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Performance Analysis of Inp Based High Electron Mobility Transistor Devices in Nano Regmie

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ABSTRACT: This paper presents an comparison between the performance of the single and double gate InGaAS/InAs/InGaAs HEMT as composite channel layer. Using composite channel we achieved greaterf_t=586 GHZ and f_{max} =770 GHZ in DG-HEMT this result is higher than existing InGaAs channel. The Double Gate HEMT (DG-HEMT) exhibit high Transconductance (g_m) and good pinch off behavior (lower g_d) as compared with the Single Gate HEMT these allows improved maximum oscillation frequency (f_{max}). In addition the multiple cap layer and T-shaped gate stem are used to decrease the source and gate resistance of the device.

KEYWORDS; Multicap layer, InAs channel, Single gate high electron mobility transistor (SG-HEMT), Double-gate high electron mobility transistor (DG-HEMT)

I. INTRODUCTION

In CMOS we used two semiconductor material silicon and germanium. In that silicon is widely used due to its high band gap property. Moore's law states that the no of transistor on a given chip can be doubled every two years, which has the roadmap of the continuous reduction of CMOS devices. Scaling of silicon in CMOS technology gives rise to the short channel effect. To overcome the drawbacks of CMOS device III-V material (HEMT) are used because these materials have high mobility, speed, and performance.

The HEMT is also known as MODFET (Modulation-doped FET), TEGFET (Two-dimensional Electron Gas FET), SDHT (Selectively Doped Heterostructure Transistor) or simply, HFET (Heterojunction FET). The unique feature of the HEMT is a channel formation from carriers accumulated along a grossly asymmetric heterojunction, i.e. a junction between a heavily doped high band gap and a lightly doped low band gap region.

The Emerging MMIC application needs for extremely high cut-off frequencies (f_t) and high maximum oscillation frequency (f_{max}). InP based HEMT are the most promising device for future high-speed application because it performs superior electronic transport properties like high mobility and high saturation velocity in low voltage. InP HEMT usually use InGaAs or InAs/InGaAs composite channel for improved RF performance. T-gate recess structure also plays a critical role to increase high frequency performance for the HEMT device. To keep on increasing the frequency performance of the transistor device (especially regarding (f_{max}), an alternative solution DG-HEMT is used which is a HEMT with two gates placed on each side of the conducting InGaAS/InAs/InGaAs channel.

II. DEVICE TECHNOLOGY

The Fig.1 shows the single gate structure of InAs composite single gate HEMT structure. 500nm InP substrate and InAlAs buffer layer was grown on top of substrate layer with 200nm dimension. The composite channel layer is used a 2nm InAs channel layer with 5 nm InGaAs upper sub channel and lower sub channel. The InGaAs sub channels layer is used to enhance the electron confinement in the thin InAs layer and improve the etch stop and a 25nm InGaAs/InAlAs multi cap layer with electron transport properties. A 5nm InAlAs spacer, a delta doping with 5 x 10^{12} cm^{-2} , a 4nm thick InAlAs barrier, a 2nm thick InP 2x 10^{18} cm^{-3} si-doping were grown on top of the composite channel layers. The

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Germanium materials were grown on source and drain layer. A 40 nm T shaped gate structure is placed above the barrier layer and the si_3n_4 passivation layer is used to minimize the gate leakage in device. The double gate HEMT structure is constructed without buffer and substrate this provides better charge control in the device. The DG- HEMT has two gates placed on each side of the conducting InGaAs/InAs/InGaAs composite channel.

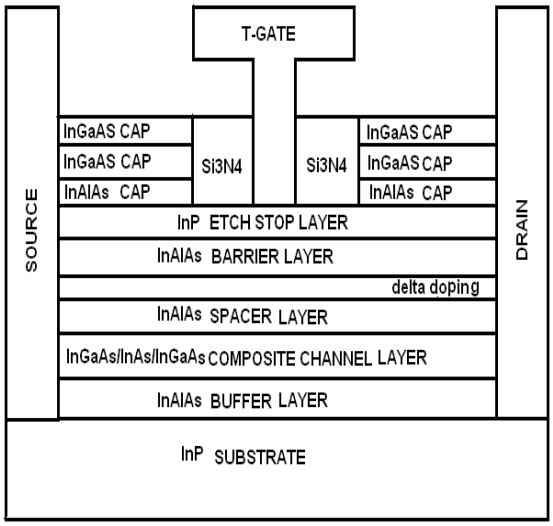

Fig 1. The Schematic view of Single-gate HEMT device

III. RESULTS AND DISCUSSION

*A.*DC Performances

Fig. 2 shows the drain current vs gate voltage (Id vs Vgs) characteristics of a 40 nm-gate HEMT for SG-HEMT and DG-HEMT under a drain voltage vds=0.5 V as constant. The obtained Id for double gate is higher than single gate HEMT due to less short channel effect in double gate device. Fig. 3 shows the maximum Transconductance (g_m) of SG- and DG-HEMT the double gate exhibit a very good pinch off characteristics and saturation current of 3000 mA/mm at vg=0V when vd=0.5V as constant. This very high drain current was mainly due to the superior electronic mobility in the composite channel InGaAs/InAs. The improvement of g_m in DG-HEMT is due to the addition of two gates in the device.

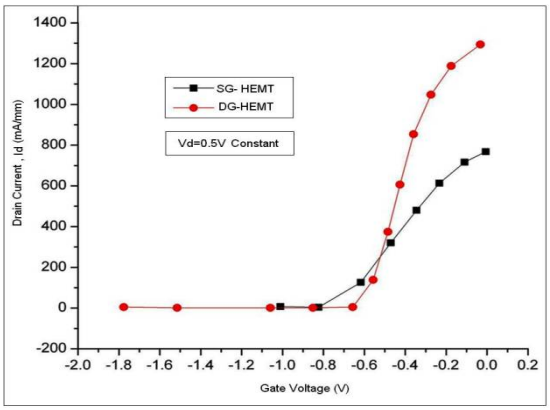

Fig. 2. Comparing the Drain Current vs Gate voltage (Id vs Vgs) curve characteristics for SG-HEMT and DG-HEMT device at Vds=0.5V.

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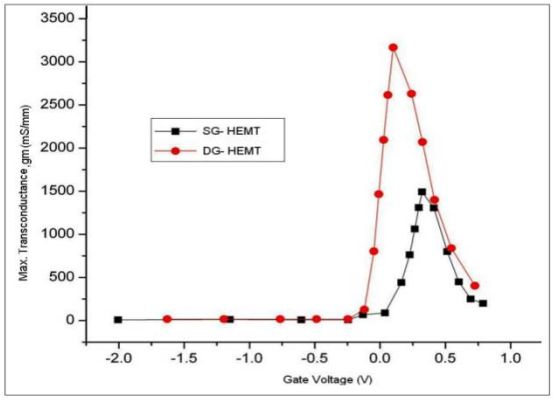

Fig. 3. Comparing the maximum Transconductance (g_m) curve characteristics for SG-HEMT and DG-HEMT device

Fig. 4. and Fig. 5. Shows the output characteristics drain current vs drain voltage for SG and DG-HEMT the gate bias curve for the top curve is 0V and the measurement step of the gate bias is -0.25V. The DG-HEMT exhibits high drain current than single gate device

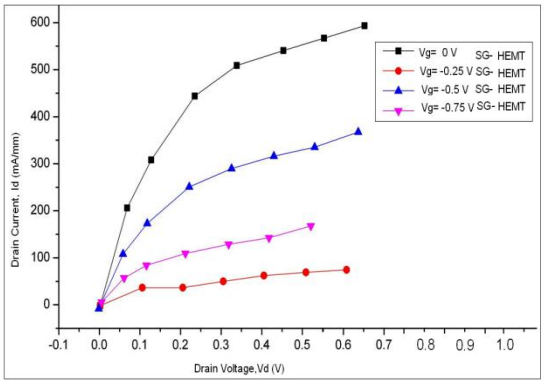

Fig. 4. Drain Current Vs Drain Voltage (Id vs Vd) curve characteristics for SG-HEMT

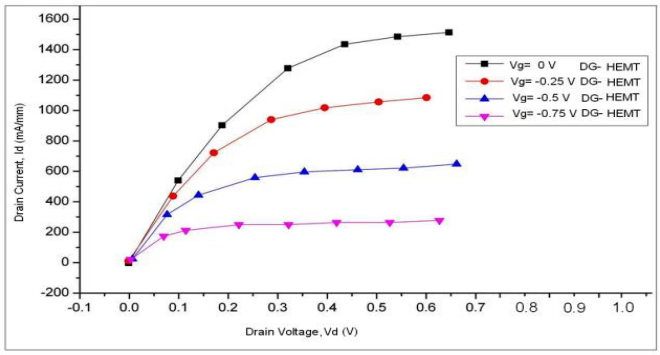

Fig. 5. Drain Current Vs Drain Voltage (Id vs Vd) curve characteristics for DG-HEMT

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***B.*AC ANALYSIS**

Fig. 6. shows the cut off frequency for SG and DG HEMT device the single gate exhibit f_t =340 GHz and the double gate device exhibit f_t =450 GHz the double gate HEMT produce high cut off frequency compared to single gate and the short channel effect also improved. The cut off frequency ft improved is due to the use of thin InAs has the channel layer.

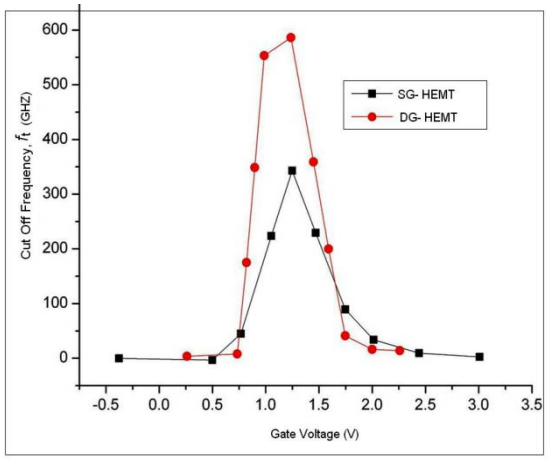

Fig. 6. Comparing the cut off frequency (f_t) for SG-HEMT and DG-HEMT device

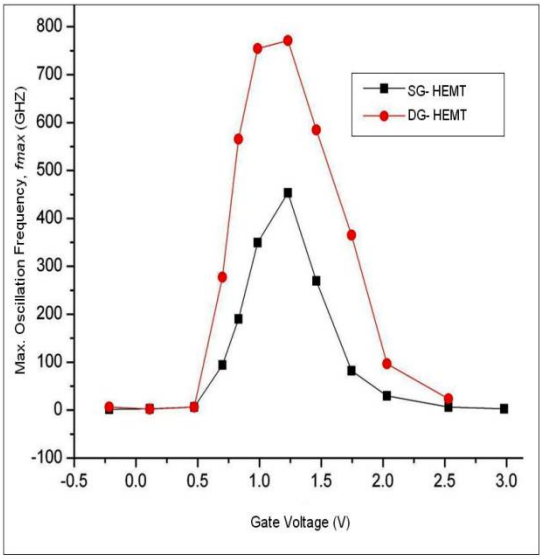

Fig. 7. Comparing the maximum oscillating frequency (f_{max}) for SG-HEMT and DG-HEMT device

Fig. 7. Shows the maximum oscillating frequency of SG and DG HEMT device the single gate exhibit f_{max} =586 GHz and the double gate device exhibit f_{max} =770 GHz. The maximum oscillating frequency f_{max} is improved in double gate by the addition of another gate in the device compared to single gate.

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TABLE I.
SUMMARY OF THE HEMT DEVICE PARAMETERS FOR SINGLE AND DOUBLE GATE

DEVICE	Id(mA/mm)	g_m (mS/mm)	f_t (GHZ)	f_{max} (GHZ)
SG-HEMT	700	1500	340	450
DG-HEMT	1300	3000	586	770

IV. CONCLUSION

This letter shows, the DG-HEMT has the superior DC characteristic and RF performance than SG-HEMT and the short channel effect is reduced for smaller gate length. The DG-HEMT device exhibits a high Transconductance of 3000mS/mm; this is two times greater than SG-HEMT and this behavior involve an improvement of f_{max} in the device. The cutoff frequency f_t is improved with the help of thin InAs/InGaAs composite channel. The multi cap layer and T-shaped gate structure reduce the source, drain and gate resistance, as well as the overall capacitance of the device.

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