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A Trial of Dual Emitter HBT for MMIC Power Amplifier Application

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1. Introduction

We designed the several structures of InGaP/GaAs HBTs, and analysis their performance in the aspect of thermal limitation and power density. Structural optimization of unit HBT device for both power capability and controlled thermal dissipation is one of key issues for power amplifier development. In this work, we have devised a new emitter/base finger structure of InGaP/GaAs HBT, and evaluated the current drivability, heat dissipation and power gain performance comparing with conventional emitter/base structure.

2. General Characteristics

In order to achieve high current reliability HBTs were designed with InGaP/GaAs hetero-junction of which epitaxial structure was optimized for high breakdown voltage: BV_{CBO} above 25 V and BV_{CEO} above 15V. The structure of emitter and base fingers were designed aiming high current density per unit chip area, reduced base-collector capacitance, and relaxed thermal concentration. We fabricate the variable structure of unit cell, such as dual emitter HBT composed of 1 base finger 2 with emitter fingers (1B2E) and conventional HBT composed of 2 base fingers with 1 emitter finger (2B1E) [1]. Fig. 1 shows the planar view of the proposed unit cell of the HBT, 1B2E, where two fingers of emitter surround a base finger. The unit cell repeats every 27.5 um and carries 11.7 mA, while conventional 2B1E repeats every 26.5 um and carries 5.8 mA at V_{BE}=1.4 V and V_{BC}=0 V, as shown in Fig.2.

3. Thermal Characteristics

The approximated form of heat generation in the devices has the following form, [2]

$$H \approx \left[\frac{\left|\overrightarrow{J_n}\right|^2}{q\mu_n n} + \frac{\left|\overrightarrow{J_p}\right|^2}{q\mu_p n} \right] \qquad (1)$$

This equation means that high temperature region is the collector layer and means the extrinsic area of HBT is not hotter than intrinsic area because the ionized impurity scattering is dominant in collector region by high electric field. This is the reason why the 1B2E structure's temperature is lower than 2B1E structure's. Fig.3a and Fig.3b show cross-sectional view of thermal distribution for each type of unit cell while I_c=235 uA/um^2 (collector current density) at V_{CE}=2 V. As shown in these simulation results, the emitter crowding effect is occurred when device has large emitter width and heavily doped base, like devices for power amplifier applications [3, 4]. Also this simulation result reveals that the maximum temperature of 1B2E structure is lower than that of 2B1E structure by 12K, 332 K and 344 K respectively. Because of high lattice temperature of 2B1E unit cell, 2B1E structure has poor thermal stability. The 2B1E array has current gain collapse at 6.2 V of V_{CE} and i_b=480 uA as indicated by ellipses while 1B2E array does not show current gain collapse below 8V of V_{CE}. The 2B1E structure shows current gain collapse below 8 V even as low as 252 uA of collector current density as shown in Fig .4. This result provides good evidence for the thermal stability of the array composed of three 1B2E HBTs, current capability and less influenced behavior by thermal limitation due to the low temperature profile.

4. Power Gain Performance

Fig. 5 shows that the array composed of 3 1B2E unit cell has maximum available gain of 16.4 dB at about 2 GHz while the stability factor, k keeping larger than 1 through 50MHz ~ 40GHz[5]. This result shows better power gain by 2.5 dB than the array of 3 conventional 2B1E unit cell. as suitable performance for small size power amplifier at 300 uA of total base current.

5. Conclusion

We examine two structures of HBT for power amplifier application. The simulation result shows good evidence that thermal characteristic of 1B2E structure is superior to 2B1E structure because the maximum temperature of 1B2E is lower than that of 2B1E at 235 uA/um^2 of collector current density. Also the measured data of array with three 1B2E unit cells is not apt to occur current collapse compared with 2B1E array. Also it's power gain performance at 2 GHz shows good potentialities for chip size reduction of the monolithic power amplifiers. Additionally these collector currents are proportional to emitter area, the collector current density of 1B2E is about 2 times of the 2B1E structure's current. From results of our research, we believe that the proposed 1B2E structure shows optimized thermal properties and power performance for power amplifier application.

Acknowledgments

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References

[1] B. Bayraktaroglu and J. A. Higgins *"HBTs for Microwave Power Applications"*, in *Current Trends in Heterojunction Bipolar Transistors*, M. F. Chang, eds. World scientific Publishing Co, 1996, pp 153-218

[2] Robert Anholt, *"Electrical and Thermal Characterization of MESFETs, HEMTs, and HBTs,"* Artech, 1994.

[3] William Liu, *"Handbook of III V Hetero-Junction Bipolar Transistor,"* JOHN WILLY & SONS, 1998.

[4] Lee L. Liou, *IEEE transaction on ELECTRON DEVICES*, Vol. 40, No.1, pp. 35-43 (1993).

[5] Guillermo Gonzalez, *"Microwave Transistor Amplifiers,"* Prentice Hall, 1997.

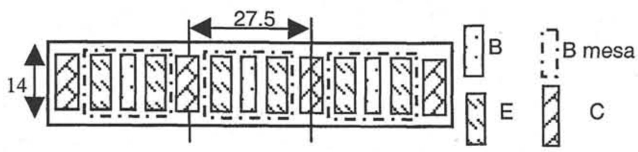


Fig. 1 Planar view of the proposed HBT array composed of three 1B2E unit cells; unit cell of 1B2E structure is larger than 2B1E structure by 1 um x 14 um.

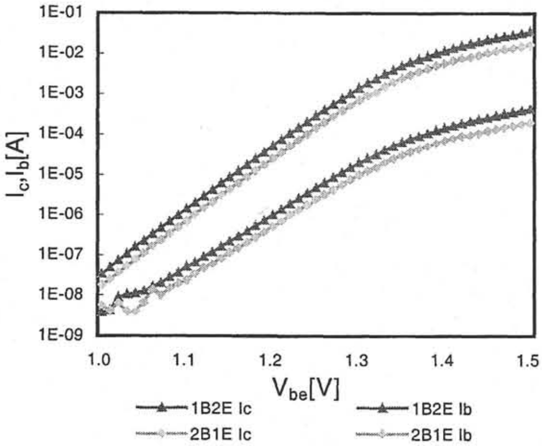
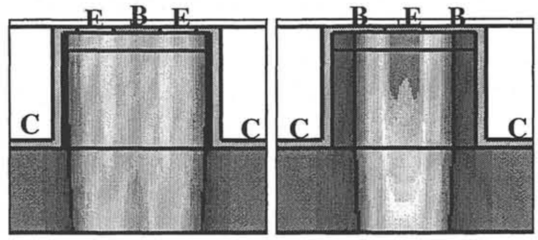


Fig. 2 I_C-V_{BE} plot of 1B2E and 2B1E structure



a) b)

Fig. 3 simulation results of thermal distribution at 0.24 mA/um^2 of collector current a) 1B2E structure; this result shows that the lattice temperature splits below the each emitter finger due to emitter crowding effects, b) 2B1E structure; this result shows that the lattice temperature coupled below the emitter finger.

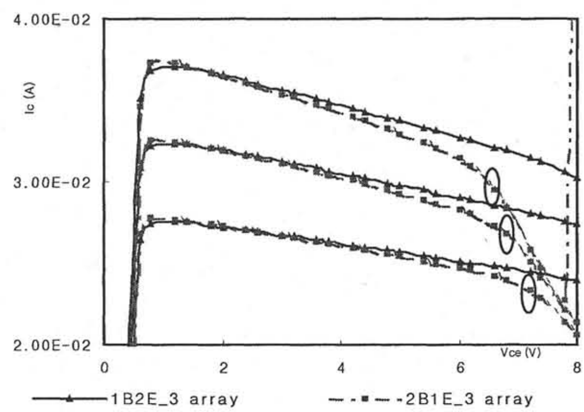


Fig. 4 Measured data of array with 3 unit cell, I_B step= 60 uA, from 360 ~480 uA; ellipses show those starting points of current gain collapse for each base input current.

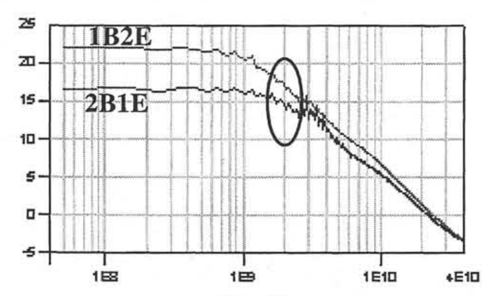


Figure 5. The simulated maximum stable gains (K>1) for 3 unit cells of 1B2E and 2B1E structure using measured data for unit cells