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Influence of emitter-ledge thickness on the surface-recombination mechanism of InGaP/GaAs heterojunction bipolar transistor

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Abstract

In this work, the characteristics of InGaP/GaAs heterojunction bipolar transistors (HBTs) with various emitter-ledge thicknesses are comprehensively studied and demonstrated. Based on the two-dimensional analysis, some important parameters such as the recombination rate and DC characteristics are studied. The simulated analyses are in good agreement with experimental results. It is known that better HBT performance, including lower recombination rate in the surface channel, and higher DC current gain are obtained in the studied devices with the emitter ledge thickness between 100 and 200 Å.

Keywords: Emitter-ledge thickness; Recombination rate; DC current gain

1. Introduction

Heterojunction bipolar transistors (HBTs) based on GaAs material system are attractive devices in applications to microwave power amplifiers and high-speed optical communication circuits due to their excellent DC and RF performance [1–4]. However, one major problem

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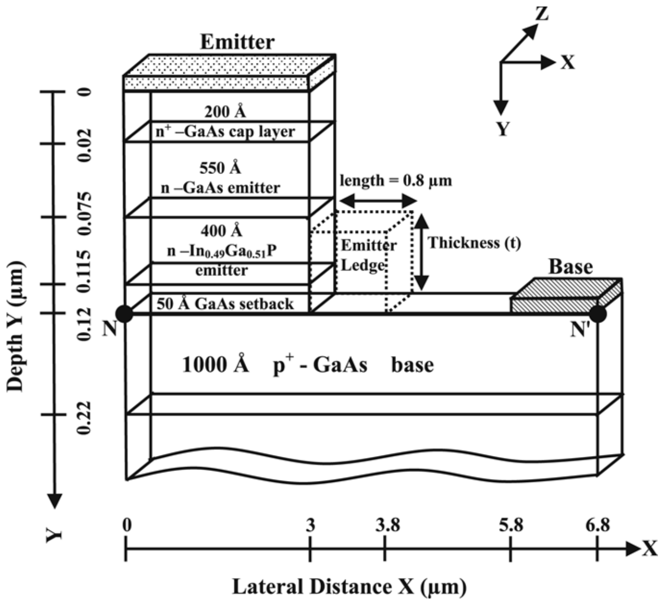

Fig. 1. Schematic cross-section of the simulated device.

in the circuit applications is the current gain degradation with the decrease of emitter–base junction size, *i.e*. the emitter size effect [5]. It's well known that the unpassivated GaAs surface is distracted by a high density of surface states. This causes the undesired pinning effect of surface Fermi level within the band gap of the semiconductor [6–9]. Many studies have been reported to solve this problem, such as emitter-ledge structure, sulphide-based chemical treatment and hydrogen plasma treatment [5–9]. Typically, the emitter- ledge structure is a simple method to decrease the surface recombination current and overcome the emitter-size effect [6,7]. Although, the emitter-ledge structure could improve part of HBT performance [9], the undesired surface-channel phenomenon on the exposed base surface between the base contact and emitter ledge is still presented. In addition, if the emitter ledge is too thick, part of the electron current injecting from the emitter and travelling towards base, will flow through the undepleted ledge region. This certainly degrades the emitter size effect. In contrast, if the emitter ledge is too thin, it may not effectively passivate the surface [10,11]. Thus, the thickness of the emitter-ledge structure is a significant issue and should be carefully considered.

In this work, a comprehensive investigation of InGaP/GaAs HBTs with various emitter-ledge thicknesses is implemented. The related recombination rates and DC characteristics of studied devices are demonstrated and studied. The theoretical analysis and simulations are made by using a two-dimensional simulator Atlas [12,13]. In addition, the corresponding experimental devices are fabricated and compared. The simulated data are in good agreement with measured results.

2. Model and device structure

The schematic cross-section of a simulated device structure, symmetrical with respect to the centre line of emitter contact is shown in the Fig. 1. Basically, the studied devices consist of a 5000 Å n^+-GaAs ($n^+ = 4 \times 10^{18}$ cm^{-3}) subcollector, a 3000 Å n^--GaAs ($n^- = 2 \times 10^{16}$ cm^{-3}) collector, a 1000 Å p^+-GaAs ($p^+ = 2 \times 10^{19}$ cm^{-3}) base, a 50 Å n-GaAs ($n = 3 \times 10^{17}$ cm^{-3})