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Characterization of Single and Double Gate InSb Based HEMT Devices for High Frequency Application

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ABSTRACT: We report the implementation of double gate symmetric Metal Oxide Semiconductor HEMT(DG-MOSHEMT) based on AlInSb/InSb material .The DG-MOSHEMT consist of 30nm gate length and it exhibit high transconductance (G_m) , high cut off frequency (f_t)and maximum drain bias. We achieved greater f_t=750 GHz and f_{max} =950 GHz this result is higher than single gate AlInSb/InSb MOSHEMT. The High Electron Mobility Transistor (HEMT) is an important device for high speed, high frequency and microwave circuits.

KEYWORDS: IndiumAntimonide, MOSHEMT, symmetric MOSHEMT

I .INTRODUCTION

The Sb-based devices have intrinsic advantage of high speed and low power consumption that can provide the technology required for these application. In III-V narrow band gap semiconductors such as InAs andInSb have showed extremely high electron mobility because of their smallelectron effective mass [table1], which has brought about an increasing interest in themselves as promising channel materials for future logic, communication and terahertz devices.

The two-dimensional electron gascreated at the interface between the channel and the barrierlayers of High Electron Mobility Transistors (HEMT) provides a high concentration of electrons in the channelwith very high mobility. In AlInSb/InSbparticularly suitable for low-drain voltage operation,this material reduced DC-power consumption than GaAs. In Metal oxide Semiconductor HEMT(MOSHEMT) with insulating dielectrical are widely investigated, and excellent performance utilizing Al_2O_3, TiO_2, HfO_2.In AlInSb/InSb MOSHEMT using Al_2O_3 as gate dielectric.

In symmetrical High electron mobility transistor the drain current(I_d) and transconductance (g_m) is high. In single gate High mobility electron transistor the short channel effect is high than compare to double gate. In double gate MOSHEMTin order to improve higher values of the transconductance over drain conduction ratio g_m/g_d and lower gate resistance $R_g$these resulting improved the maximum oscillating frequency f_{max} .

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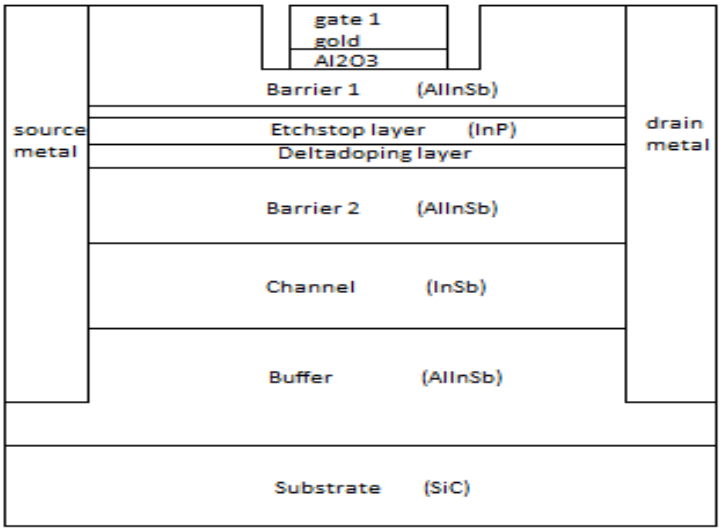
	GaAs	InGaAs	InAs	InSb	units
Energy gap	1.43	0.75	0.356	0.175	eV
Electorn effective mass	0.072	0.041	0.027	0.013	eV
Mobility for pure material	8500	14,000	30,000	78,000	$cm^2 V^{-1} s^{-1}$
Electron saturation velocity	$1.2*10^7$	$8*10^8$	$3*10^7$	$5*10^7$	$cm\ s^{-1}$
Intrinsic carrier concentration	$1.1*10^7$	$5*10^{11}$	$1.3*10^{15}$	$1.9*10^{16}$	cm^{-3}
Electron free mean path length	80	108	194	226	nm

Table[1] comparison of III-IV semiconductor materials

II. DEVICE STRUCTURE



(a)

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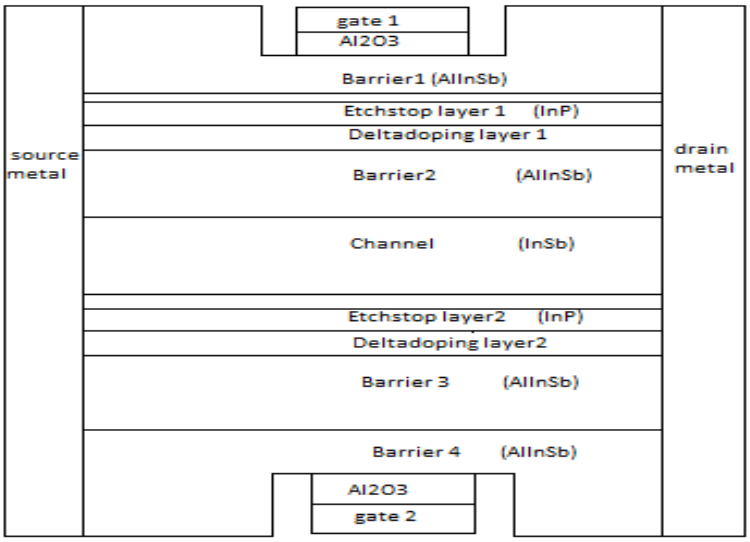

(b)

Figure1:(a) & (b) Schematic diagram of single gate &double gate symmetric MOSHEMT based on AlInSb/InSb

In Figure1 shows the schematic illustration of the device geometry. In single gate symmetric MOSHEMT grown on 100nm SiC substrate.The barrier1/barrier2 are $Al_{0.15}In_{0.85}Sb$ with 14nm/15nm dimensions. The donor sheet density of theδ-doping layer is constant as $2.0*10^{12}$ cm^2.An etchstop layer placed above the δ-doping layer with 5nm for the purpose of controlling the threshold voltage. The source/drain are fabricated in metal with 50nm length and 70nm height. The distance of Lsg and Lgd are 5nm .The Oxide layer(Al_2O_3) placed below the gate with 3nm thickness. In double gate symmetric MOSHEMT barrier3/barrier4 are grown below the channel with 14nm/15nm dimensions.

III . RESULTS AND DISCUSSIONS

In Figure2, shows the V_g and $I_d$at source to gate voltage at 0.5V for single and double gate symmetric MOSHEMT. From this plot the double gate drain current (I_d) is higher than compare to single gate symmetric MOSHEMT. In Figure 3,shows the V_g and Gm for V_{gs} at 0.5V. In double gate symmetric MOSHEMT achieve greater transconductance (G_m) than compare to single gate MOSHEMT. The $Al_{0.15}In_{0.85}Sb$
Barrier/buffer, the electron distribution into the barrier as source to gate voltage increases, because of shallower quantum well (QW) channel.

In fig4, which shows the measurement of cut off frequency(f_T) versus gate voltage. At drain voltage 0.5V, anf_T of 500GHz for single gate MOSHEMT and 750 GHz for double gate symmetric MOSHEMT. From fig 5, shows the AlInSb/InSb device shows the maximum oscillation frequency (f_{max}) at drain voltage 0.5V. The estimated f_{max}in InSb devices at V_d 0.5V for single gate & double gate symmetric MOSHEMT are 550 GHz and 950 GHz respectively.

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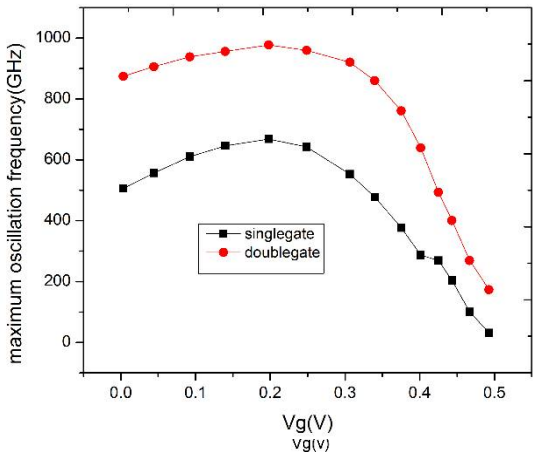

Figure 2 , V_g and I_d as a function of V_{gs} at 0.5 V for single & double gate symmetric MOSHEMT .

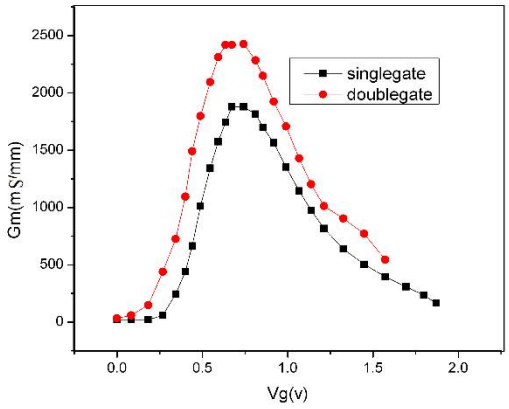

Figure 3, V_g and G_m function of V_{gs} at 0.5V for single & double gate symmetric MOSHEMT.

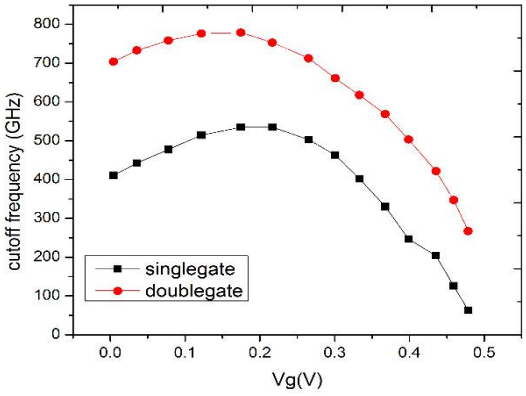

Figure4,cutoff frequency versus gate voltage of single & double MOSHEMT.

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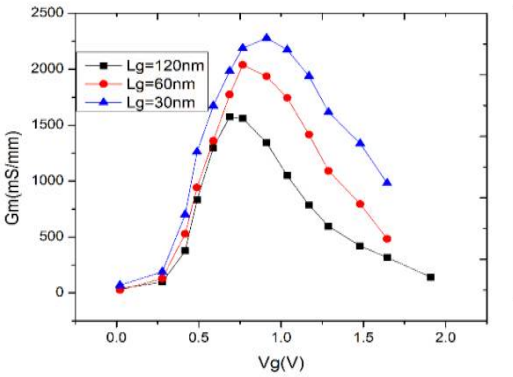
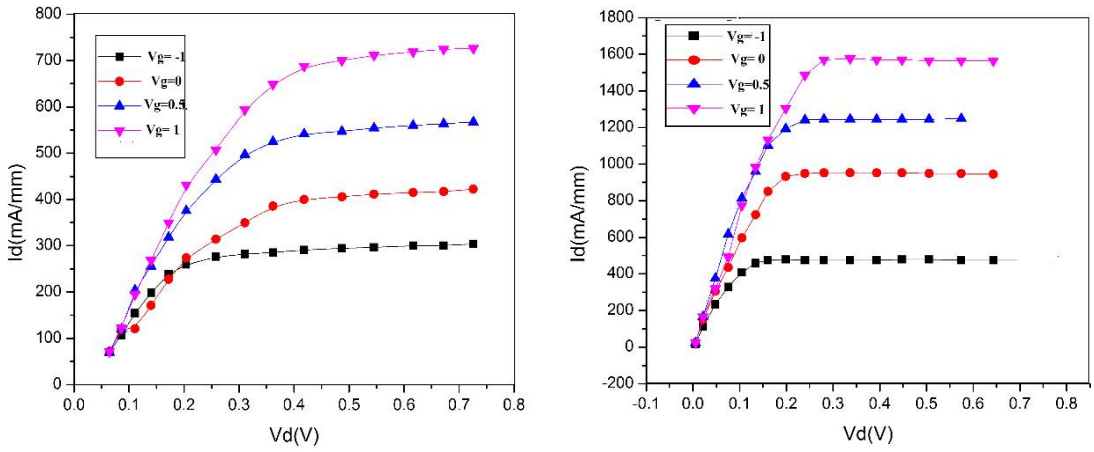


Figure5, maximum oscillation frequency versus gate voltage for single & double gate MOSHEMT.



(a) (b)

Figure6 : plot (a) and (b) shows the I_d versus V_{ds} characteristics of single & double gate MOSHEMT.

From fig 6, shows the InSb channel show I_d versus V_{ds} characteristics with Lg 30nm for single & double gate MOSHEMT at drain voltage 0.5 V. The gate voltage varies from -1.0 V to 1.0 V the corresponding drain current (I_d) increased in mA/mm. In this graph, the double gate MOSHEMT reaches the high drain current than single gate symmetric MOSHEMT. The device exhibits excellent pinch-off and drain current saturation behavior up to V_d = 0.7 V.

In fig 7,shows the V_g and G_m for different gate length at 0.5 V for single gate MOSHEMT. The different gate length the transconductance (G_m) increased. From the plot the different gate length are 120nm,60nm and 30nm the corresponding transconductance values are increased 900,1200 and 1400(mS/mm) respectively. In fig 8, shows different gate length at 0.5 V for double gate symmetric MOSHEMT. From the plot the different gate length are 120nm,60nm and 30nm the corresponding transconductance values are increased 1500, 2000 and 2250 (mS/mm) respectively. Compare to double gate transconductance value is greater this make our device technology attractive for high – performance and very low power application.

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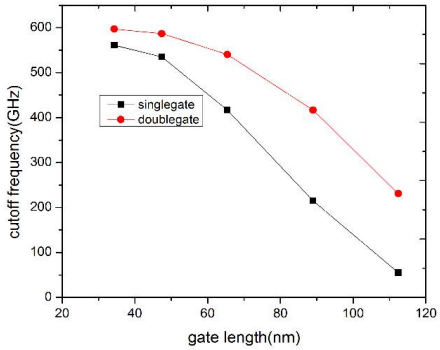

Figure 7, $V_g$versus G_m for different gate length at 0.5 V for single gate MOSHEMT.

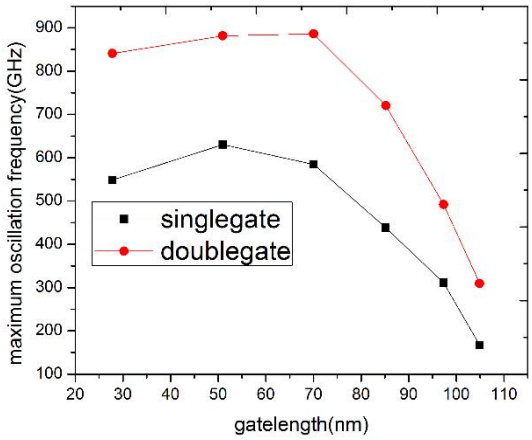

Figure 8, V_g and G_m for different gate length double gate MOSHEMT.

From fig 9, shows cutoff frequencies (f_T) versus different gate length in nm at drain voltage at 0.5V. In different gate length the cutoff frequencies are increased. From the plot the different gate length are 120nm, 90nm, 70nm, and 30nm the corresponding cutoff frequencies are 100GHz, 200GHz, 400GHz and 550GHz respectively. From the relation *ft=Gm/Cox* the transconductance (G_m) increased it leads to high cutoff frequencies.

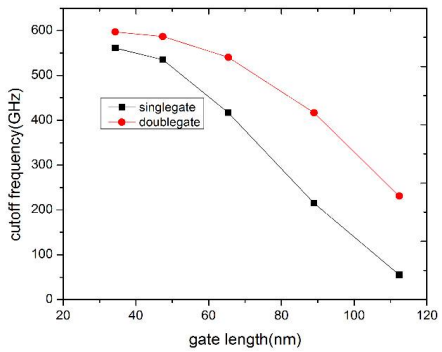

Figure 9,cutoff frequencies versus different gate length in nm at drain voltage 0.5V for single & double gate MOSHEMT.

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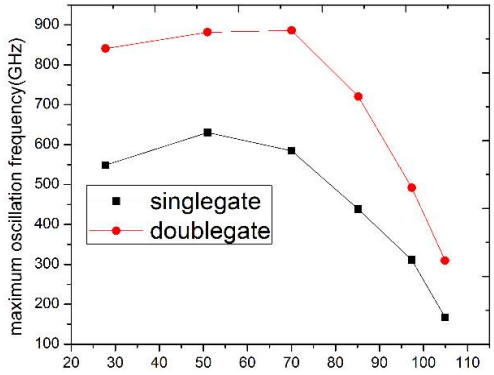

Figure 10, maximum oscillation frequency versus gatelength in nm at drain voltage 0.5V for single and double gate MOSHEMT.

In fig10, the f_{max}versus $V_g$at drain voltage 0.5 V for single and double gate symmetric MOSHEMT. In single gate the different gate length are 30nm, 70nm, 100nm and 110nm the corresponding f_{max} are 550GHz, 500GHz, 350GHz, 100GHz respectively. In double gate MOSHEMT the gatelength are reduced the frequencies are increased. The different gate length are 110nm, 100nm, 70nm, 30nm the corresponding frequencies values are 300GHz, 550GHz, 800GHz, 850GHz respectively.

IV. CONCLUSION

We have demonstrated InSb quantum well transistors down to 30nm gatelength with comparable high frequency performance to today's Si MOSFET's. The device exhibit excellent transfer and output characteristics to extract current voltage curves. Frequency analysis predicted a cutoff frequency f_T = 750GHz and a maximum oscillation frequency f_{max} = 950GHz for double gate symmetric MOSHEMT. In future work, according to Moore's law requires continuous scaling of Si MOSFETs. The physical gatelength of Si – transistors that are utilized is about 100nm. It is expected that critical dimension will reach about 10nm in the future to improve the transfer, output and RF characteristics of these devices to improve the high performance with low power.

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