InGaP HBTs Offer Enhanced Reliability

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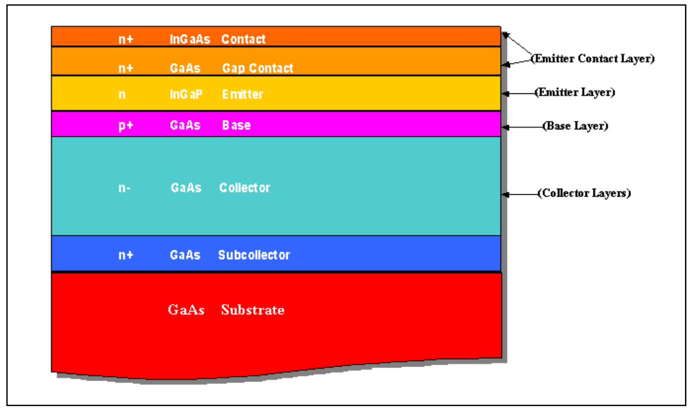
As wireless applications proliferate, the seemingly endless quest for "smaller, better and inexpensive" continues to drive equipment manufacturers and their suppliers. GaAs HBT technology has advanced all three of these objectives and continues to provide an outstanding solution for certain applications. This article will review some of GaAs HBT's evolutionary history, as well as discuss some recent reliability considerations.

To begin with, the combination of GaAs and the Hetero-junction Bipolar Transistor (HBT) structure not only afforded superior performance to many applications but also provided the highly desirable cost advantages of a highly reproducible process, tighter DC and RF parameter distributions and smaller die. This compares very favorably with other RFIC technologies.

The conventional aluminum gallium arsenide (AlGaAs) HBT structure is well known. In the early days, the formation of the p+ base region in this structure was achieved by using molecular beam epitaxy (MBE) equipment for beryllium (Be) doping. This technology met the enhanced performance and cost goals, however, at the same time it also created two specific and well recognized problems. The first is that the Be dopant, being a very small atom, is unstable and diffuses relatively rapidly. Elevated junction temperature and higher junction current density accelerate this phenomenon, resulting in DC current gain (beta) degradation. The second issue is that the access base surface near the emitter-base junction of the AlGaAs HBT is relatively unstable. This requires a careful surface passivation technique (ledge passivation) to reduce surface recombination effects. This surface effect leads to further beta degradation due to the increase of base current.

The first problem is addressed by converting the base dopant from beryllium to the much larger and more stable carbon (C) atom. However, with the required high effusion cell temperatures, this cannot be accomplished using the MBE process. Instead, the Metal Organic Chemical Vapor Deposition (MOCVD) epitaxial technique overcomes this obstacle.

Employing the MOCVD process was definitely a step in the right direction, but beta degradation due to the surface effect at the AlGaAs HBT base access region was not yet solved. Higher current density across the emitter junction further aggravates this phenomenon. Applications with continuous current flow or in high temperature environments are highly vulnerable; these include wireless, optical and CATV infrastructure equipment. Fortunately, a proven solution to this problem exists in indium gallium phosphide (InGaP) HBT.



▲ **Figure 1. The InGaP HBT structure.**

Conversion of the AlGaAs emitter to an InGaP emitter offers a robust and reliable solution. InGaP HBT has been used successfully in the optical communication industry since the early 1990s. Its structure is shown in Figure 1.

The potential for reliability problems related to high T_j has previously been recognized for MBE AlGaAs materials in certain applications. Because of this, a decision to manufacture with MOCVD InGaP HBT material, paying special attention to circuit design as it relates to the emitter finger junction temperature, is wise. The results thus far have been highly favorable.

The most stringent of stress conditions were employed to determine the MTTF, because the InGaP HBTs do not degrade under less stringent conditions. Figure 2 summarizes the reliability data from three sets of InGaP HBTs. They are mounted on ceramic packages, with their current density and T_j conditions documented for accelerated life testing. To date (October 1, 2000), those biased at 25 kA/cm^2 and 50 kA/cm^2 have been running for more than 6,500 hours, and most devices have not yet failed. Only when driven at 75 kA/cm^2, with a T_j of 330 degrees C, was noticeable degradation finally achieved. Using a 20 percent degradation of beta as failure, the MTTF at this level of stress is approximately 3,200 hours.

The projected MTTF, shown in Figure 3, is expected to be greater than 7.4 million hours at T_j equal to 125 degrees C and a current density of 75 kA/cm^2, using a

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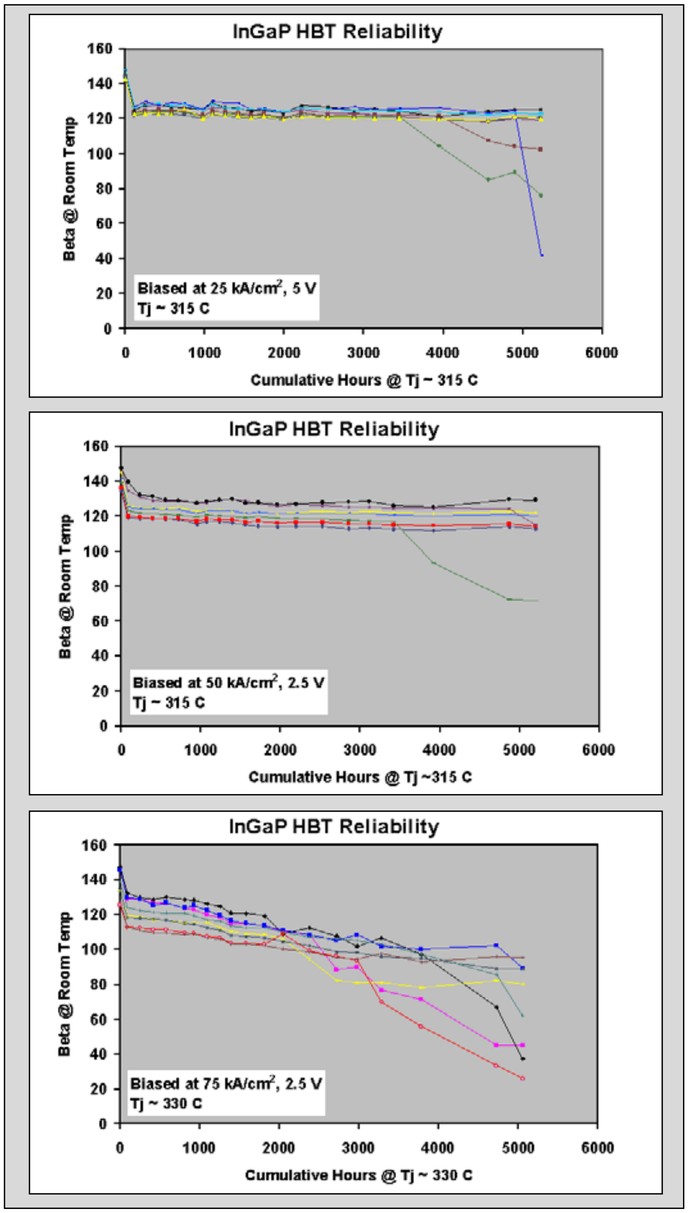
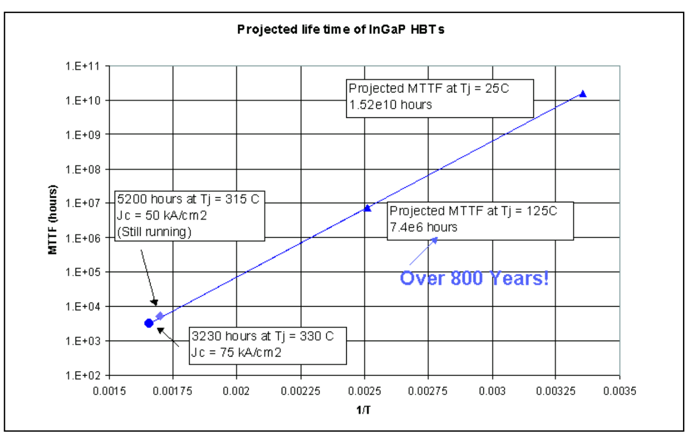
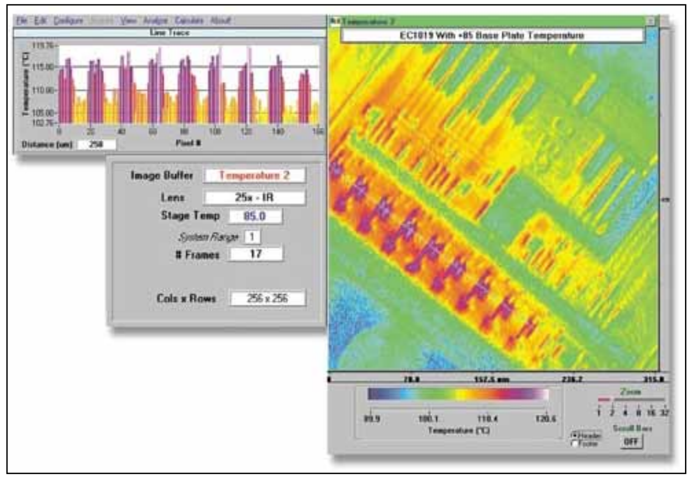


▲ **Figure 2. Reliability graphs for InGaP HBT, with increasing stress from the top figure to the bottom one.**



▲ **Figure 3. Measured and projected lifetime for InGaP HBTs.**



▲ **Figure 4. Junction temperature profile of the EC-1019 broadband amplifier IC.**

conservative activation energy of 0.8 eV. Contributing further to this robustness is the relatively cool T_j of the subject transistors under normal bias conditions. With a careful thermal budget design in product circuits, the emitter finger junction can exhibit a relatively low temperature. Figure 4 shows the amazing junction temperature profile of the EC-1019 (broadband amplifier) using an infra-red scanning microscope. The hottest point is shown in the emitter region with a white line.

This data confirms the design target of lower than 125 degrees C. These graphic results are highly encouraging and demonstrate the irrefutable advantages of the combination of MOCVD InGaP HBT technology and a careful thermal budget in circuit design for the manufacture and application of MMICs. ■

Author information

Dr. Barry Lin is the Senior Vice President for Manufacturing at EiC Corporation. He received his PhD in electrical engineering at Princeton University, following an MSEE at the University of Florida and a BSEE from the National Taiwan University. Since 1985, he has been involved in HBT and PHEMT manufacturing with an emphasis on process improvements. He has held key positions at Litton Solid State, Hewlett-Packard Company and KFI Technology. In those positions, his duties ranged from development of specific performance improvements to supervising the development of a complete high volume GaAs HBT production line

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