Transfer of GaAs pHEMT Technologies from Infineon to TriQuint

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Abstract

This paper documents the transfer of two AlGaAs / InGaAs Pseudomorphic High Electron Mobility Transistor (pHEMT) Technologies from the Infineon Technologies AG facility in Perlach Germany to TriQuint Semiconductor in Hillsboro, Oregon.

We will present:

- **The methods used for early technology compatibility assessments and goal setting.**
- **The qualification of equipment transferred from Infineon after modifications to conform to U.S. standards.**
- **The qualification of epitaxial suppliers.**
- **The development methodologies of technologies new to TriQuint.**
- **The transfer and integration of Infineon processing experts into the TriQuint organization.**
- **Comparisons of pHEMT parameters of devices fabricated at Infineon and TriQuint.**

INTRODUCTION

In April 2002 TriQuint Semiconductor and Infineon Technologies AG announced a partnership to develop radio designs for wireless phones and devices. The agreement called for TriQuint to acquire Infineon's GaAs business. Infineon designers formed the nucleus of the Munich-based TriQuint Europe. The Infineon products in manufacture were to be transferred to TriQuint's Oregon facility. The time allotted for the technology transfer and ramp to production levels was about one year. Infineon would support manufacturing in their Perlach Facility until June of 2003.

The challenges of such an undertaking are obvious. Six thousand miles and international borders separated the two facilities. TriQuint had long experience in fabricating GaAs devices but needed to acquire all the equipment and expertise necessary to fabricate pHEMTs based on sidewall technology. The key to meeting this aggressive schedule was the transfer of seven Infineon technologists to Oregon.

EXECUTIVE SUMMARY

The two Infineon technologies were based on a 0.13um and 0.4um gate length depletion mode pHEMTs with self aligned ohmic contacts. Circuits combined two levels of thick metal global interconnects (one an Air Bridge), MIM capacitors and 35um diameter substrate "micro" vias.

The 0.4um variant was being produced in production quantities at Infineon. A true "copy exactly" approach was not possible but circuit performance was duplicated by careful attention to the original transistor and circuit topologies. Processing equipment not needed in support of manufacture at Infineon was brought to Oregon. The epitaxial structure for the pHEMTs was a fairly conventional double heterojunction design done with Molecular Beam Epitaxy. Neither Infineon nor TriQuint attempt to grow their own production epi, so building relationships with professional epi suppliers is required. Infineon had worked on that extensively but had not yet established mature lines of supply. Distinct (and different) specifications were used for each vendor, a practice antithetical to TriQuint's wafer supply methodology. A single specification for each process was evolved, and previously unspecified aspects were nailed down. For example, the epi buffer layer was no longer left to the epi vendor's preference, but rather was specified in detail. This eventually resulted in more consistent circuit noise figure and better quality substrate via etching in the process as it evolved at TriQuint. Critical fabrication processes that needed to be developed on new tools were isolated by selectively fabricating portions of the circuits at both manufacturing sites. Very close collaboration and cooperation developed between Infineon and TriQuint engineers.

The strategy for the 0.13um-pHEMT technology was slightly different because no products were yet at production volumes. The goal of this transfer was to produce at TriQuint pHEMTs that matched the performance of those produced at Infineon. TriQuint standard process modules were applied to the new pHEMT architecture wherever possible.

CHRONOLOGY OF THE TRANSFER

April 2002:

TriQuint GmbH Munich Germany was established with ~ 70 Design / Marketing staff. Seven IFX process experts committed to transfer to TriQuint Oregon. This group together with some Infineon engineers formed a transition team, which would train TriQuint engineers until the personnel transfers were competed. The remaining Infineon engineers would support manufacturing at the GaAs FAB until it's scheduled closing in June of 2003.

The first technology to transfer was the 0.4um gate length pHEMT, followed by the 0.13um process. Schematics of these pHEMTs are shown below.

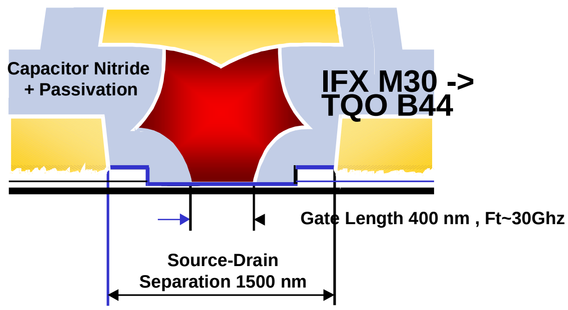

Fig. 1 0.4 um Schematic

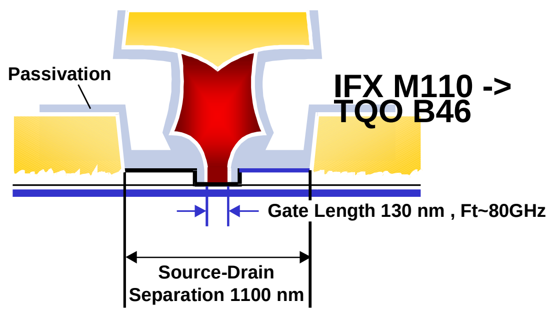

Fig. 2 0.13 um Schematic

Process equipment available to move to TQO was identified. Facilities preparation for transferred equipment began in TQO.

May2002

Nine TQO process engineers received 1 to 2 weeks cross training at IFX. IFX technologists that were slated to join TQO began weeklong visits to Oregon.

The Infineon transfer team along with TriQuint engineers identified the crucial transfer process modules. Careful attention was paid to the architecture of these modules because they would directly impact the RfFperformance of the active devices and passive elements.

See figure 3 for some examples of crucial modules.

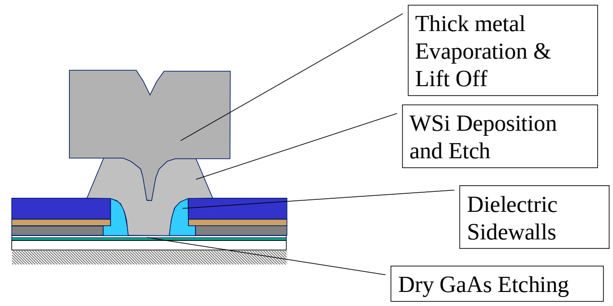

Fig. 3 Examples of Critical Process Modules

June 2002

Three TQO equipment engineers received 10 days training at IFX on the process tools slated for transfer to TQO. The TQO engineers worked with their IFX counterparts to decommission and prepare the equipment for transfer to the U.S.

TQO FAB facilities preparation began in Oregon for transferred process equipment.

Modifications to Oregon equipment began to allow process development where IFX equipment could not be transferred.

The first spacer dielectric etches with Oregon equipment was demonstrated.

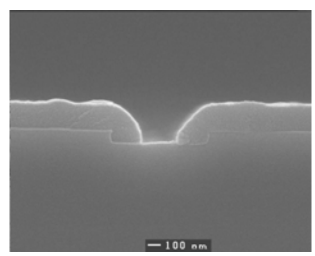

Fig. 4 Infineon deposited Sidewall SiN Etched at TQO 6 / 2002

Cross processing experiments began (TQO / IFX). Those process steps not ready at TQO were done at IFX i.e.:

- Gate recess etching done at IFX on wafers with spacers etched at TQO.
- Substrate vias etched at TQO with IFX defined Photoresist.

July / August 2002

Equipment transfers from IFX to TQO were completed:

ASM5500/100 I-line Stepper.
Semitool Chemical cleaning system.
Temescal Metal Evaporator.
LAMTCP Dielectric Etch System.

The first mask set consisting of characterization pHEMTs and passive elements as well as representative circuits was designed. The glass contained both TQO and IFX process control monitors. Duplicate masksets were purchased for both locations.

Infineon / TriQuint lithography tools were "matched" allowing co-processing of development runs.

First co-produced development runs were started.

Early runs with gate WSi deposited with OR equipment were etched at IFX.

IFX evaporations system on-line in OR.

IFX stepper on-line

Photoresist profiles developed at TQO for thick metal lift-off and sloped air bridges.

First crucial unit process capability demonstrated at TriQuint.

September / October 2002

First IFX technologists moved to Oregon.

Full B44 process capability achieved at TQO.

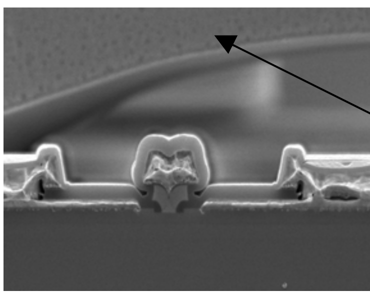

Fig. 5
TQO 0.4um pHEMT with Air Bridge

First fully TQO-processed wafers completed on epitaxial material with in spec DC / RF wafer level parameters.

First TQO processed wafers with IFX style substrate vias.

TQO produced circuits ready for open cavity testing.

Emphasis placed on finalizing "standard process flow" for 0.4um-pHEMT technology.

November / December 2002

Finalized the TQO B44 process.

First production maskset started.

TQO fully processed wafers from three separate product qualification runs sent for packaging.

January / February 2003

The 013um flow and development maskset were defined. The first epitaxial runs were started after 0.13 um gate features were demonstrated on mechanical substrates.

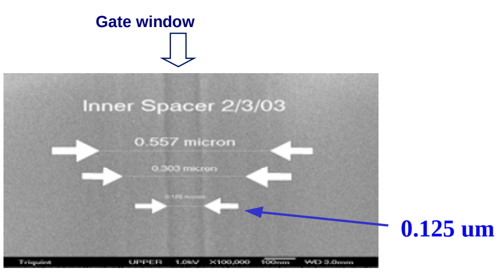

Fig. 6 Iterative Sidewall Spacer Process

March / April 2003

Baseline B46 process defined, and first 0.13um pHEMTs fabricated, with Ft > 80Ghz.

June / July 2003

TQO 0.4um fully qualified.

Production shipments of B44 CDMA receivers begun.

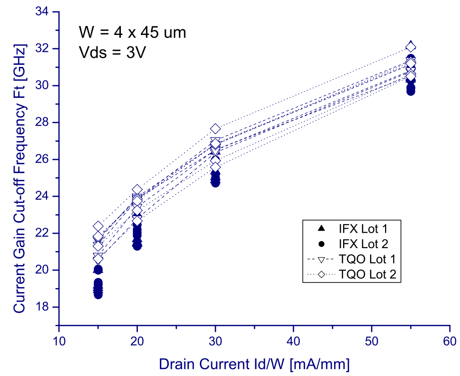

Fig. 7 0.4um pHEMTs TQO Vs. IFX

October 2003

0.4um process released to manufacturing.

0.13um devices meet equivalent IFX performance:

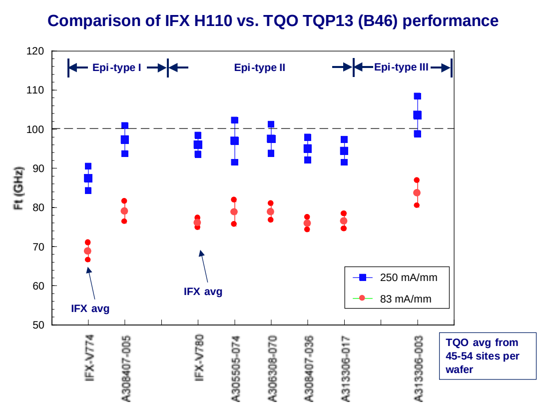

Fig. 8 0.13um TQO Vs IFX

Conclusions:

Resulting from this transfer, TriQuint's TQP40 and TQP13 processes are 0.4 um and 0.13um gate length depletion mode pHEMT Technologies with self-aligned ohmic contacts, two level thick metal global interconnects (one an Air Bridge), MIM capacitors, and 35um substrate "micro" vias. Both are fabricated at TriQuint's Hillsboro, Oregon facility. The TQP40 (Ft 31Ghz) and TQP13 (Ft 77Ghz) processes support RF and mixed mode applications up to LSI complexity. The TQP40 technology has been "released to manufacture", TriQuint's designation for a fully qualified and documented process flow running under the control of the manufacturing organization.

The lead product in the TQP40 technology is the SC-7195 which is a 2.7 to 4.0 Volt high linearity, dual band Low Noise Amplifier / Mixer designed specifically for dual band multi-mode CDMA/Amps mobile phone applications with an integrated bypass switch.

Each LNA has two modes of operation:

(1) High Gain mode (HG)
(2) Bypass mode

The SC-7195 is packaged in a 3.5 X 4.5-mm leadless SMT package.

Circuits using the TQP13 technology have passed final qualification in Oregon. The lead product offering is the CFH120 which is a 12GHz DBS LNA.

ACKNOWLEDGEMENTS

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We also thank Corey Nevers and Dorothy Hamada for identifying and diagnosing the root causes of process and reliability problems in the transferred technologies, allowing elimination of the problems.

ACRONYMS

pHEMT: In general, the term is used to describe lattice-mismatched (Pseudomorphic) heterojunction transistors. In this paper it refers to an AlGaAs / InGaAs Pseudomorphic High Electron Mobility Transistor.

IFX: Infineon Technologies

TQO: TriQuint Oregon.

DBS: Direct Broadcast Satellite.

LNA: Low Noise Amplifier.

SMT: Surface Mount Technology