Novel Bi-HEMT Technology for LTE Handset Application

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Abstract

Monolithic integration of pHEMT and InGaP HBT Technology on 150-mm GaAs wafers has been widely used in 3G and WiMAX application. This is due to BiHEMT (H2W is the code name at WIN) technology provide the degrees of freedom for design of power amplifier. The threshold voltage (I_{ds}= 1mA/mm) and drain-to-source current density (I_{dss}) of pHEMT are -1 V and 335 mA/mm, respectively. The on-resistance of pHEMT is only 0.9 ohm.mm. We get over 50% on-resistance reductions as compared with previous H2W versions. In addition, the gate leakage current and breakdown voltage of pHEMT still can be maintained sufficient level for normal rf switch operation.

INTRODUCTION

Recently the growth of mobile internet and multimedia services has been explosive [1]. The handset spends most of time at or around a fairly low power level. New generation power amplifiers with two-state (high and low power mode), it can internally optimized at both high and low power states and improve PAE.

Currently, WIN semiconductors has released two versions of H2W technologies. However, the on-resistance of pHEMT of these processes are all higher than stand-alone pHEMT switch devices. As a result, the poor insertion loss performance could degrade the power added efficiency at low power mode operation. Therefore, it could limit the H2W processes for high linearity requirement application such as 4G/LTE.

In order to improve the on-resistance, we had developed a new H2W technology with the signal gate recess process and optimized pHEMT epi-structure design to further improve the rf switch performance.

In this paper, we're going to report the development status of WIN's new H2W technology. In addition to devices fabrication, after evaluating the device-level dc, small-signal, rf performance, we demonstrated the InGaP HBT power amplifier and depletion-mode (D-mode) pHEMT switch small signal and linearity characteristics.

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DEVICE FRABRICATION AND FEATURES

New H2W devices were fabricated with WIN's latest Bi-HEMT epi-structure and latest HBT4 process [1]. The single-recess 0.5-μm gate is defined by i-line stepper. For the metal-interconnection, It includes two-interconnection metal layers (M1 and M2) and a thicker SiN layer as the dielectric layer between M1 and M2. A thicker SiN film instead of using Polyimide as dielectric film can provide better mechanical and moisture protection. MIM capacitors with unit capacitance of 570 pF/mm^2, stacked MIM capacitors with unit capacitance of 870 pF/mm^2, and thin film resistors and epi resistor with sheet resistance of 50 Ohm/sq and 175ohm/sq respectively can be used for MMIC designs.

Due to the high topology feature of HBT, obtaining uniform 0.5-μm single and multiple-gate pHEMT devices across an 150-mm wafer is the greatest process challenge in H2W technology development. Fig.1 shows the cross-section of multi-gate structure of new H2W structure.. It is shown that WIN new H2W technology exhibits multiple-gate process ability, which can be used for high isolation and high linearity switch application.

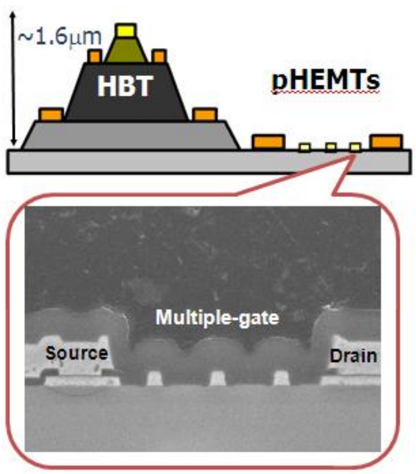


Fig1. New H2W construction and multiple gate cross-section image.

DEVICE DC & RF PERFORMANCE

For the HBT's characteristics, the typical turn-on voltage of the is 1.265 V. The base layer is designed with dc current gain of 130. BC and EC breakdown voltages are 28V and 14V, respectively.

Table1. HBT DC & RF characteristic

Parameters	Unit	H2W	New H2W
Current Gain @ 1.25kA/cm^2	N/A	125	130
BE Turn-on @ 1.25kA/cm^2	V	1.265	1.265
BVceo @ 0.05kA/cm^2	V	14	14
BVcbo @ 0.05kA/cm^2	V	28	28
BVebo @ 0.05kA/cm^2	V	9.5	9.5
HBT Ft @ 25kA/cm^2	GHz	36.5	37

The D-mode pHEMT dc transfer characteristics are shown in Fig. 2, which exhibits excellent device pinch-off characteristics. . The pHEMT threshold voltage (I_{ds}= 1mA/mm) and drain-to-source current density (I_{dss}) of pHEMT are -1 V and 335 mA/mm, respectively. The on-resistance of pHEMT is 0.95 ohm.mm, achieving a 50% on-resistance reduction compared with previous H2W versions

Table2. pHEMT DC & RF characteristic

Parameters	Unit	H2W	New H2W
Gm peak @ Vd=1.5V	mS/mm	340	450
Idss @ Vg=0V	mA/mm	265	335
Channel On-resistance	Ohm-mm	1.7	0.95
Vdg breakdown	V	20	18
Threshold voltage @ 1mA/mm	V	-1	-1
pHEMT Ft @ Vds=3.6V	GHz	33	34

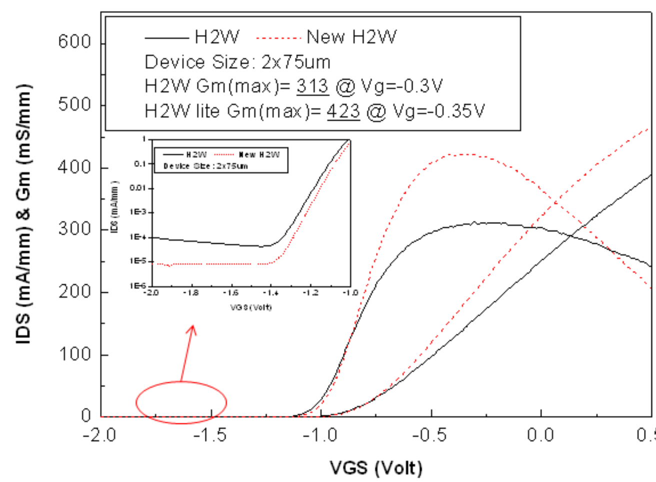


Fig2(a). pHEMT DC characteristic comparison of new H2W (Ids vs Vgs)

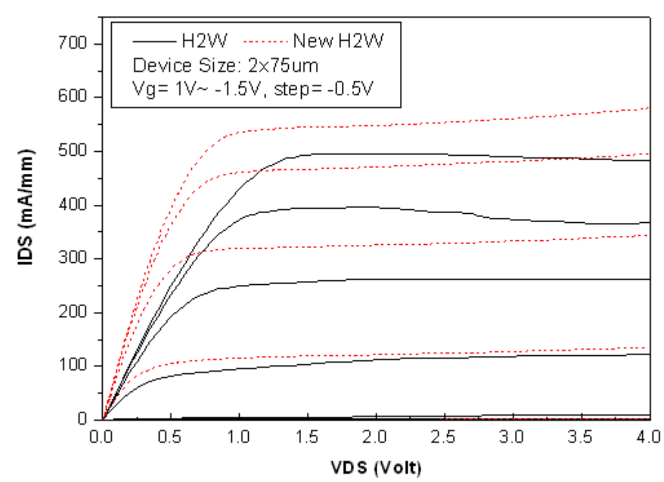


Fig2(b). pHEMT DC characteristic comparison of new H2W (Ids vs Vds)

As we know, the gate leakage current is critical parameter for switch application. For the new H2W process, single gate process can achieve 18 gate-to-drain breakdown voltage, which is smaller than previous version. Nevertheless, the gate leakage current pHEMT still can maintain sufficient level for normal rf switch operations shown in Fig. 3.

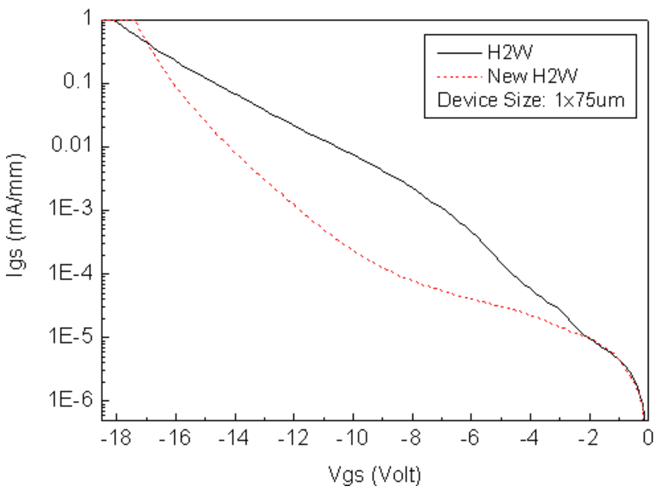


Fig3.New H2W Schottky gate characteristic comparison

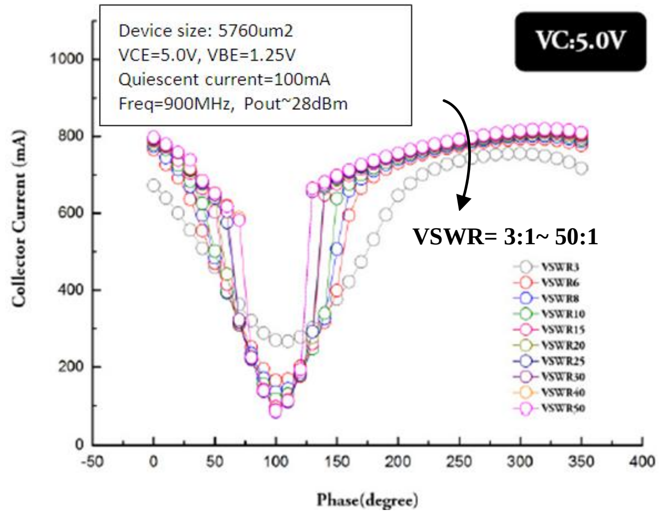
HBT RUGGEDNESS AND SWITCH HARMONIC

In order to further confirm ruggedness performance of HBT devices [2]. The ruggedness test of 5760um^2 power cell is shown as Table 4. DUT power cell was partially matched on an evaluation board and it can deliver 28dBm output power at 900 MHz. VSWR varied from 10:1 to 50:1 all phase rotation during ruggedness test at VCE was 3.6V and 5V respectively. This work shows the excellent ruggedness performance which can pass under VSWR 50:1 for both VCE was 3.6V and 5V.

Table 4

Various VSWR from 10:1 to 50:1 ruggedness test results under 28dBm output power for VCE was 3.6V and 5V. Power cell size is 5760um^2.

VSWR	10:1	20:1	30:1	40:1	50:1
VCE=3.6V	Passed	Passed	Passed	Passed	Passed
VCE=5V	Passed	Passed	Passed	Passed	Passed



Moreover, we also carried out the RF switch performance by using single gate 9x125-um device with full periphery design, 20K gate isolation resistors, and S/D resistor.[3] The insertion loss are 0.1 and 0.15 dB for new and original H2W processes, respectively. The off-state harmonic ratio is tested on device shunting RF path at -3V and 900MHz . As to switch linearity characteristics, the 80 dBc of second-harmonic and third-harmonic rejection ratios were obtained when device was biased at -3V as shown in Fig 4. It clearly shows that the H2W optical gate lithography process is suitable for low loss, high power and high linearity applications under low control voltage. ly

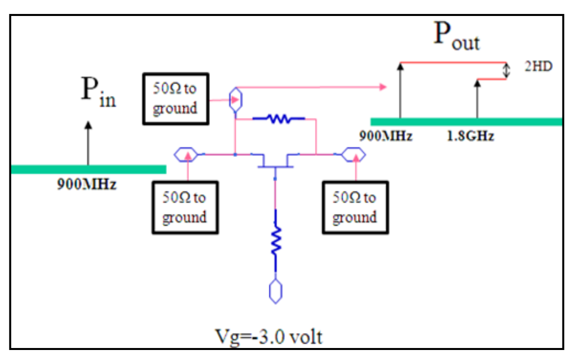


Fig4(a). Switch harmonic measurement method at off-state

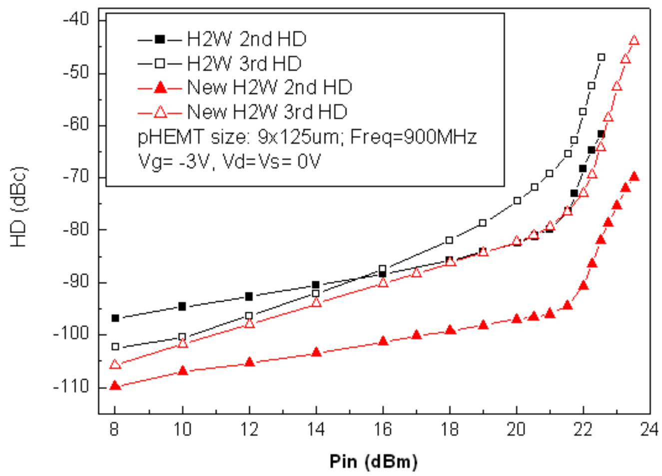


Fig4(b). H2W pHEMT switch harmonic comparison (off-state)

CONCLUSIONS

In this paper, WIN presents a low cost, excellent performance of 0.5-µm Bi-HEMT technology. HBT is optimized for power cell to provide sufficient power level for 3G/LTE application. The pHEMT is optimized insertion loss and harmonic for power switching application. In summary, WIN Semiconductor's new H2W technology provides world class pHEMT performance combined with rugged and proven HBT technology for the design of next generation power amplifiers for LTE high linearity application.

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ACRONYMS

HBT: Heterojunction Bipolar Transistor

pHEMT: pseudomorphic high electron mobility transistor

VSWR: Voltage Standing Wave Ratio