Current gain enhancement of light-emitting transistors under different ambient temperatures

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INTRODUCTION

III–V alloys with direct band gaps and carrier injection have made possible the operation of light-emitting diodes (LEDs) and transistors. Due to the temperature sensitivity of their forward bias current-voltage (*I-V*) characteristics LEDs have been commercially available for some time as temperature sensors [1-2]. They provide wide range of operating temperatures (1.4 K to 500K), high sensitivity (units-hundreds mV/K), high signal level (from hundreds mV to Volt) at high stability and reproducibility [3].

Heterojunction bipolar transistors (HBTs) are widely used in high speed devices and microwave integrated circuits. For many system applications, the ambient temperature is significantly higher than room temperature due to power dissipation effects. When the HBT is operated at high power condition, thermal phenomenon such as the negative differential resistance (NDR) and collapse of current gain occur [4-5]. In early work a new class of light emitter, a three-port heterojunction bipolar light-emitting transistor (HBLET) [6-8] has been demonstrated by incorporating quantum-wells (QWs) into the base region of a HBT to enhance the base radiative recombination, and hence the optical output. Unlike HBTs, LETs possess a faster recombination lifetime and a GHz spontaneous modulation bandwidth.

In the present letter we investigate the temperature dependent characteristics of an InGaP/GaAs LET (with two undoped InGaAs QWs) and demonstrate the modulation of current gain by varying ambient temperatures. The current gain of conventional InGaP/GaAs HBT was also measured for comparison. Furthermore, we present the high sensitivity of current gain of LET is suitable for temperature sensor. Figure 1 shows the devices layout.

DEVICE CHARACTERISTICS AND RESULTS

The *I-V* characteristics (Figure 2) imply that the radiative recombination is effectively enhanced by QWs in LET. Figure 3 shows β versus ambient temperature. The β_{HBT} only decreases slightly with T_{amb} due to the small increase of base back-injection current. However, for LET, β_{LET} increases evidently with T_{amb}. When the ambient temperature increases, electrons injected from the emitter gain more thermionic energy and increase the possibility to escape from QWs when transporting through the base region. In other words, the thermionic emission lifetime (τ_{emi}) in Eq.1 [9] is reduced and more electrons are collected by the collector and do not have time to recombine with holes in QWs, resulting in an increase of current gain β_{LET}.

$$\tau_{emi} = \left(\frac{2\pi m^{*} {L_w}^{2}}{k_B T}\right)^{1/2} \exp\left(\frac{E_B}{k_B T}\right) \quad (1)$$

where E_B is the effective barrier height, m* is the carrier mass, k_B is the Boltzmann constant, and T is temperature.

In conclusion, we have investigated the electrical performance of an HBT and LET at four different ambient temperatures. By incorporating two InGaAs QWs into the base region of an HBT structure, the current gain is sensitive to ambient temperatures. The LET demonstrates the current gain increase of 76.77% from room temperature to 85°C. The positive temperature characteristics of current gain make the LET as a sensitive temperature sensor. More discussion will be provided in the extended abstract.

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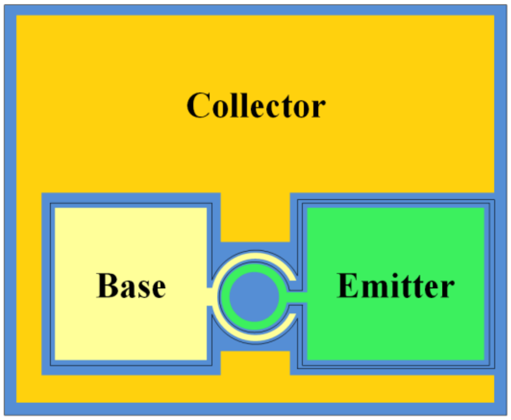

Figure 1. Top view layout of the HBT and LET.

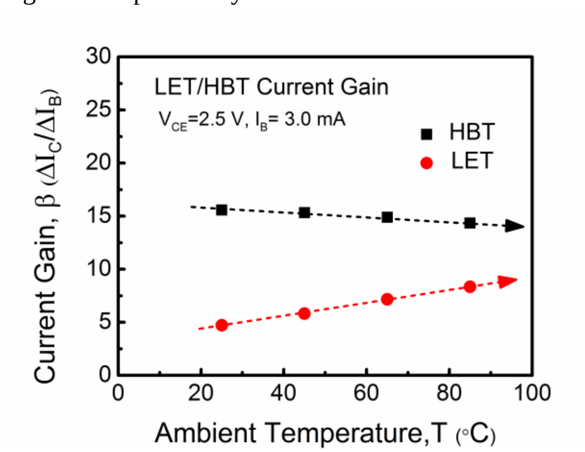

Figure 3. Current gain (β) versus substrate temperature. β_{HBT} is decreasing with ambient temperature but β_{LET} is increasing.

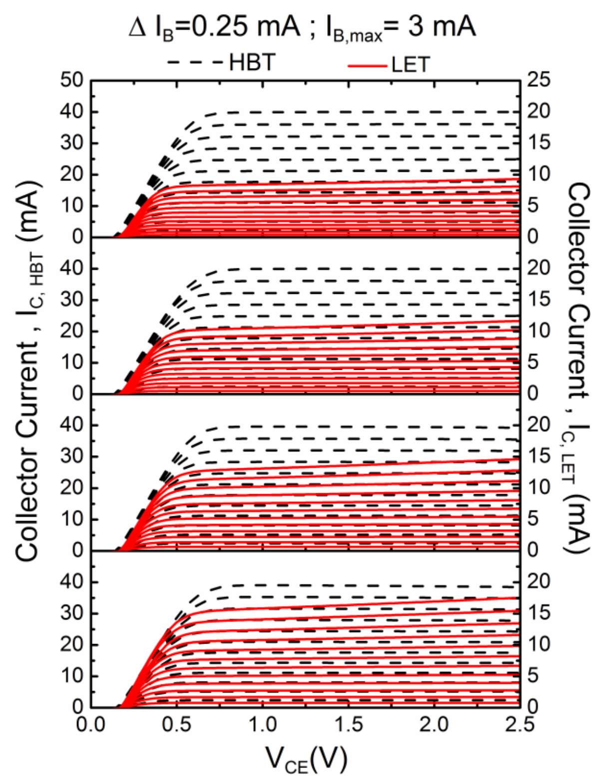

Figure 2. The I-V characteristics of HBT (dashed lines) and LET (solid line) corresponding to stage temperature (a) room temperature (b) 45°C (c) 65°C (d) 85°C

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