



Investigations on the Impact of the InGaP Ledge on HBT-Performance

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It is well known that GaAs-HBTs with InGaP emitter material can be improved with respect to reliability if the emitter material remains over the complete p-doped base layer [1]. Outside the active emitter area remains the so-called InGaP ledge. In this paper we study by means of two-dimensional device simulation the influence of the ledge thickness and of presence of surface charges on the device performance and its impact on reliability.

Introduction

The two-dimensional device simulator MINIMOS-NT deals with different complex materials and structures such as binary and ternary alloys with arbitrary material composition profiles. Various physical effects, such as band gap narrowing, surface recombination, and self-heating, are taken into account. The efficiency of the models was proven by hydrodynamic DC-simulations with self-heating of forward, reverse and output characteristics of one finger AlGaAs/GaAs and InGaP/GaAs-HBTs [2], furthermore, by small-signal RF-simulation [3]. Simulation results are in good agreement with measured data. However, so far the particular influence of the InGaP-ledge on InGaP/GaAs-HBTs on the device performance has not been studied in detail.

Impact of the InGaP Ledge

In Fig.1 we show the measured and simulated collector and base currents of a one finger InGaP/GaAs-HBT operating under forward gummel plot conditions with $V_{BC} = 0$ V. Measurement refers to a device with 40 nm thick ledge. So far for simulation no surface charges at any of the device interfaces have been introduced. As can be taken from Fig.1 simulated and measured base currents differ significantly in the case of a 40 nm thick ledge. Only simulation with a ledge thickness less than 20 nm delivers a good match. This is due to the fact that at this bias the depletion region is only approximately 20 nm thick and enables a leakage path for electrons on top of it as shown in Fig.2. However, this leakage path could be overcome by means of electrically isolated base contacts.

The influence of fixed negative surface charges, which are homogeneously distributed along the interface between ledge and passivation, was investigated. As can be taken from Fig.3, where simulation refers to a device with 40 nm ledge, base current can be reduced if more negative surface charges are introduced. The upper part of the ledge is also depleted [4] and the leakage is reduced (Fig.4). Thus, with a surface charge density of 10^{12} cm^{-2} the measured base current can be simulated very well.

Device Reliability

Based on these investigations it is possible to explain the base current degradation (see open triangles in Fig.3) of a device which was strongly stressed under conditions far from normal operating conditions. In this case the base current degradation in the middle voltage range can be explained by decreasing surface charge density along the interface between ledge and passivation from 10^{12} cm^{-2} to $4 \cdot 10^{11} \text{ cm}^{-2}$. This might be due to compensation of the negative surface charges by H^+ ions, which are known to be present in the device due to the epitaxial manufacturing processes [5].



References

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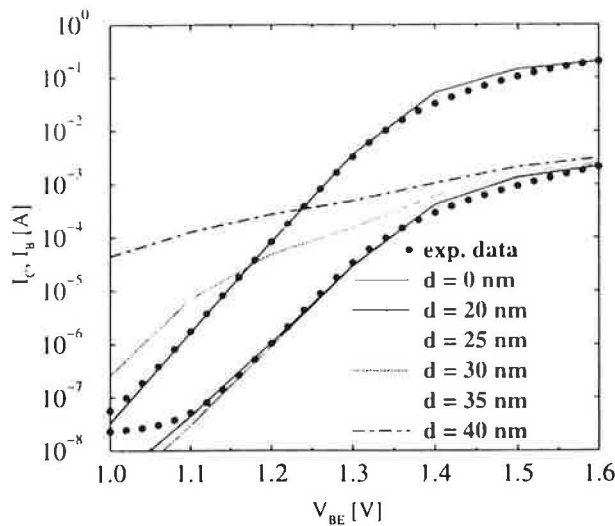


Figure 1: Dependence of I_B on the InGaP ledge thickness compared to measurement.

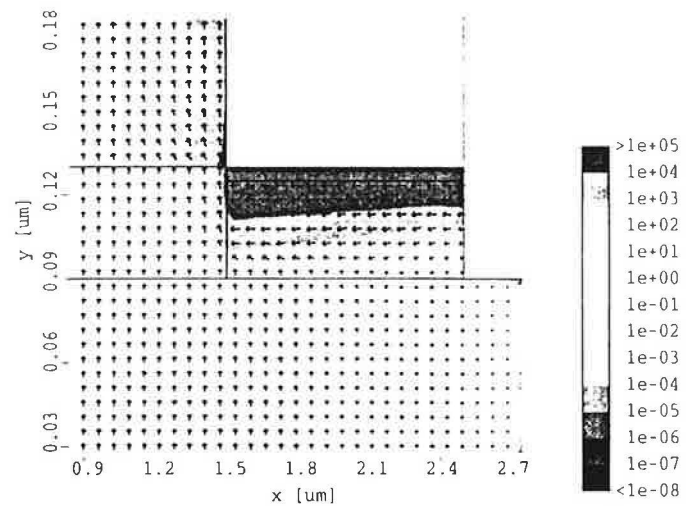


Figure 2: Electron current density [A/cm^2] at $V_{BE}=1.2\text{V}$. Simulation without surface charges.

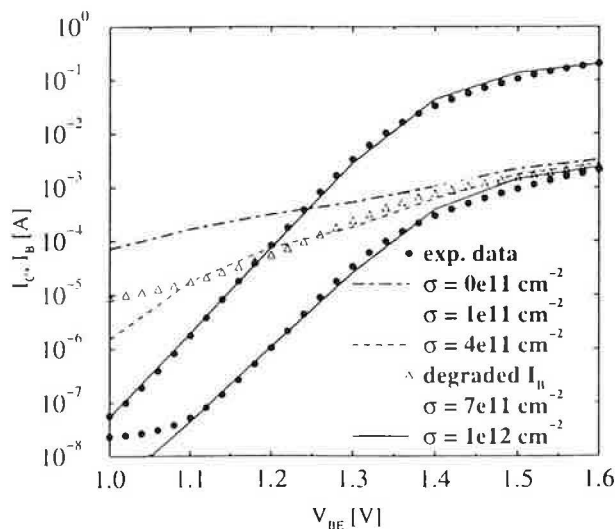


Figure 3: Dependence of I_B on the charge density at the ledge/nitride interface compared to measurement. Measured degraded I_B included.

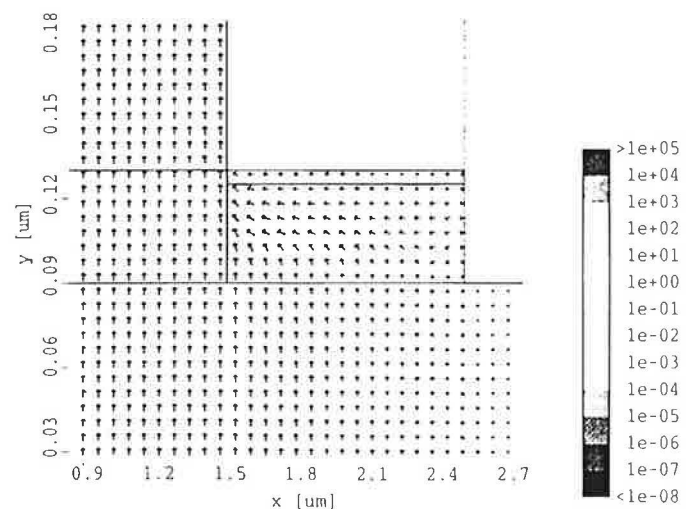


Figure 4: Electron current density [A/cm^2] at $V_{BE}=1.2\text{V}$. Simulation with surface charge density of 10^{12} cm^{-2} .