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Design and Fabrication of AlGaAs/GaAs MESFET for Minimizing Leakage Current

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Abstract

To develope output characteristics of GaAs MESFET, which utilized in high frequency ranges, $Al_{0.2}Ga_{0.8}As/GaAs$ layer was used.

In this case, to minimize effects of deep-level in $Al_{0.2}Ga_{0.8}As/GaAs$ layer, aluminium mole fraction was design to 0.2.

HP 4145B was used in measurement, I_{dss} was 25mA when $V_G=0$. Maximum transconductance was 168.75mS/mm, electron mobility was 3750 cm^2/V-s, therefore, it must be suitable for active device in MMIC. Also, Ideality factor was 1.26, which was similar to that of ideal schottky diode.

I. INTRODUCTION

In 1971, Turner proposed GaAs MESFET, that has used in high frequency application devices since it has fast electron mobility and velocity.[1]

Especially, as the uses of satellite broadcasting system and celluar phone operating in high frequencies has been wide, it has been necessary more and more for device of small size to operate in maximum high speed using minimum power.

GaAs devices have 6~times fast mobility and twice fast electron velocity than silicon devices, so, it is suitable for device which has above characteristics.[2]

But, GaAs MESFET has a few serious problems since it was composed of compound elements, while it has outstanding electron properties.

Especially, it shows leakage current, which lead to bad output characteristics and noise figure in high frequency range, because it does not have insulating layer, and consists of multi-layers.

To minimize this bad effects, we used AlGaAs/GaAs layer instead of GaAs/GaAs.

Electron leakage components were decreased because $Al_xGa_{1-x}As$ layer has wide bandgap(about 1.69eV when x=0.2).

Therefore, we fabricated device using AlGaAs/GaAs layer, focusing on reducing leakage current and developing DC characteristics.

Ⅱ. STRUCTURE CHARACTERISTICS

The issue of this experiment is to reduce leakage current in GaAs MESFET.

So, we fabricated MESFET by inserting 1500nm $i-Al_{0.2}Ga_{0.8}As$ buffer layer between n-GaAs and i-GaAs.

GaAs/GaAs MESFET increases in all saturation region as V_{ds} increases. It is caused by leakage current through i-GaAs buffer layer if n-type active layer is depleted completely, and leakage current to the gate is very little.

This current reduce output characteristics, therefore, power gain and f_{max} is reduced.[3]

AlGaAs layer was utilized to prevent leakage current, to develop output characteristics, because AlGaAs has wider bandgap than GaAs.

Also, since AlGaAs layer has large resistance, it prevents carriers which flows into active layer. And we can obtain high output characteristics because i-AlGaAs layer has low saturated velocity caused by low mobility even if current flows into AlGaAs.[4]

Also, AlGaAs has deep-levels when Al mole fraction is more than 0.3 because of its unique band structure. It causes to collaspse I-V chracteristics, to shift threshold voltage, to make persistent photoconductivity effect.[5]

Therefore, we made device that had 0.2 mole fraction to prevent leakage current and to minimize deep level effects.

Ⅲ. FABRICATION PROCESS

In this experiment, we grew epi-layer under optimum conditions by MOCVD.

First of all, we cleaned S.I.-GaAs(100) substrates of 600㎛ depth, and grew GaAs layer and AlGaAs layer on it by MBE technique, and grew GaAs active layer.

Next, we made metal electrode, and then fabricated AlGaAs/GaAs MESFET completely.

The growth rate was set about 0.7㎛/hr.

First, in order to isolate devices, we etched 4000Å by mesa method with $1NH_4OH : 1H_2O_2 : 100H_2O$ solution and then isolated by implanta with boron.

And then, we evaporated AuGe/Ni/Au alloy on drain and source electrode and then lifted off for ohmic condition.

That process was following; photolithography -> evaporation -> lift-off -> Alloy.

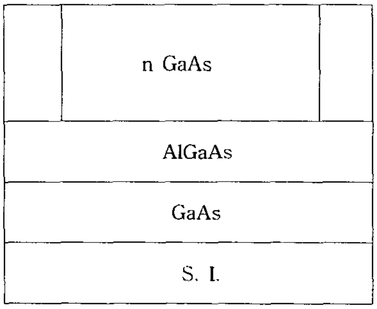
Next, gate was recessed by $1NH_4OH : 1H_2O_2 : 500H_2O$ solution until the value of ungated I_{dss} equaled to 60mA.

Then, to minimize gate resistance, we evaporated Ti/Pt/Au alloy on gate electrode and then lifted off.

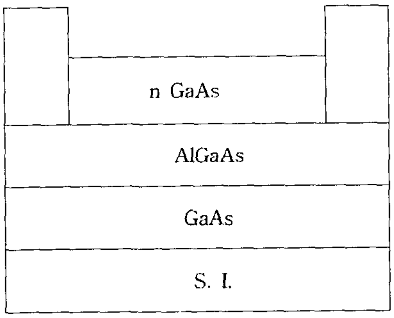
* Device Processing *

n+ GaAs	1×10^{17}	1000Å
$Al_{0.2}Ga_{0.8}As$	undoped	15000Å
GaAs	undoped	5000Å
Semi-Insulating		600㎛

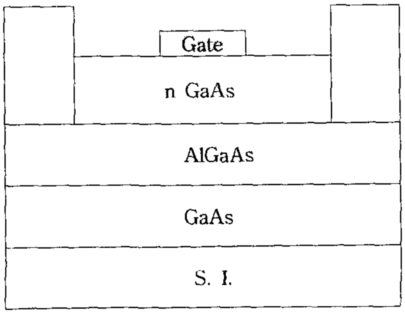
(a) Etching and Isolation



(b) Ohmic Electrode Metal



(c) Gate Recess



(d) Gate Electrode Metal

IV. EXPERIMENTAL RESULTS

Basically, device properties were measured by HP4145B parameter analyzer.

The DC-chracteristics of π-gate AlGaAs/GaAs MESFET(L_g= 1μm W= 320μm) were following;

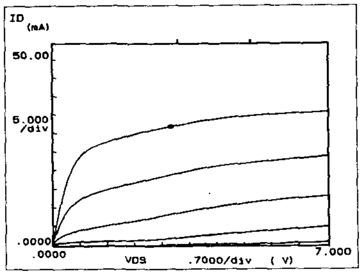


Fig. 1. AlGaAs/GaAs MESFET I-V Curve.

I_d -V_d curve was shown in Fig 1, we observed high saturation current and qualifying curve.

It has seemed to be a result of being prevented leakage current by AlGaAs layer that I_d-V_d curve didn't have a big slope.

The variation of saturation points in drain current was observed in 0V~-1.2V of gate voltages because it was fabricated as depletion mode device.

In details, the drain saturation current was 25mV when V_G=0V, and mark showed drain current of 3V(drain voltage)

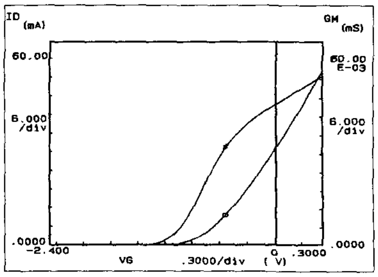


Fig. 2. AlGaAS/GaAs MESFET G_m Curve

In Fig. 2. maximum transconductance was 170mS/mm, transconductance was 150mS/mm when V_G=0. The capacitance, which was dependent on doping concentration when gate voltage was zero, was about $1.2\times10^{-4}(F/m^2)$, therefore electron mobility was calcurated as $3750cm^2/V$-s, this value was similar to that of general compound semiconductor switching devices, so it seemed to be suitable for GaAs device of MMIC.

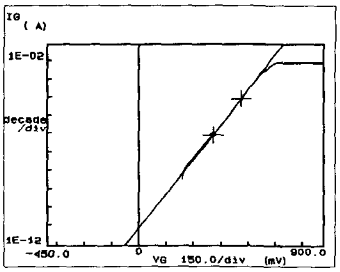


Fig.3. AlGaAs/GaAs MESFET Ideality Factor

In Fig. 3. ideality factor was 1.26, which was very similar to that of ideal schottky diode, by means of analyzing I_G-V_G curve. The useful voltage range was suitable for being below 225mV of gate voltage, because leakage current flowed toward gate at 225mV in the Fig. 3.

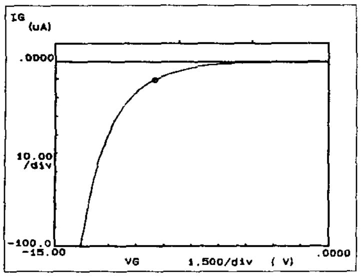


Fig. 4. AlGaAs/GaAs MESFET -
Breakdown Voltage

In Fig. 4. gate-source breakdown voltage was about -9.5V if -10μA was defined as standard current. Device parameters were listed as following in details;

Table 1. AlGaAs/GaAs 1㎛-gate MESFET Electrical Chracteristics

SYMBOL	PARAMETER	CONDITION	VALUE
I_{DSS}	**Saturated Drain Current**	V_G = 0V	*25mA*
$I_{DS.Sat}$	**Saturated Drain Current**	V_G = -0.3V	*11mA*
		V_G = -0.6V	*2mA*
V_{PO}	**Pinch-off Voltage**	V_G = 0V	*0.8V*
		V_G = -0.3V	*0.5V*
		V_G = -0.6V	*0.2V*
$G_{m.max}$	**Maximum Transconductance**	V_G = 0.3V	*168.75mS/mm*
G_m	**Transconductance**	V_G = 0V	*150mS/mm*
μ	**Mobility**	V_D = 3V	*3750cm²/v-s*
$V_{G.cut-off}$	**Drain Current Gate Cutoff Voltage**	I_D = 0A	*-1.2V*
η	**Ideality factor**	$\eta = \frac{q}{kt} \frac{dV}{d(\ln I)}$	*1.263*
I_{GSS}	**Gate to Source Leakage Current**	V_{GS} = 225mV	*1E-09A*
BV_{GS}	**Gate to Source Breakdown Voltage**	I_{GS} = -10μA	*-9.56V*

V. CONCLUSION

For the purpose of upgrading output characteristics, we designed GaAs/$Al_{0.2}Ga_{0.8}As$ structure MESFET to use in high frequency range without noise figure, to prevent electron carriers flowing into epi-layer . The DC-characteristics of 1㎛-gate MESFET were displayed on Table 1.

I_{dss}=25mA when V_G=0, $G_{m.max}$ was 170mS/mm, Gate-Source breakdown voltage was -9.56V. Also, electron mobility was 3750 cm^2/V-s, ideality factor was 1.26.

Device, which has a AlGaAs layer, was fabricated for low-noise MESFET in this experiment, we obtained output characteristics that was similar to that of general devices.

It will be a futherwork for upgrading power gain and incresement of maximum useful frequency that electrode metal, and material preventing leakage current completely is developed.

References

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