Analysis of AlGaN/GaN for High Frequency Application using HEMT Transistor

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Abstract: The performance of AlGaN/GaN high electron mobility transistor (HEMT) that were passivated with Si_3N_4 region at the gate terminal and simulated with Sapphire substrate. Output characteristics, transfer characteristics, threshold voltage and the cut off frequency of the device are observed. The device exhibits a threshold voltage V_T= -4V, peak current is about 500mA, sub-threshold slope of 185mV/dec and unity current gain cut off frequency f_T=73.6GHz. All simulations are made using SILVACO software.

***Keywords* - AlGaN/GaN HEMT transistor, threshold voltage curve, cross-sectional view of AlGaN/GaN HEMT, unity current gain cutoff frequency.**

Introduction

In this paper we have studied the analysis of AlGaN/GaN HEMT for high frequency application using high electron mobility transistor. HEMT more known as HEFT (heterostructure field effect transistor) has been studied for its high-power handling capability and application in microwave source and in power amplifier such as MMICs (monolithic microwave integrated circuits) and digital on-off switches.

HEMT is PN-junction diode incorporating a junction between two material with different band gaps(i.e., a heterojunction) with highly doped n-type region and moderately doped p-type region. A commonly used material combination GaAs With AlGaAs, though there is wide variation, dependent on the application the device ,so more often devices incorporating indium generally shown better higher frequency performances but in recent years GaN HEMTs low attracted attention due to their high power performance.

HEMT transistors are able to operate at high frequencies than ordinary transistors, up to millimetre wave frequency and are used in high frequency products such as cell phone satellite television receivers, voltage converts and radar equipment they are widely used in satellite receivers in low power amplifiers and in the defence industry.

Advantages of HEMTs are that they have high gain this make them useful amplifiers, high switching speed, which are achieved become the carriers and minority carriers are not significantly involved, and extremely low noise valves because the current variation in these devices is low compared to other FETs

I. FABRICATION

AlGaN and GaN films were deposited in a modified LPCVD system onto etched mesaisolated AlGaN/GaN HEMT structures with 25-nm Al0.25Ga0.75N barriers grown on semi-insulting layer SAPPHIRE. Dielectric deposition was performed at 750 °C at a pressure of 2 torr, with trimethylaluminum, dichlorosilane, and ammonia as precursors. The conditions for the deposition of the SiN films were adjusted to produce low-stress slightly Si-rich films. The aluminum fraction (controlled by the trimethylaluminum flux) of the AlGaN dielectrics was measured to be ~6 at. by x-ray photoelectron spectroscopy. At a wavelength of 1 µm, the refractive index was measured to be 2.008 for AlGaN and 2.014 for SiN. A side-by-side capacitance–voltage (CV) comparison measurement provided a 2-D electron gas (2DEG) concentration of 7.5×10^12 cm-2 in an unpassivated sample, 8.9×1012 cm-2 in a GaN-passivated sample, and 7.1×10^12 cm-2 in an AlSiN-passivated sample. SiN passivated structures had a corresponding sheet resistance of ~450 O/square. Ta/Ti/Al/Mo/Au source/drain and Ni/Au gate contacts were placed in windows etched using CF4 and SF6/BCl3/Ar reactive ion etching (RIE) chemistries, respectively, defined by electron beam lithography. A cross-sectional diagram of the HEMT structure is shown in Fig. 1.

II. DEVICE STRUCTURE

The structure shown in figure (a) shows a cross-sectional view of the AlGaN/GaN HEMT transistor. The nitride layer consists of 0.5 microns Al0.1Ga0.9N p-type back-barrier layer, 0.2 microns n-type GaN channel layer, 15.5nm thick cap layer. Finally, the structure is layered with 100nm Si3N4 substrate. The structure is having a square shaped gate having a work function of 4.4eV where gate length is 0.6microns and source-gate length with drain-gate distance of 0.6 microns. Source-drain distance is 2.2 microns. Length of source and drain are 0.3 microns. The AlGaN layer is having a doping concentration of 4.5*10^12 cubic cm. The GaN channel and GaN cap layers having a doping concentration of 6*10^12 cubic cm and 6*10^12 cubic cm.

The parameters are given in the following table:

PARAMETERS	VALUES
Gate Length	0.6 microns
Channel Length	2.2 microns
Source Length	0.3 microns
Drain Length	0.3 microns
Gate Work Function	4.4 microns
GaN doping concentration	$6*10^{\wedge}12$ cm^{-3}
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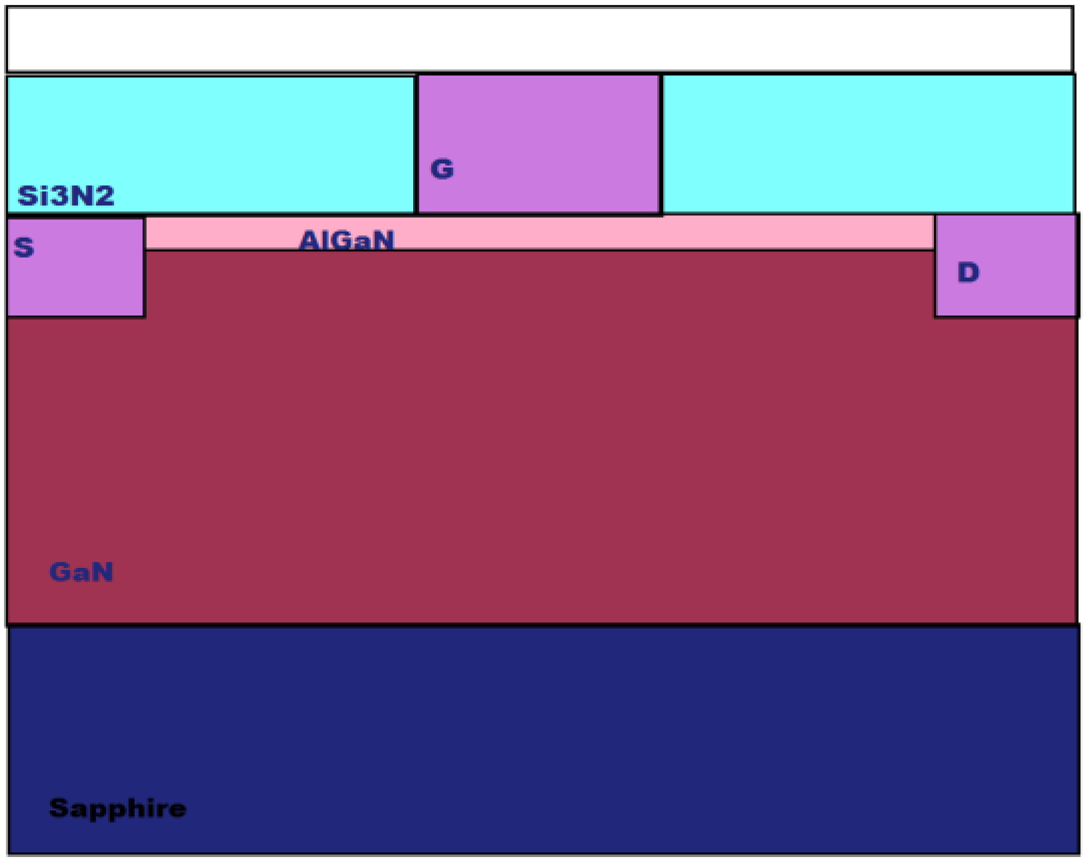

Fig(a): Cross-sectional view of the AlGaN/GaN HEMT transistor

III. SIMULATION AND RESULTS

Characteristics simulation of the AlGaN/GaN HEMT transistor is obtained by using SILVACO software. The device is simulated with Shockley-Read-Hall (SRH) recombination model which is used to capture the phonon the phonon transitions occurring with the forbidden band-gap of the semiconductor in the presence of a trap. Albrecht low field electron mobility of electrons. The devices gives a maximum range current of 0.44amp at Vgs=0V and V_{Ds} =8V.

Fig(b) represent the family of curves v/s gate voltage at varies value of V_g which as V_D is raped from 0 to 16 volt and as seen from the (I_D –V_D) curves of the I_D –V_D characteristic the device enter into saturated at V_D =7volt .

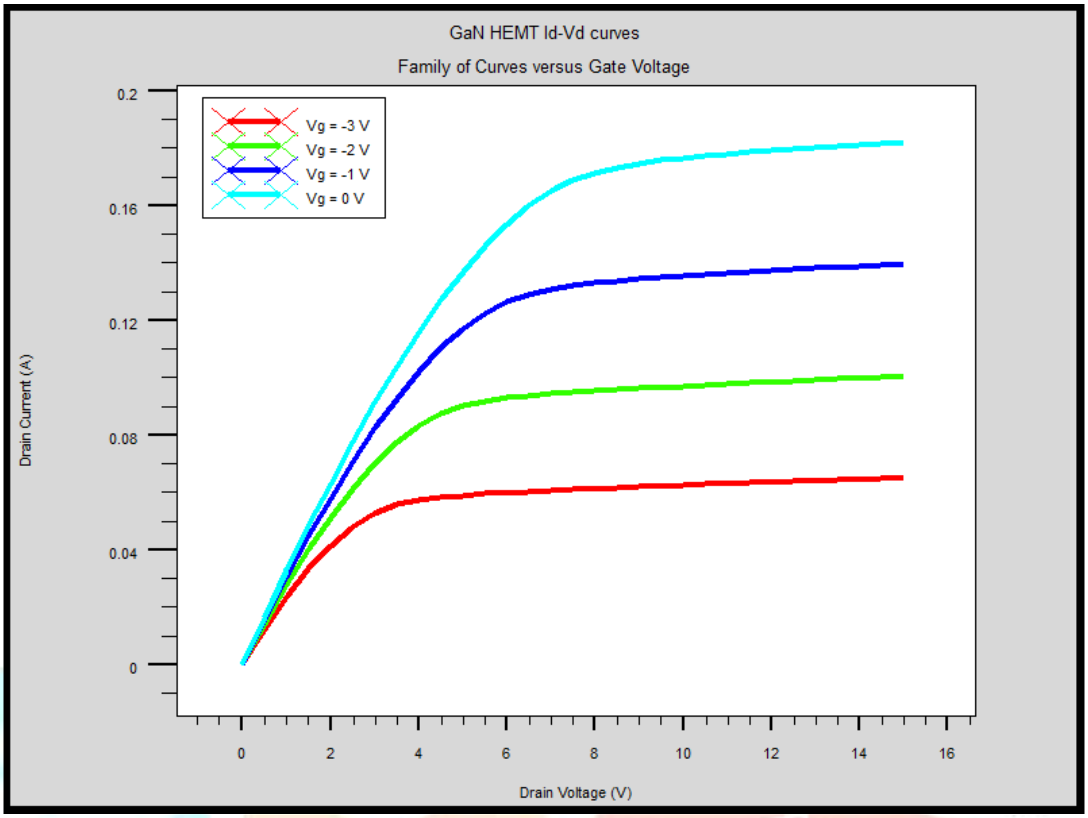

Fig (b): Family of curves of drain current (I_d) v/s drain voltage (V_D) at various values of V_g

Fig(c) shows the transfer characteristics of (I_D –V_D) curves of the simulated HEMT. It is observed that the threshold voltage of the device V_T =-6volt as gate voltage is ramped form -10V to 2V. Threshold voltage V_T =-6 volt because Current increases rapidly at that pinch-off point and before that the current is zero .

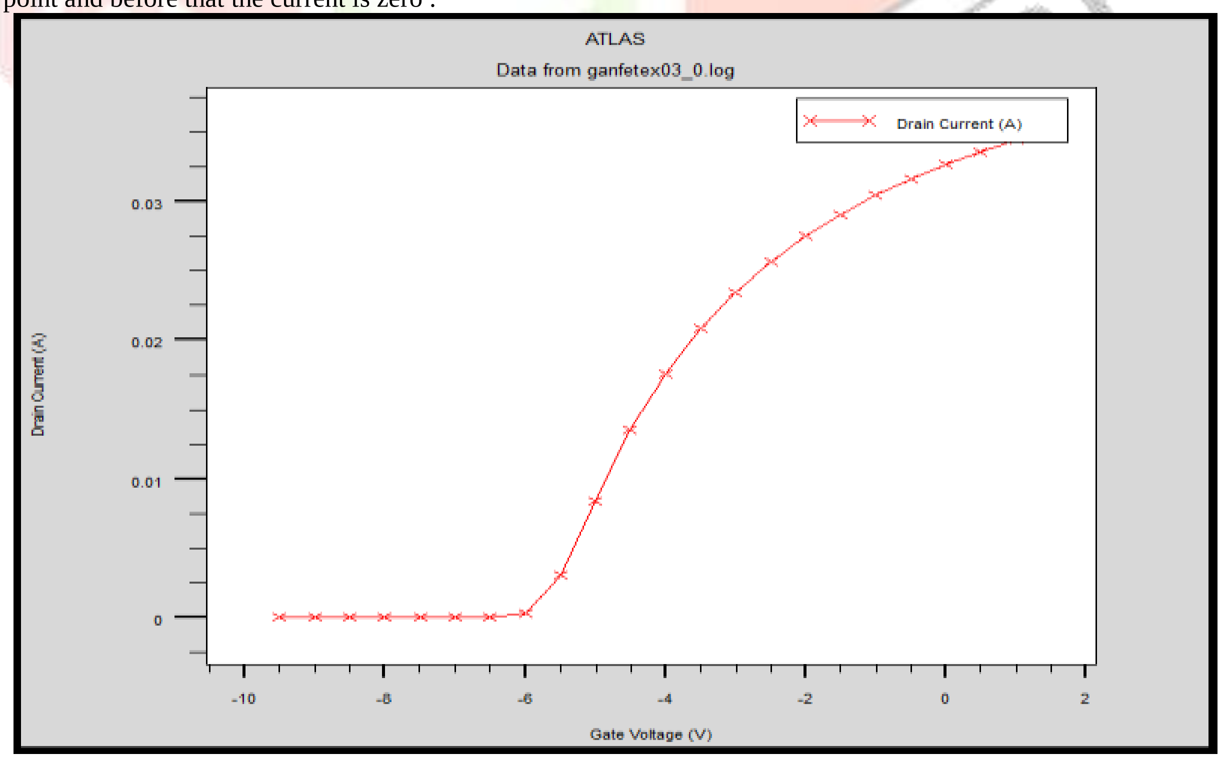

Fig (c): Transfer characteristics of the simulated structure

Fig. C also shows the same family of curves v/s gate voltage as show in fig D the only difference is that in fid D the drain current range from 0 to 0.16 mA and here V_d=7V.

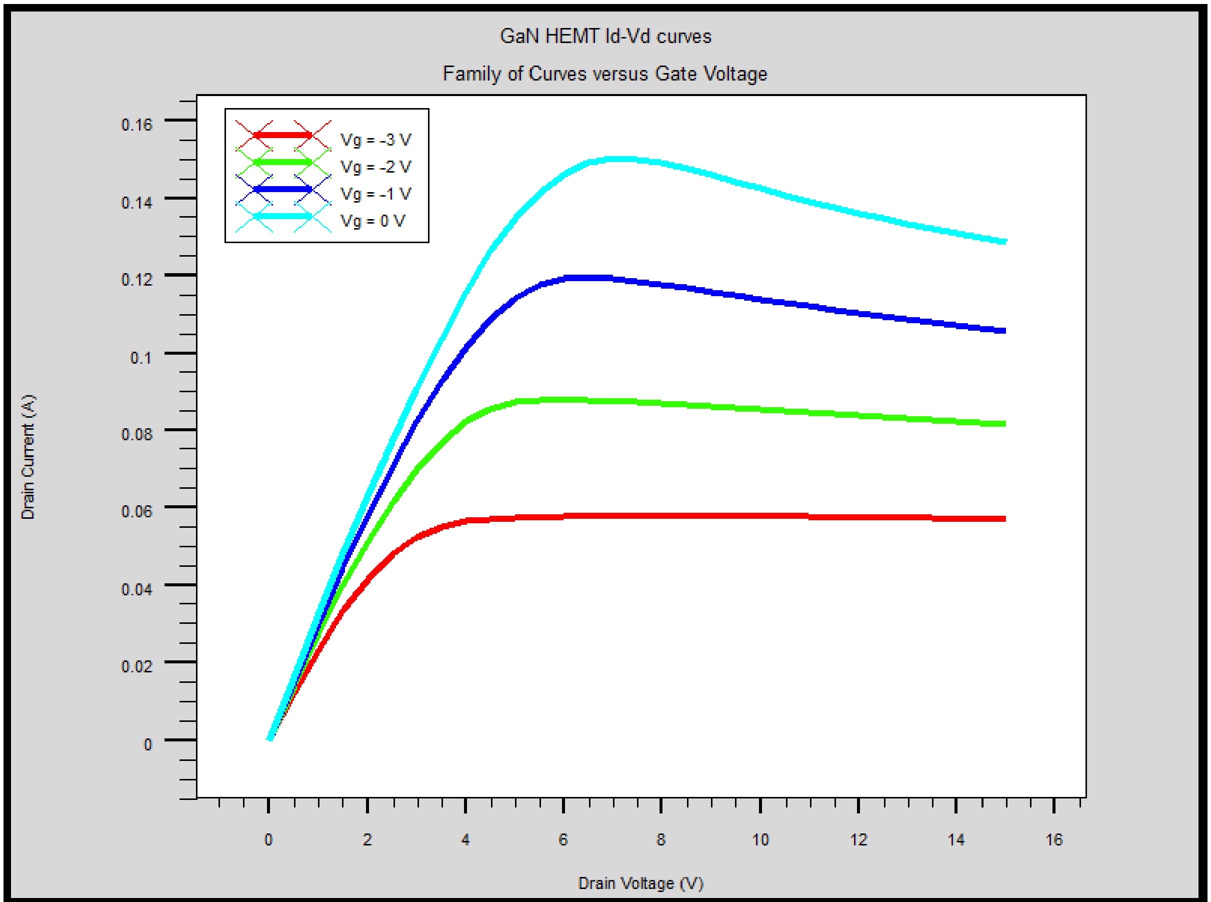

Fig (d): I_D versus V_D characteristics

IV. Conclusion

In the proposed paper we have studied the analysis of AlGaN/GaN high frequency application using HEMT transistor which achieves a threshold voltage V_t=-6V. Hence, the device is suitable for high frequency application. As a result of difference is observed between fig(b) and fig(d) from the drain current axis. Also, comparatively lower value of the subthreshold slope is obtained which indicate high switching speed of the device.

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