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A 600 mW-Output Power Amplifier for Cellular Applications Using APCVD-Grown SiGe Base HBT

T.-H. Han, B. R. Ryum, D.-H. Cho, and S.-M. Lee

Semiconductor Div., Electronics and Telecommunications Research Institute(ETRI),
P.O. Box 106, Yusong-gu, Taejon, 305-600, Republic of Korea
Phone/Fax: 82-42-860-5962/82-42-860-6108, E-mail: thhan@etri.re.kr

1. Introduction

Emerging wireless communication systems at a frequency range of 800 MHz - 2.5 GHz require RF devices with low cost and high performances. Up to now, the III-V compound semiconductor devices, such as GaAs MESFETs and AlGaAs/GaAs HBTs have been dominantly applied for the RF applications. In the meantime, SiGe HBTs have drawn attention due to not only the high speed performance but fabricating process compatibility with other Si devices. From this point of view, high performance ICs[1-5] demonstrating a potential of SiGe HBTs in analog, digital, and RF applications have been recently reported. For instance, a VCO and a power amplifier fabricated using SiGe HBTs showed a good performance in view of the noise figure, the linearity, and the power efficiency. In the previous work[6], we presented a SiGe HBT with a cut-off frequency (f_T) of 27 GHz using an atmospheric-pressure chemical vapor deposition (APCVD) system having a higher throughput at a production level.

In this paper, for the first time, we have demonstrated a power amplifier for the hot-issued cellular applications using the APCVD-grown SiGe base HBT. In order to reduce the base resistance and thus increase a maximum oscillation frequency (f_{max}) for power applications, a titanium disilicide ($TiSi_2$) formed by sputtering a $TiSi_{2.6}$ composite target was used as a base electrode layer.

2. Fabrication of the SiGe power HBT

A buried collector was formed by an arsenic implantation in a p-type Si-substrate with a resistivity of 18-22 Ω.cm. Using the APCVD, a n-type collector epitaxial layer with a phosphorus concentration of 5×10^{15} cm^{-3} and a thickness of 2.7 μm giving a required breakdown voltage was grown thereon at 1100°C in cap-purge-grow sequence suppressing the arsenic autodoping from the buried collector into the growing layer. After LOCOS isolation, collector sinker formation, and standard wafer cleaning, the wafer was prebaked for 10 minutes at 900 °C in H_2 (20 slm) to get rid of the native oxide on the silicon surface. Then, using a SiH_4-based process at 650 °C and 40 torr with 1 % GeH_4 and 1 % SiH_4 gas sources, a SiGe base layer was grown on the LOCOS-patterned wafer. The boron doping was achieved in-situ with diborane. In the SiGe base layer, the boron concentration was 2×10^{19} cm^{-3} and the Ge mole fraction ramped from 0 at the emitter side to 0.2 at the collector side over 25 nm. In order to suppress the tunneling current[7] at the emitter-base junction and the parasitic potential barrier[8] at the collector-base junction, undoped Si and $Si_{0.8}Ge_{0.2}$ epitaxial layers were grown on the top and the bottom of the SiGe base layer, respectively. After BF_2 implantation into the extrinsic base region, an a-$TiSi_{2.6}$ layer was formed thereon by sputtering a hot-pressed $TiSi_{2.6}$ composite target in order to reduce the loss of the underlying Si[9] and subsequently patterning the a-$TiSi_{2.6}$ layer prior to any thermal processing. For the activation and drive-in of the As^+ ions in the polysilicon-emitter, furnace annealing was performed at 840 °C for 20 min. In the meantime, phase transition of the a-$TiSi_{2.6}$ layer to the $TiSi_2$ of the C54 phase with lower resistivity was made[9]. A SEM photograph of a fabricated SiGe power HBT is shown in Fig. 1. In order to increase collector current (I_C) up to a required level for the power amplifier, 80 transistors with an emitter area of 2×8 μm^2 were connected in parallel using a double metal process without an electrical short.

3. Performances of the SiGe power HBT

The power HBT was packaged to be used in a power amplifier. DC characteristics of the packaged HBT were measured using an hp4145B parameter analyzer. Extrapolating the I-V characteristics in Fig. 2 gives an Early voltage of 120 V which is high enough to be used in the power amplifier. Breakdown voltage BV_{CEO} of 18 V is obtained as required. Measured resistance of the $TiSi_2$ is typically 6-7 Ω/□, which is much lower that that of a boron-doped polysilicon base electrode. As shown in Fig. 3, maximum current gain (β_{max}) is 110. In addition, from the nearly constant β over four decades of I_C, good linearity of the power amplifier to be made is presumed. S-parameters of the packaged power HBT were measured using an hp8510B network analyzer and an Inter-Continental Microwave (ICM) test fixture with 3.5 mm connectors. Fig. 4 shows f_T and f_{max} as a function of I_C. f_T and f_{max} peak at 6.5 GHz and 8.5 GHz respectively at I_C of 150 mA and V_{CE} of 10 V.

4. Power amplifier performances

Output power of the packaged power HBT was measured using a tunable jig. The jig substrates are commercial epoxy fiber glass boards with a dielectric constant of 4.8 and a thickness of 0.8 mm. The packaged power HBT was mounted using silver epoxy on an Au-coated brass carrier for heat sinking. Input and output matching circuits consist of 50

Ω-microstrip line and variable capacitors. A constant current is sourced to the base and a constant voltage to the collector. The bias condition is class-A which is preferred for higher linearity at the expense of the power efficiency, An output power and a power added efficiency measured at V_{CE} of 10V and I_C of 272mA are presented in Fig. 5. Maximum 1'dB compression output power is 27.8 dBm and power gain is 10 dB.

5. Conclusions

The SiGe power HBT has been realized by connecting 80 transistors with 2 × 8 μm^2 emitter in chain. A peak f_T of 6.5 GHz and a peak f_{max} of 8.5 GHz were obtained at I_C of 150 mA. A class-A amplifier which would be used as a driving amplifier in cellular base station has also been fabricated. At the cellular frequency of 850 MHz, the amplifier exhibits a 1'dB compression output power of 27.8 dBm and a power gain of 10 dB. This result demonstrates a potential of an APCVD-grown SiGe power HBT as a manufacturing technology in the hot-issued cellular communication.

References

1) D.L. Harame, K. Schonenberg et al., *IEEE IEDM Tech. Dig.*, pp. 437-440, 1994.
2) F. Sato, T. Hashimoto, T. Tatshmi, M. Soda, H. Tezuka, T. Suzaki, and T. Tashiro, *BCTM*, pp. 82-88, 1995.
3) A. Gruhle, A. Schüppen, U. König, U. Erben, and H. Schumacher, *IEEE IEDM Tech. Dig.*, pp. 725-728, 1995.
4) C. Kermarrec, G. Dawe, T. Tewksbury, B. Meyerson, D. Harame, and M. Gilbert, *IEEE MW & MMW Circuit Symposium, Digest*, pp. 1-4, 1994.
5) H. Schumacher, U. Erben, and A. Gruhle, *IEEE MW & MMW Circuit Symposium, Digest*, pp. 213-216, 1994.
6) B. R. Ryum, and T. -H. Han, *ESSDERC95*, p. 505, Sept. 1995.
7) D.L. Harame, E.F. Crabbé, et al., *IEEE IEDM Tech. Dig.*, pp. 19-22, 1992.
8) E.J. Prinz and J.C. Sturm, *IEEE IEDM Tech. Dig.*, pp. 853-856, 1991.
9) B. R. Ryum, and T.-H. Han, *Solid-State Electronics*, Vol. 39, No. 11, p.1643-1648, 1996.

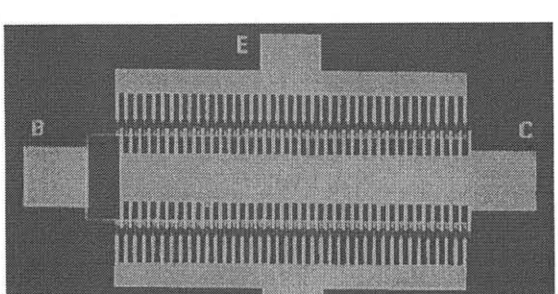

Fig. 1. SEM photograph of the SiGe power HBT with 2 × 8 × 80 μm^2 emitter.

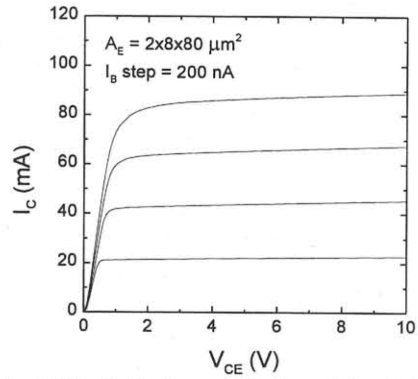

Fig. 2. The I-V characteristics of the SiGe power HBT.

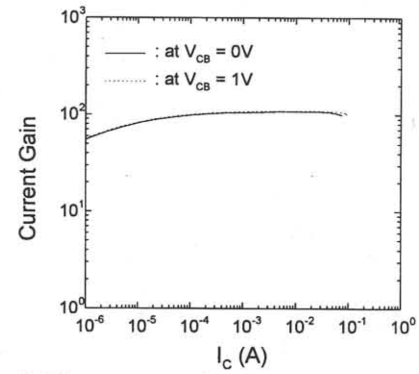

Fig. 3. The current gain characteristics of the SiGe power HBT.

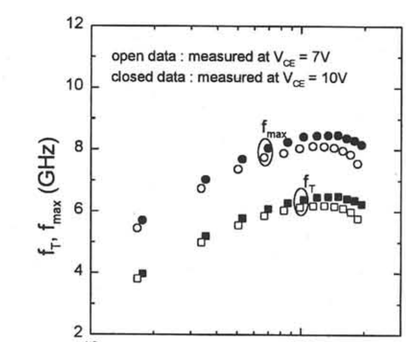

Fig. 4. f_T and f_{max} dependence on the collector current at the different V_{CE} values.

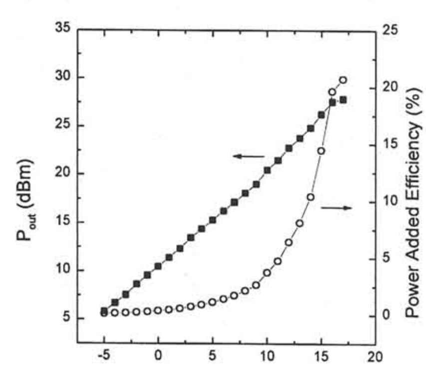

Fig. 5. Output power characteristics and power added efficiency at 850 MHz for the one-stage SiGe power amplifier.