Extended Abstracts of the 2001 International Conference on Solid State Devices and Materials, Tokyo, 2001, pp. 338–339

E-4-3

A Novel HBT with Composite Collector for Power Amplifier Application

Shih-Tzung Su, Kao-Way Tu, Ching-Lin Cheng, Feng-Tso Chien,
Tuo-Hsin Chien, Jen-Huei Dung, and Yue-Ming Hsin[1],
R&D DEPT, Chino-Excel Technology Corp. ,Chung-Ho,Taiwan ,R.O.C.
Phone:886-2-22233315ext.303 Fax:886-2-22233332 E-mail:Peter_Su@cetsemi.com
[1]Department of Electrical Engineering, National Central University, Chung Li, Taiwan 320, R.O.C.

1. Introduction

AlGaAs/GaAs and InGaP/GaAs Heterojunction bipolar transistor (HBT) had been widely used for high-speed, analog/microwave, and analog-to-digital conversion applications. It is also known that the Double Heterojunction bipolar transistors (DHBT) become more and more important HBT devices, owing to the use of a wide-bandgap material in the collector. DHBT provides higher breakdown voltage, lower Offset voltage and suppress the recombination current, which increases the current gain (β) and reduces the charge storage time ,therefore increasing the speed of the transistor switching application.[1] In addition, narrow band-gap material provides high electron mobility, which can reduce the on-resistance and transit time. In this work, we use a composite collector combines with wide-bandgap (AlGaAs/InGaP) and narrow-bandgap (GaAs) material to implement the HBT. At first, the simulation is done by two-dimensional simulator (MEDICI), and then the conventional (non self-aligned) process technology was used for the HBT device.

2. Device Structure and Fabrication

The Epi-structure of a novel composite collector HBT is shown in Fig.1.A 200 Å undoped GaAs and a 200 Å high n-type doping AlGaAs layer were used to reduce the conduction band barrier at base-collector junction, which can increase the electron tunneling probability through the barrier[2][3]. The breakdown voltage (BV_{CBO}) with different thickness of GaAs in collector was simulated and shown in Fig.2, and fig.3 shows the simulated RF performance with different GaAs thickness. According to the simulation and experiment results, the novel composite collector HBT shows the benefits of higher breakdown voltage (wider operation range for power amplifier) and lower offset voltage, lower on-resistance(thus increasing power-added-efficiency).

3. Result and Discuss

The novel composite collector HBT, which collector thickness are AlGaAs 500Å and GaAs 3500Å had been fabricated and characterized (Sample A). Another composite collector HBT (InGaP/GaAs:500/3500Å) had also been fabricated and characterized (Sample B). Fig.4, shows the common-emitter I-V characteristics of sample A. Using a wide bandgap material (InGaP) in the collector, the results are also as we expected. The novel Epi-layer structure of InGaP/GaAs composite collector HBT is shown in fig.5. The Measured I-V characteristics for all devices are shown in Fig.6. The power performance of sample B is shown in Fig.7. A novel AlGaAs/GaAs composite collector (d=3500 Å) HBT, has the results of ΔV_{CE}=0.12 V, BV_{CBO}=17.35 V, f_T=18 GHz, f_{max}=20 GHz. Another novel InGaP/GaAs composite collector (d=3500 Å) HBT, has the results of ΔV_{CE}=0.12 V, BV_{CBO} =18 V, f_T=30 GHz, f_{max}=24 GHz. The power performance of sample B are 21.8 dBm for $P_{out,max,}$ and 48.2% for PAE_{max}. The total results are summarized in Table(I),(II).

4. Conclusion

The novel composite collector HBT, which combines with wide-bandgap (AlGaAs or InGaP) and narrow-bandgap (GaAs) material in collector, have been simulated and fabricated. The improvement in on-resistance is attributed to the high electron mobility from GaAs. The trade-off between Breakdown Voltage and Cut-off frequency can be designed depending on circuit application. The higher BV, f_T , f_{max} of sample B are benefit for device RF power performance.

References

[1]P. M . Abseck, R.L. Pierson, P.F. Chen.IEEE Trans. Microwave Theory and Techniques 1999;47(8):1433-1438

[2]E. Tokumitsu , A.G. Dentai, C.H.Joyner, Appl. Phys. Lett. 1990 ;57:2841-2843

[3] Yue-Ming Hsin, Shih-Tzung Su, Chang-Chung Fan Appl. Phys. Lett. 2000:77:1538-153

Table (I) Novel AlGaAs/GaAs with Composite Collector HBT

AlGaAs composite Collector	SHBT(d=4000Å)	DHBT(d=0 Å)	Sample A(d=3500 Å)
$V_{CE,\ offset}$ (V)	0.15	0.03	0.12
BV_{CBO} (V)	15.7	26	17.35
f_T (G Hz)	22.3	16.5	18

Table (II) Novel InGaP/GaAs with Composite Collector HBT

InGaP Composite Collector	SHBT	NEW DHBT	DHBT
Ron(Ω)	17.5	20.5	24.6
R_B+R_C(Ω)	12.1	15.2	19.5
$V_{CE,\ offset}$(V)	0.16	0.12	0.12
BV_{CBO}(V)	14	28	31

Structure	Type	Doping concentration(cm^{-3})			Thickness
Cap layer	N	InGaAs	In:0.5	1E19	400 Å
	N	InGaAs	In:0~0.5	1E19	400 Å
	N	GaAs		5E18	1200 Å
Emitter	N	AlGaAs	Al:0.25~0	4E17	200 Å
	N	AlGaAs	Al:0.25	4E17	600 Å
Base	P	GaAs		4E19	800 Å
	undoped	GaAs			200 Å
	N	AlGaAs	Al:0.25	5E17	200 Å
Collector	N	AlGaAs	Al:0.25	3E16	4000-d Å
	N	GaAs		3E16	d Å
	N	GaAs		5E18	4000 Å
S.I GaAs Substrate					

Fig.1 Epi-structure of AlGaAs/GaAs novel composite collector HBT

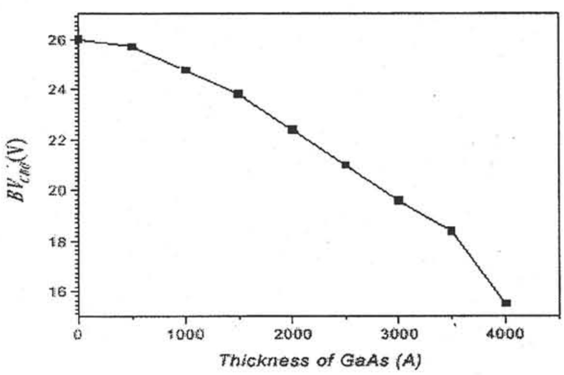

Fig2.BV_{CBO} for AlGaAs/GaAs DHBT with different thickness Of GaAs in collector (simulated)

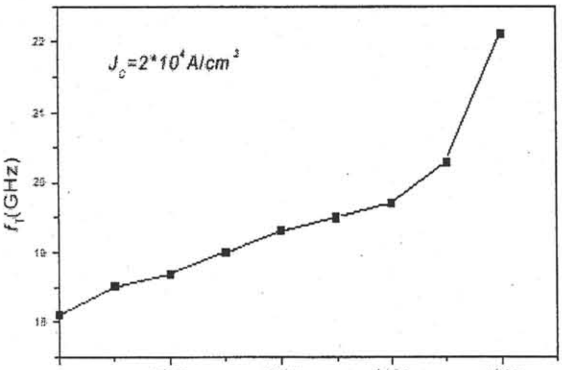

Fig.3.The cutoff frequency with different GaAs thickness(simulated)

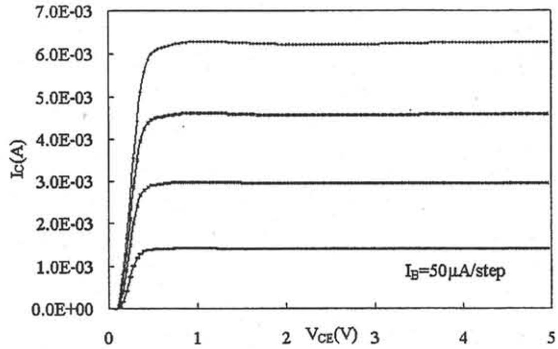

Fig4.The Measured I-V characteristics (SampleA,A_E=80x80μm^2)

	SHBT	Modulation -DHBT	DHBT	Doping Concentration	Thickness (Å)
Emitter Cap	InGaAs	InGaAs	InGaAs	1E+19	400
	InGaAs	InGaAs	InGaAs	1E+19	400
	GaAs	GaAs	GaAs	5E+18	1200
Emitter	InGaP	InGaP	InGaP	5E+18	300
	InGaP	InGaP	InGaP	4.6E+17	600
Base	GaAs	GaAs	GaAs	4E+19	500
Spacer		GaAs	GaAs	Undope	200
		InGaP	InGaP	5E+17	200
Collector	GaAs	InGaP	InGaP	3E+16	3000
	GaAs	GaAs	InGaP	3E+17	3500
Sub-Collector	GaAs	GaAs	GaAs	5E+18	6000
Substrate					

Fig5. The novel Composite collector (InGaP/GaAs) Epi-structure

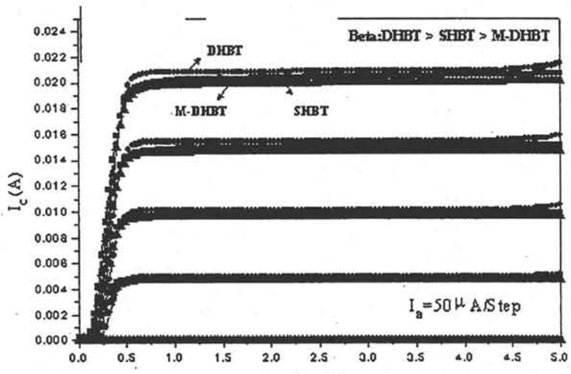

Fig.6.Measured I-V characteristics of three different InGaP/GaAs HBT(A_E=80x80μm^2)

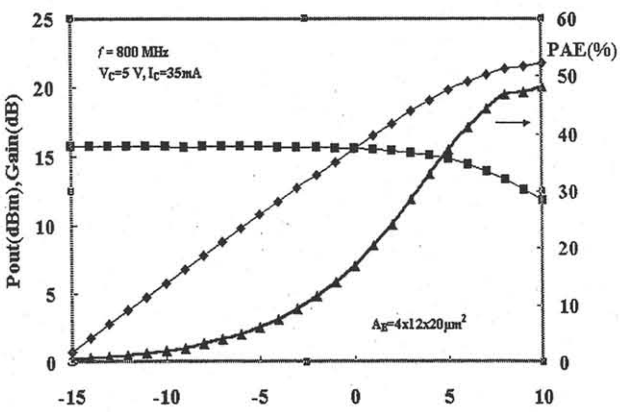

Fig7. Measured Pout,PAE vs Pin (Sample B)