back barrier layer on the device performance of the proposed structure is done by using 2D Sentaurus TCAD simulations by Drift–Diffusion (DD) model, which are calibrated/validated with the previously published experimental results. Simulation are done to analyze the transfercharacteristics, transconductance (gm), Gate leakage current (Ig), threshold voltage (V_{th}), On-current Off current ratio (I_{on}/I_{off}), gate capacitance (C_{gg}) and cut off frequency (f_r) of the proposed device. A comparison is done between the device without back barrier layer and the proposed device with p-GaN back barrier layer.

Key words:- p-GaN BackBarrier Layer, 2DEG, Heterostructure, Ig, Vth, fr.

1. INTRODUCTION

The AlInN/GaN-based high electron mobility transistor (HEMT) has emerged as superior alternative to the conventional AlGaN/GaN HEMT for high-power, high-frequency applications. The AlInN/GaN heterostructure is gaining importance due to several structural advantages over AlGaN/GaN heterostructure. In these paper we are including double gate structure for AlInN/GaN/AlInN. Lattice matching using by 17% of indium in AlInN i.e. $Al_{0.83}In_{0.17}N/GaN/Al_{0.83}In_{0.17}N$ avoids stress at the interface, which helps to improve the device's reliability.Another advantage is strong spontaneous polarization in an AlInN/GaN/AlInN heterostructure induces a higher two-dimensional electron gas (2DEG) density in the channel which implies radio-frequency (RF) performances could be much improved by scaling down gate length as well as the AlInN barrier thickness. Taking the advantage of these material properties, excellent performance has been reported for the AlInN/GaN/ AlInN HEMT devices over past decade. Using of double gate structure to attain, In these present work, we propose and perform the simulation by using p-GaN backbarrier. This device would support enhancement mode operation, exhibit reduced short channel effects, reduced leakage and higher fT. In this structure the AlGaN back barrier layer is avoided by doping a small portion of the existing GaN buffer layer with p type material, making it p-GaN back barrier layer. The performance of the proposed device as been analyzed comprehensively for checking its viability for high frequency and switching applications. Thus, extensively simulations are done to analyze the performance of the proposed device. The parameters analyzed in the simulation include transfer characteristic, g_m, gate leakage, I_{on}/I_{off} and f_T. These results as been obtained from the simulations and compared with the previously published experimentally data.

2. DEVICE DESCRIPTION

The proposed structure of the device by using of P-GaN as back barrier in AlInN/GaN/AlInNGate-Recessed Enhancement-Mode HEMT. The p-GaN back barrier device of has gate length (Lg) of 50 nm, 4.8 nm AlInN barrier, 1 nm AlN spacer layer, 30 nm GaN channel, 100 nm p-GaN back barrier layer.

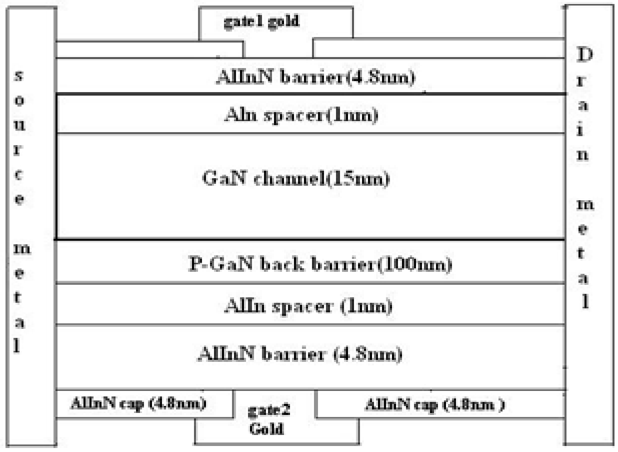

Fig.1.Device structure

The gate consists of Au (50nm) metal. Source and drain consist of metal and a contact resistance Rc in simulation. The source/drain regions are doped with a concentration 5E20 cm3 and have abrupt doping profile at the source and drain ends. Narrow bandgap GaN layer just beneath the wide bandgap AlInN barrier. Where a double gate structure as been used to obtain high performance. Where T-gate as been used in the structure to have gate contol on the structure.

3. SIMULATION MODEL CALIBRATION

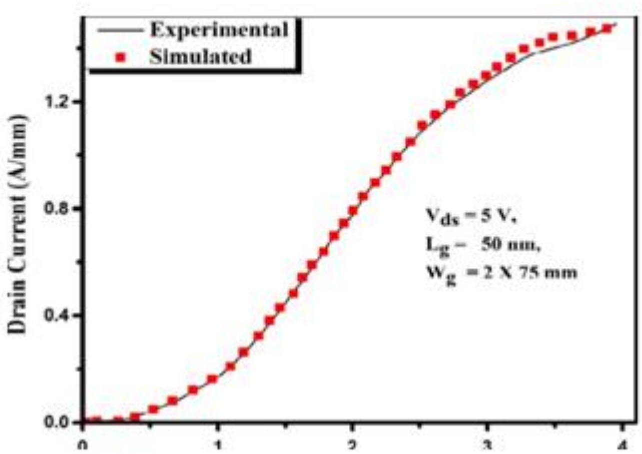

Fig.2. Experimental and simulated transfer characteristics

In this section we simulated the AlInN/GaN/AlInN without back barrier Gate Recessed Enhancement Mode HEMT device for calibrating the simulation model. The simulated transfer characteristics are compared with the experimentally obtained transfer characteristics from previously published work [2]. These model parameters are tuned to achieve close matching between experimental and simulation results. Once matching is done, the calibrated simulation model is then applied for simulating the proposed structure of AlInN/GaN/AlInN Gate-Recessed Enhancement-Mode HEMT device with p-GaN backbarrier. These simulations are done by using Sentaurus TCAD Drift– Diffusion (DD) transport model [2]. The DD model provides relatively fast simulation and runs with an acceptable level of accuracy. As the temperature effects are not analyzed in this work, the Thermodynamic and Hydrodynamic model are not chosen.

4. RESULTS AND DSCUSSION

The transfer characteristics of the gate length 50 nm of AlInN/GaN/ AlInN Gate-Recessed Enhancement-Mode HEMT devic with 100 nm width p-GaN back barrier with a hole concentration of $1x10^{17}cm^{-3}$ device.

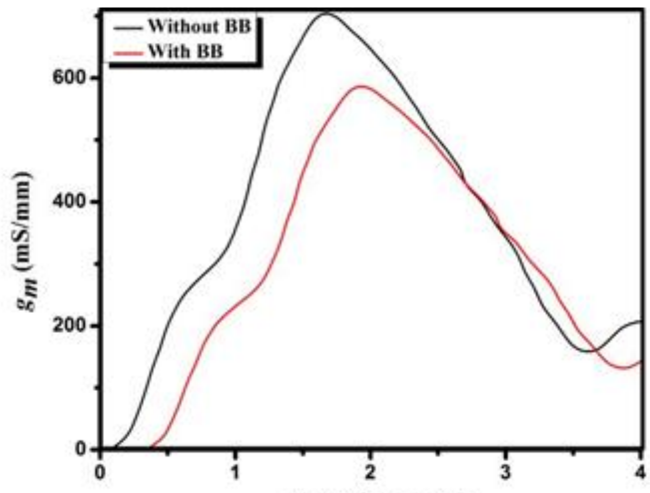

Fig.3. Simulated waveform

Where these device as been leads to drain current versus gate voltage in the gate length of 50nm. Where a gate leakage as been reduced by introducing the p-GaN back barrier in AlInN/GaN/AlInN. Where these value as been referred to the experimental value of presence back barrier and without back barrier .

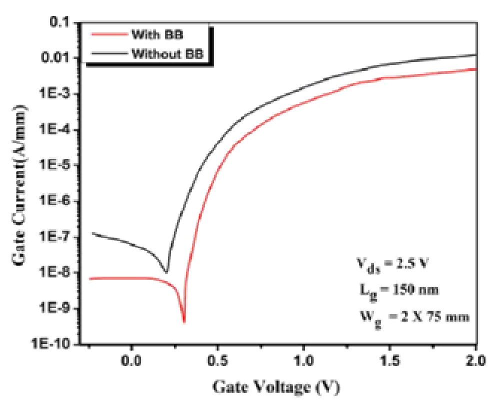

Fig.4. Curves of current gas leakage

where these output shows the leakage current comparison between with back barrier and without back barrier. Where a gate capacitance value as been detected, where a simulated and experimental curves shows the gate capacitance value by comparison to with back barrier and without back barrier.

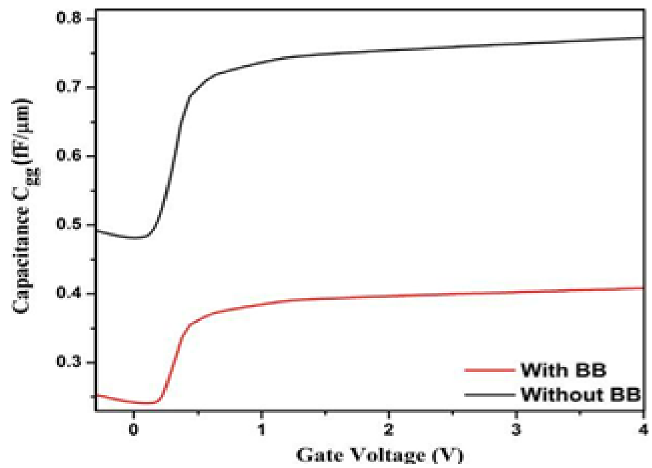

Fig.5. Simulated curves for Cgg versus Vgs curve

Where a cut frequency as been increased by the insertion of p-GaN used as a back barrier. Where these result as been compared to the absence back barrier as the experimental value.

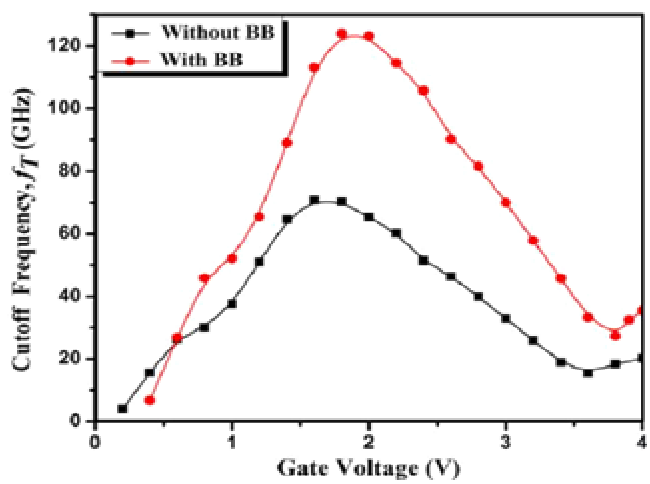

Fig.6. Simulated curves (both) for f_T variations with Vgs

CONCLUSION

We have studied by the simulation of $Al_{.83}$In.17N/GaN/$Al_{0.83}In_{.17}N$ (for mole concentration x=0.17) using double gatestructure, where the effect of p-GaN back barrier layer on the device performance of the proposed structure of AlInN/GaN/AlInN Gate-Recessed Enhancement-Mode HEMT. These results obtained from the simulations are compared with the previously reported results by other group of the device without back barrier layer. These device with p-GaN back barrier shows the excellent electrostatic control leading to obtain a very low gate leakage value. These device also shows a very high Ion/Ioff ratio in the range of 10^7.

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