High Efficiency and High Ruggedness InGaP/GaAs HBT EPI Design

Rei-Bin Chiou, Ta-Chuan Kuo, Cheng-Kuo Lin, Shu-Hsiao Tsai, Shin-Yi Ho, Tung-Yao Chou, Dennis Williams, and Yu-Chi Wang

WIN Semiconductors Corp. Kuei Shan Hsiang, Tao Yuan Shien, 333, Taiwan

E-mail: reibinc@winfoundry.com, tachuank@winfoundry.com

Abstract

In the past years, a well known trade-off between the efficiency and ruggedness of InGaP/GaAs HBT power amplifier (PA) has been widely studied, and the figure of merit (FOM) to estimate a HBT performance is the production of cut-off frequency and breakdown voltage which are mainly affected by the collector design.

This work is to demonstrate an optimized HBT epi design assisted by TCAD simulation tool. With the help of well calibrated DC and RF characteristics, the simulation results are useful to analyze and to predict the device performance of different collector design, and successfully realized a HBT PA with superior RF performance.

Fig.1 shows the comparison of measurement and simulated I-V, C-V curves of a device with 3um x 40um x 3 emitter size, and its current gain is 75 for both EPI-A and EPI-B with only varying collector doping profile. The EPI-A has been applied for the high efficiency mobile phone application, and the EPI-B has mainly applied to base station with high ruggedness requirement. The difference of these two epi structures could be revealed by the C-V profiles.

A well designed EPI-C combined both advantages of high efficiency and high ruggedness together compared to both EPI-A and EPI-B, the small signal measurement result were shown in Fig.2. The higher cut-off frequency and also larger safe operation area (SOA) at higher current density indicated the EPI-C had a good figure of merit (FOM) than both EPI-A and EPI-B. Fig.3 (a) is the 1-tone large signal measurement results at 900MHz, well matched at highest PAE by load-pull system for each epi design, and Fig. 3(b) shows the maximum efficiency of EPI-C 74.6% which is 3.5% higher than EPI-A and also 6.5% higher than EPI-B. The ruggedness test results of EPI-C by increasing collector bias voltage with 10:1 VSWR all phase sweeping is shown in Fig. 4, and Table.1 summarized the ruggedness test results that the EPI-C had superior ruggedness than EPI-A and EPI-B.

With the assist of TCAD simulation, we successfully developed a new epi structure with superior efficiency and high ruggedness, and also saved the cost of epi growth and wafer process, especially to shorten the develop time.

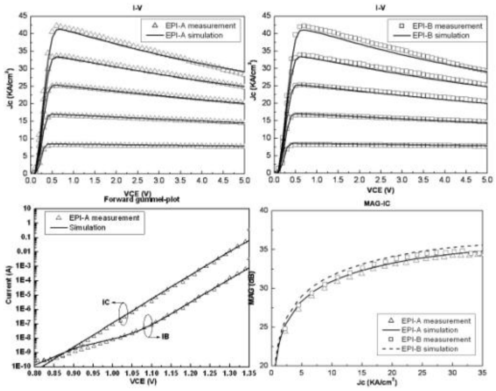

Fig 1

Fig. 1 The typical DC and RF characteristics comparison of measurement (symbol-line) and TCAD simulation results (solid-line).

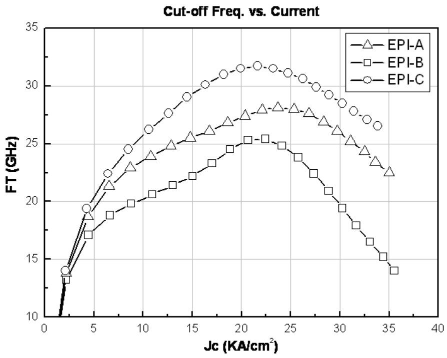

Fig 2(a)

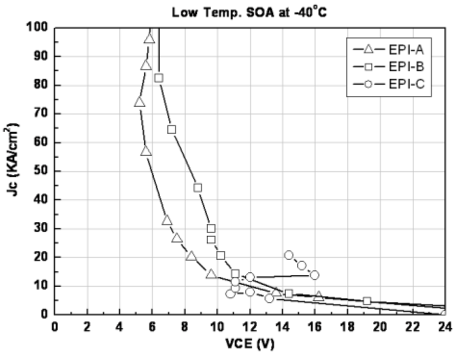

Fig 2(b)

Fig. 2 Measurement results of three epi structures: (a) Cut-off frequency vs. collector current, and (b) DC safe operation area at low temperature -40°C.

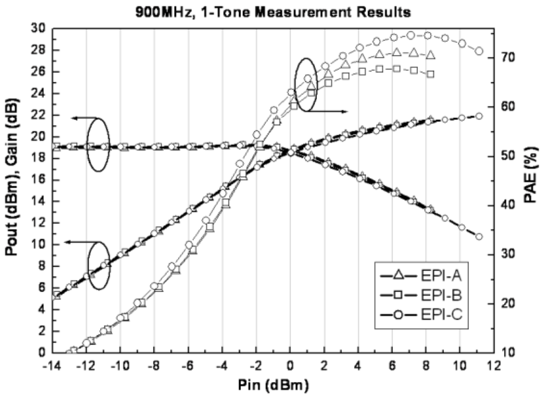

Fig. 3(a)

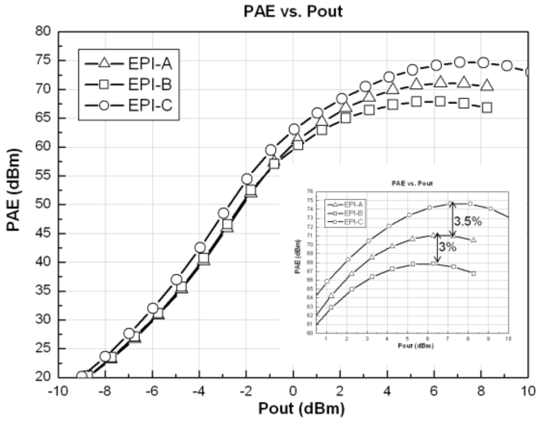

Fig. 3(b)

Fig. 3 (a) 1-tone large signal measurement results of new designed epi compared with typical epi structure. (b) The maximum PAE of EPI-C is improved about 3.5% than that of EPI-A.

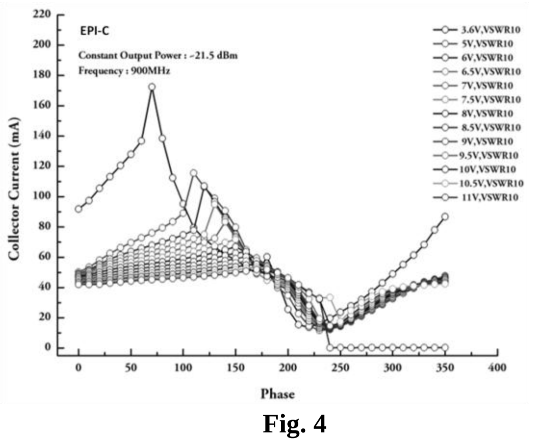

Fig. 4

Fig. 4 Ruggedness test results by 10:1 VSWR all phase swept with increasing collector voltage.

Table. 1 Ruggedness test results

EPI name	EPI-A	EPI-B	EPI-C
Passed voltage (V)	7	9.5	10.5