

Transfer and Qualification of a Layout-Compatible Second Source HBT Technology for Mobile Phone Applications

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RF Micro Devices (RFMD) and TRW have completed the transfer and qualification of TRW's GaAs HBT process to RFMD, establishing for the first time a layout-compatible second source for HBT-based RFICs. HBTs have significant performance and cost advantages for high efficiency and high linearity power amplifiers, low cost gain block ICs, as well as frequency converters and LNA mixers for wireless applications. HBT technology has found application in several high volume commercial products, and, until now, there has not been a qualified second source for this advanced technology. These applications are produced in very high volumes, in the million parts per week level, and require a second source production facility to insure meeting production requirements. To meet these needs RFMD and TRW transferred TRW's HBT technology to RFMD's new fabrication line in Greensboro, North Carolina. The transfer included the HBT process and the critical, high-reliability molecular-beam epitaxial (MBE) growth process. We believe this is the first successful transfer of HBT technology from one production facility to another.

Achieving a layout compatible second source was not a matter of replicating the exact processes used by TRW, as that was often not possible. Tooling could not be exactly duplicated in many cases because of the transition to 4-inch wafers. RFMD also acquired a 5-to-1-reduction stepper and changed several photo processes to use negative working resist.

A layout-compatible process requires the on-wafer product be identical, not necessarily the processes. Therefore the focus during process development at RFMD was on reproducing process results. These include those monitored by in-process metrology (layer thicknesses, mesa heights and widths and other dimensions) and by

DC test (sheet resistances, TLM patterns and chain resistances). Targets and limits were provided by TRW for all parameters and development at RFMD focused on achieving the same on-wafer results as were being delivered by TRW.

If the process parameters were successfully reproduced, the discrete circuit elements should be identical, as should the final RFIC product. The verification of this conclusion occurred at several levels: process parameters, DC PCM, RF PCM, reliability, product characterization and final production yield both at RFMD and in the customer's final assembly.

Process Parameters

Initial process development at RFMD focused on reproducing the physical on-wafer characteristics of the TRW process: thin-film thicknesses, mesa heights, mesa widths, line widths. As an example, the emitter-mesa to base metal spacing is a critical parameter that is the product of TRW's self-aligned base metal (SABM) process. The normalized distribution of this parameter (as measured by SEM on sampled wafers) achieved by RFMD is shown in Fig. 1.

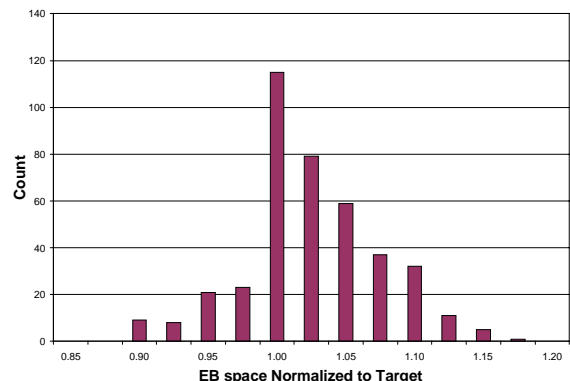


Fig. 1. RFMD fab emitter-base spacing normalized to TRW target.
DC PCM

The TRW DC PCM test plan and test structure designs were replicated at RFMD allowing for a full comparison of identical test structures and discrete circuit elements. This exact replication was invaluable in monitoring the status of the process transfer. Figure 2 shows the distribution of base metal-to-first interconnect metal via chain resistance measured on RFMD wafers and normalized to the TRW target. Figures 3 and 4 show the normalized distributions for HBT beta and Vbe.

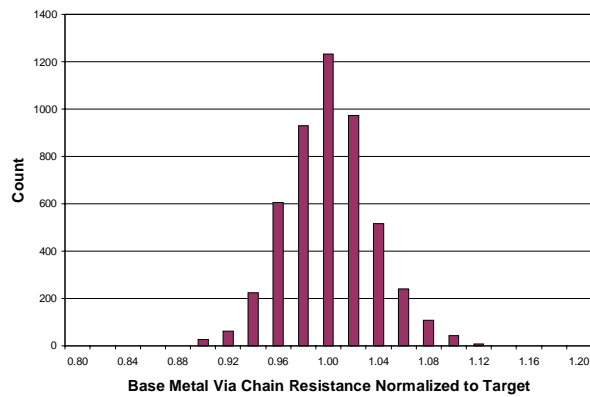


Fig. 2. RFMD fab base metal-first interconnect metal via chain resistance normalized to target.

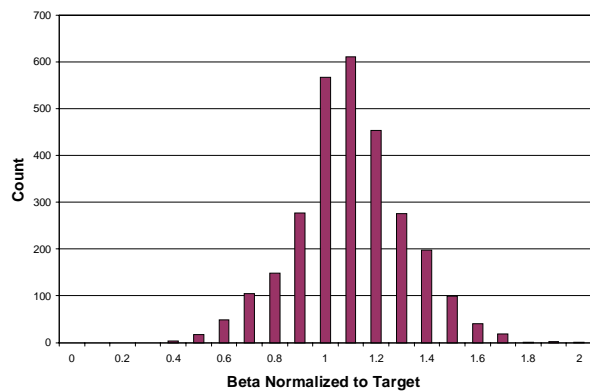


Fig. 3. RFMD fab HBT beta normalized to target.
RF PCM

On-wafer s-parameter measurements performed on several RFMD wafers were used to generate HBT small-signal model parameters for the RFMD-fabricated devices. These results were compared to baseline data for TRW-fabricated devices, and no significant differences were found. This finding has been further validated as RFMD designers continue to use the TRW device model for the development and simulation of circuit which are being successfully fabricated at RFMD.

Reliability

RFMD has performed extensive wafer-level reliability (WLR) testing to benchmark its HBT product against TRW reliability data. Initially, complete stress-to-fail tests on several wafers indicated that RFMD-fabricated HBTs had the same MTTF at $T_j = 350^\circ\text{C}$ as had been demonstrated by TRW. An abbreviated WLR “screen” test has been developed, which is used to continually monitor the RFMD HBT product. Devices are stressed at an elevated temperature for 60 minutes and changes in performance are monitored. Figure 5 shows the typical change in HBT beta after the reliability screen.

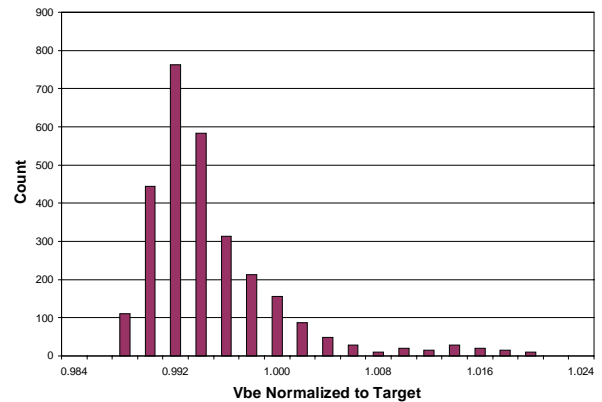


Fig. 4. RFMD fab HBT VBE normalized to target.

Table 1. Comparison of average ft measured on two RFMD-fabricated wafers and the baseline TRW average and standard deviation.

VCE (V)	TRW Baseline Average (GHz)	TRW Baseline Stdev (GHz)	RFMD Wafer 1 Average (GHz)	RFMD Wafer 2 Average (GHz)
1.5	24.9	1.11	26.6	27.9
3	22.9	1.26	23.9	24.2

4.5	20.9	1.08	22.1	22.4
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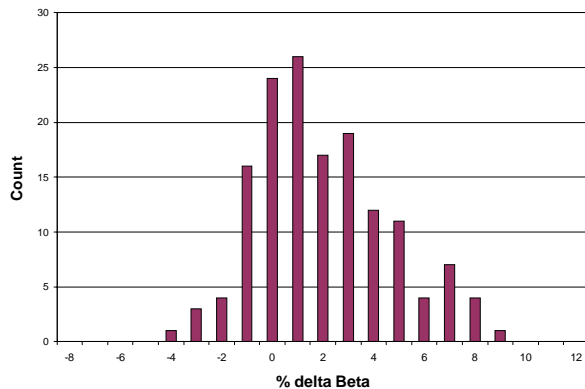


Fig. 5. Wafer-level reliability HBT screen data: distribution of delta beta.

RFMD has also produced wafers with TRW's standard reliability evaluation circuit (SEC), parts from which are currently in 3-temperature life testing at TRW. Preliminary results from this study indicate that RFMD parts have the same Ea and MTF as do TRW parts.

Product Characterization

A power amplifier for a 3-Volt, GSM-standard mobile phone was chosen as the qualification vehicle for the RFMD fab. Parts manufactured by TRW and RFMD were subjected to the full array of standard characterization tests. For all parameters, the performance difference between the two sets of parts was less than typical lot-to-lot variation. A sample comparison of the characterization data, the distribution of output power measured at the specification limits of frequency and temperature, is shown in Fig. 6.

Table 2. Normalized comparison of 3V GSM power amp final component test yield.

	Units Tested (M Units)	Normalized Yield
TRW	1.8	1.00
RFMD	2.8	1.03

Final Production Test

Final test data from millions of the GSM power amp used for qualification show that RFMD- and TRW-fabricated wafers have the same final component test yield, see Table 2. Our customer has qualified both parts interchangeably and subsequently large volumes of this part have been delivered from both fabs concurrently.

Conclusion: Layout Compatibility Achieved

Due to minor difference in photo processes, transferring layouts from TRW to RFMD does require swapping device cells (HBTs only) from those with TRW design rules to versions with RFMD design rules, however, that is the only change required. No passive device and interconnect layouts or general circuit design features have to be changed in order to yield the same product – the on-wafer results are identical. To date, more than 12 production layouts have been transferred successfully from TRW to RFMD. Furthermore, RFMD designers have interchangeably used either fab for prototype runs during the development phases of several products.

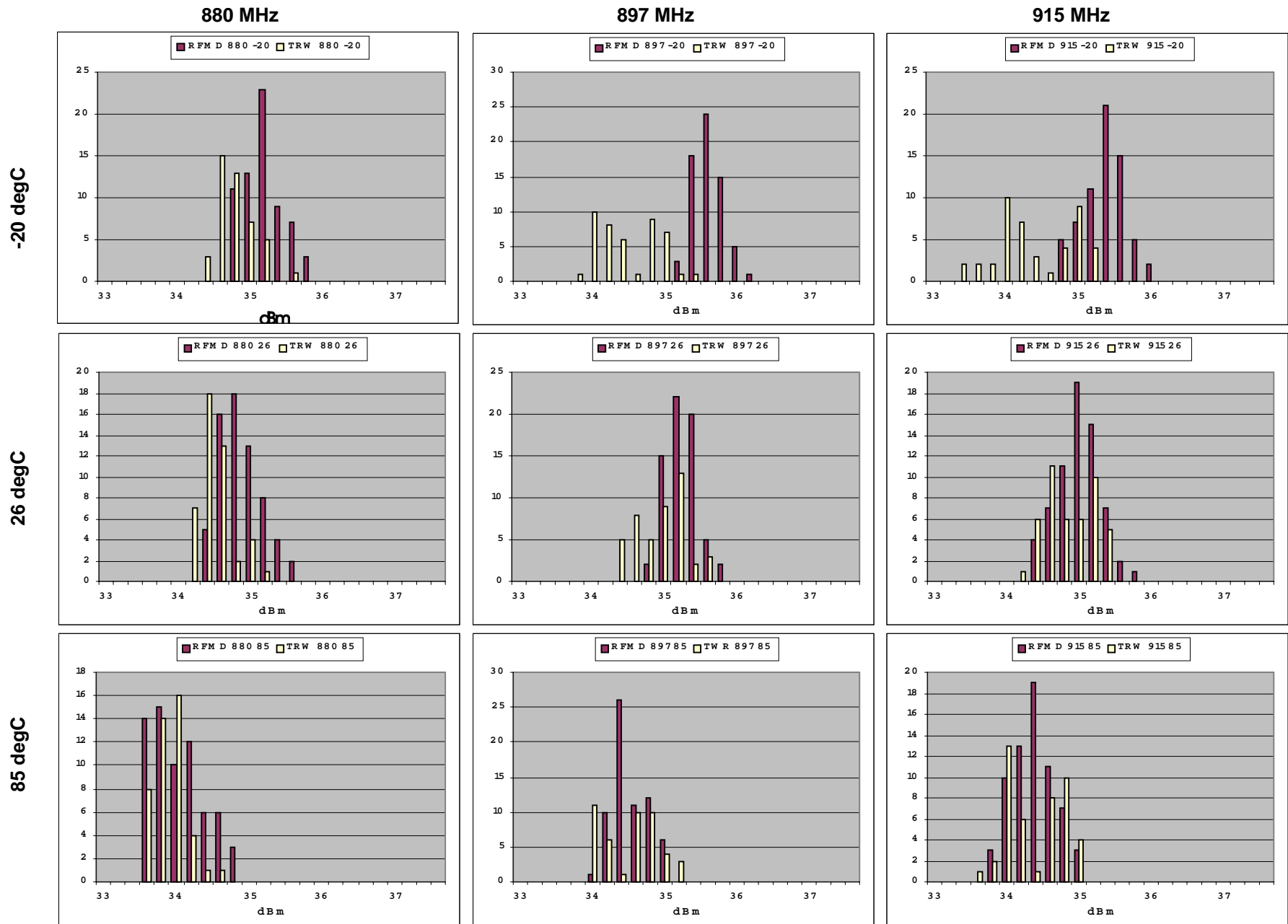


Figure 6. GSM power amplifier power out comparison between TRW- and RFMD-fabricated parts. Pout is compared at frequencies of 880, 897 and 915 MHz and ambient temperatures of -20, 26 and 80 degC.

