A New Design Method for Emitter Finger Space of Heterojunction Bipolar Transistors

Chuantao Ma[1, a]
[1]College of Physics and Electronic Engineering, TaiShan University, TaiAn, China
[a]mcht1016@163com

Keywords: Heterojunction bipolar transistors, silicon–germanium, segmented emitter, thermal stability.

Abstract: A new design method for emitter finger space of multi-finger HBT was proposed to improve thermal stability of HBT. The 3-D temperature distribution, cross section temperature distribution, cross section temperature gradient distribution of five-finger power HBT with traditional emitter structure and non-uniform emitter finger space structure at the same dissipation power are given. Compared with 3-D temperature distribution and cross section temperature distribution, the difference between traditional emitter structure and non-uniform emitter finger space structure is more distinctive, so the cross-section temperature gradient distribution is more effective for the design technique of non-uniform finger spacing of multiple finger power HBT.

1 INTRODUCTION

Heterojunction bipolar transistors (HBT) has become increasingly popular in power amplifiers for wireless communications and microwave applications because of its high-speed performance, low-noise, high cutoff frequency and compatibility with BiCMOS technology (S. P. McAlister, et.al, 2004; Wang Y, et.al, 2007; A Schuppen, et.al, 1995; C Kermarrec, et.al, 1994). HBT usually employ a multi-finger structure to improve the current handling capability and thermal dissipation capability. However, self-heating effects caused by the temperature rise due to the power dissipation and thermal coupling effects among emitter fingers result in a higher temperature at the center fingers. Because of the positive temperature coefficient of emitter current, the center fingers conduct more current and consequently generate more heat, which eventually makes the device to become unstable at high power and seriously limit the power handling capability of the device.

In order to get high thermal stability under high power dissipation, one method of non-uniform finger spacing is usually proposed. Analytical and experiment are used to investigate thermal behavior of multiple finger heterojunction bipolar transistors (HBT's) with the non-uniform mitter-finger spacing. For the non-uniform finger spacing HBT, the heat flow from adjacent to the center finger is reduced by increasing the spacing between fingers. It is shown that the HBT with non-uniform finger spacing have lower peak temperature in the device center, smaller temperature difference between fingers compared with HBT with uniform finger spacing under the same power dissipation. These results indicate that the method of non-uniform finger spacing is very useful for getting the HBT with high thermal stability. But it is difficult to get Suitable emitter finger space of multi-finger HBT using a comprehensive model for the multi-finger HBT including the effects of temperature dependence of thermal conductivity, and non-uniform, two-dimensional temperature distribution on the emitter fingers.

In this paper, a 3-D thermal simulation is performed by the finite element method (FEM) in ANSYS (A Schuppen, et.al, 1996; P A Potyraj, et.al, 1996; W. Liu, B. Bayraktaroglu, 1993; Willian Liu, Ali Khatibzadeh, and Jim Sweder, 1996; J. -S. Rieh, et.al, 2002; Jae-Sung Rieh, et.al, 2005). The results of simulation show that temperature gradient can be used to support a new method for the design of emitter finger space of HBT.

Ma, C.
A New Design Method for Emitter Finger Space of Heterojunction Bipolar Transistors.
DOI: 10.5220/0008865203980401
In *Proceedings of 5th International Conference on Vehicle, Mechanical and Electrical Engineering (ICVMEE 2019)*, pages 398-401
ISBN: 978-989-758-412-1
Copyright © 2020 by SCITEPRESS – Science and Technology Publications, Lda. All rights reserved

2 THEORY

Figure.1 shows the bulk heat flux distribution of multi-emitter HBT through the ANSYS finite analysis software. When the HBT is working, the temperature will gradually rise. The heat will send out from the chip to the outside. When the temperature don’t rise, the transistor achive a thermal stable state. According to the theory of heat conduction, the heat flux will move from the area of the high temperature to the area of the low temperature. Therefore, two adjacent emitter fingers with the same power have the same heat flux condition. The temperature of intermediate point is the highest. The heat flux downward conduction after meeting. The heat flux no longer disperse to the two sides. we establish the thermal resistance model as shown in Figure.2.

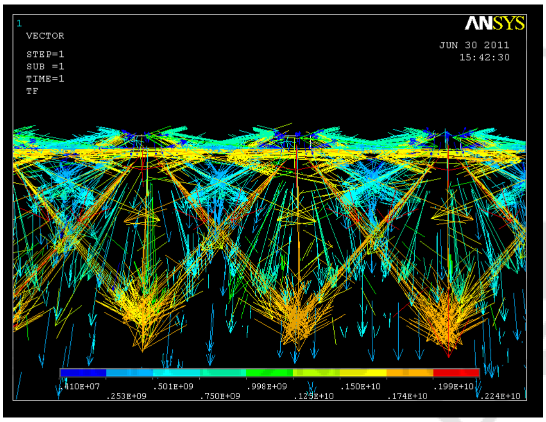

Figure 1. Bulk heat flux distribution of multi-emitter HBT.

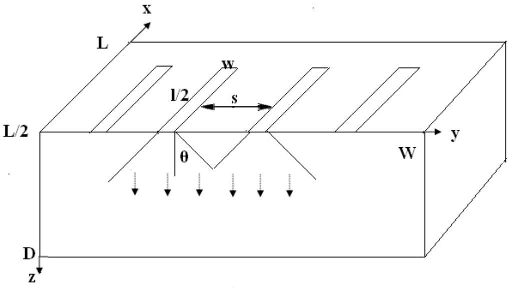

Figure 2. The thermal resistance model of a multi-finger HBT.

The device discussed in this study mainly consists of two parts: active region and substrate as shown in Fig. 3 (P A Potyraj, et.al, 1996; W. Liu, B. Bayraktaroglu, 1993; Willian Liu, et.al, 1996). Heat dissipation originates from the base-collector junction, and through two opposite directions: upward through emitter fingers and downward through substrate. For the downward case, since the thickness of collector layer is small enough compared with the substrate, the thermal resistance of substrate (Rths) was only considered. The upward dissipation can be accounted as two pieces of thermal resistor (Rthe and Rthb) representing the thermal resistance from emitter and base, respectively. The thermal resistance of the device can be expressed as a series combination of partial thermal resistances from very thin slabs along the heat flux:

$$R_{th}=\sum_i R_{th,i}=\sum_i \frac{t_i}{k_i A_i} \qquad (1)$$

Where Rth is the thermal resistance, k is the thermal conductivity of the medium, A is the effective area of the heat conduction, t is the thickness of the thin slab, and i is the number of the slabs.

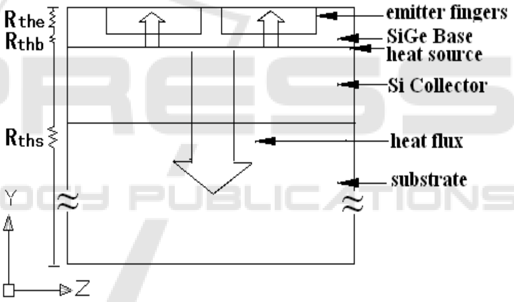

Figure 3. Cross-section of SiGe HBT showing heat flux, heat source, and thermal resistance components.

The thermal resistance for the device can be calculated from maximum temperature and dissipation power:

$$R_{th}=\frac{T_{\max}-T_0}{P_{diss}} \qquad (2)$$

Where Tmax is the maximum temperature of the device, T0 is ambient temperature.

3 RESULTS AND DISCUSSION

In order to make sure the precision of the simulation, there are two important steps in the thermal simulation: substrate simulation and active region simulation. The stepped simulation avoids the negative effect of the huge disparities of dimension among each part (the thickness of emitter is 200nm whereas it is up to 150mm for the substrate), ensures the view of the 3-D thermal distribution in active region clearly. For the first step, the model contains heat source, collector layer, and substrate. We apply the boundary temperature to the bottom of substrate and dissipation power to the B-C junction. It was assumed that the operating temperature of substrate is ambient temperature at 300K. In second step, the model of the active region consists of three parts: emitters, base and collector. The dissipation power is determined by collector current (Ic) and supply voltage (Vce). In SiGe HBT device, collector current must be less than Icritical which is the critical collector current before current gain collapse occurs.

The 3-D temperature distribution, cross section temperature distribution, cross section temperature gradient distribution of five-finger power HBT with traditional emitter structure and non-uniform emitter finger space structure at the same dissipation power are shown in Fig.4- Fig.6

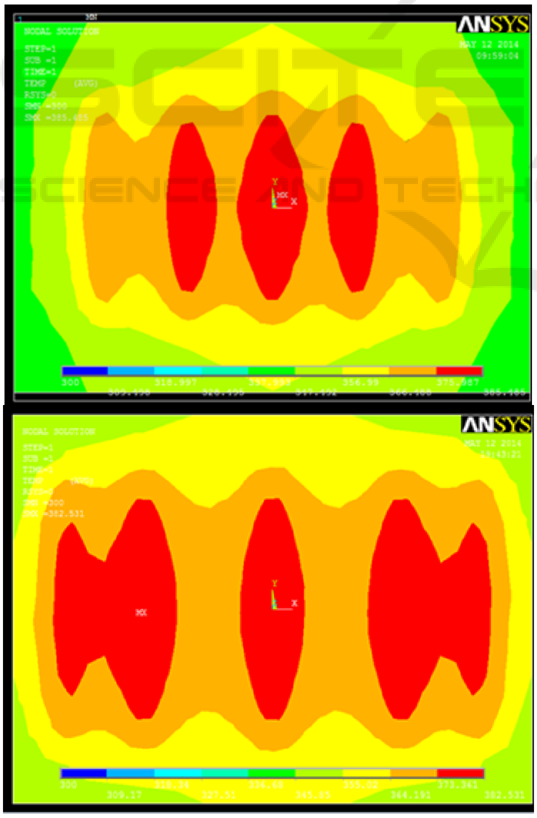

Figure 4. The 3-D temperature distribution of five-finger HBT.

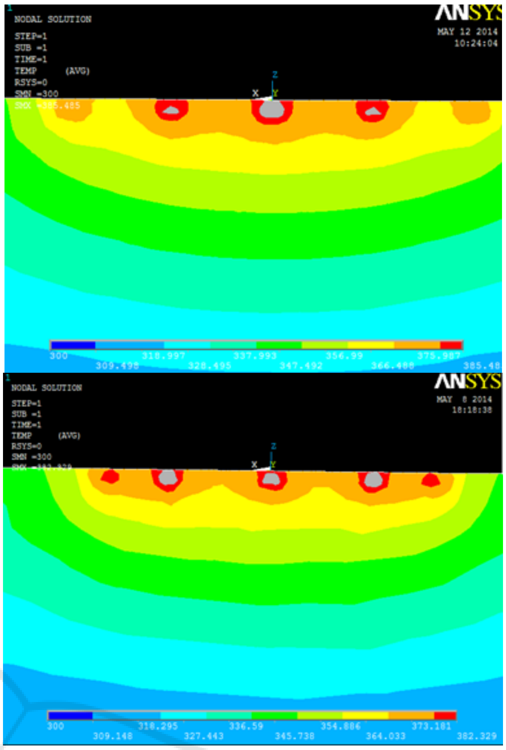

Figure 5. The 3-D cross section temperature distribution of five-finger HBT.

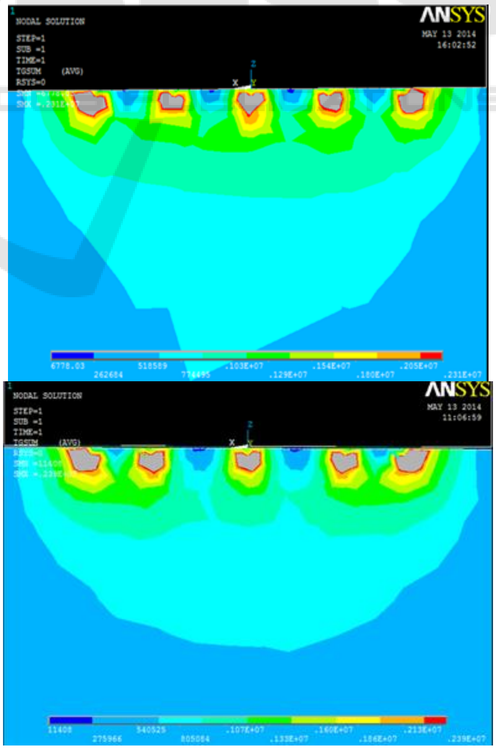

Figure 6. The 3-D cross section temperature gradient distribution of five-finger HBT.

SCITEPRESS
SCIENCE AND TECHNOLOGY PUBLICATIONS

4 CONCLUSIONS

In this paper, the 3-D temperature distribution, cross section temperature distribution, cross section temperature gradient distribution of five-finger power HBT with traditional emitter structure and non-uniform emitter finger space structure at the same dissipation power are given. Compared with 3-D temperature distribution and cross section temperature distribution, the difference between traditional emitter structure and non-uniform emitter finger space structure is more distinctive, so the cross section temperature gradient distribution is more effective for the design technique of non-uniform finger spacing of multiple finger power HBT.

REFERENCES

A Schuppen, U Erben, A Gruble. Enhanced SiGe HBT with 160Hz-fmax[C]. IEEE International Electron Devices Meeting Technical Digest, 1995: 743-746.

A Schuppen, S Gerlach, H Dietrich, et al. 1-W SiGe Power HBT's for Mobile Communication [J]. IEEE Microwave Guided Wave Letters, 1996, 6(9): 341-343.

C Kermarrec, G Dawe, T Tewksbury. SiGe Technology: Application to Wireless Digital Communications [J].IEEE Microwave and Millimeter Wave Monolithic Circuits Symposium. 1994: 1-4.

Jae-Sung Rieh,David Greenberg, Qizhi Liu, Alvin J. Joseph, Greg Freeman, and David C. Ahlgren, "Structure Optimization of Trench-Isolated SiGe HBTs for Simultaneous Improvements in Thermal and Electrical Performances," IEEE Trans. Electron Devices, vol. 52, no. 12, pp. 2744-2752, December 2005.

J. -S. Rieh, J. Johnson, S. Furkay, D. Greenberg, G. Freeman, and S. Subbanna, "Structural Dependence of the Thermal Resistance of Trench-Isolated Bipolar Transistors," IEEE BCTM, pp. 100-103, 2002.

P A Potyraj, K J Petrosky, K D Hobard. A 230-Watt SiGe HBT [J]. IEEE Transactions on Microwave Theory and Techniques, 1996, 44(12): 2392-2397.

Paul F. Combes, Jacques Graffeuil, Jean-Francois Sautereau. Microwav components, devices and active circuits. John Wiley & Sons, 1987, pp. 106.

S. P. McAlister, W. R. McKinnon, S. J. Kovacic, and H. Lafontaine, "Self-heating in Multi-emitter SiGe HBTs," Solid-State Electronics, vol. 48, issues. 10-11, pp. 2001-2006, October-November 2004.

Wang Y, Zhang WR, Xie HY, and Zhang W, He LJ, Sha YP, "Thermal analysis of power SiGe heterojunction bipolar transistor with novel segmented multi-emitter structure," In: IEEE Proceedings of 2007 International Conference on Microwave and Millimeter Wave Technology, ICMMT '07. pp. 1–4.

Willian Liu, Ali Khatibzadeh, and Jim Sweder, "The Use of Base Ballasting to Prevent the Collapse of Current Gain in AlGaAs/GaAs HBTs," IEEE Trans. Electron Devices, vol. 43, no. 2, pp. 245-251, June 1996.

W. Liu, B. Bayraktaroglu, "Theoretical Calculation of Temperature and Current Profiles in Multi-finger HBTs," Solid-State Electronics, vol. 36, no. 2, pp. 125-132, June. 1993.

SCIENCE AND TECHNOLOGY PUBLICATIONS