Characteristics of Sulfur- and InGaP-Passivated InGaP/GaAs Heterojunction Bipolar Transistors

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The InGaP/GaAs heterojunction bipolar transistors (HBT's) have recently received attention in both wireless and wired consumer products [1], [2]. In particular, they are less prone to surface oxidation than the AlGaAs/GaAs system. Furthermore, the availability of wet etchants with high selectivity between InGaP and GaAs simplify both processing yield and edge-thinning technique. However, the optimized passivation-layer thickness, depending on both emitter and base doping, is difficult to well control. This issue also severely limits the flexibility in designing the HBT structures. On the other hand, though sulfur treatments were demonstrated to effectively reduce surface recombination velocity, there are no results indicating what improvements are as compared with edge thinning technique.

In this paper, we will report HBT's having a highly carbon-doped density of $p^+=4\times10^{19}$ cm^{-3}, which were fabricated by edge-thinning technique and sulfur treatment. The studied HBT structure grown on GaAs semi-insulating GaAs substrates by LP-MOCVD typically consisted of a highly doped GaAs sub-collector, a lightly doped GaAs collector, a 1000-Å GaAs base, a 700-Å $n=5\times10^{17}$ cm^{-3} InGaP emitter, and a highly doped GaAs cap layer. After emitter, collector and base mesas, the samples with exposed GaAs base were dipped in the $(NH_4)_2S$ solution with a S weight concentration of 20% for 15 minutes at 50 ^oC. Other InGaP-passivated and non-passivated HBT's were also fabricated for comparisons.

Figure 1 shows the common-emitter characteristics of three HBT's with the same emitter area of 150×150 μm^2. All exhibit a small offset voltage and a low saturation voltage indicating good band lineup between InGaP and GaAs interface. Worthy of noting that sulfur-passivated HBT's demonstrated larger collector currents than those of InGaP- and non-passivated ones at the same base current levels. Figure 2 shows the Gummel plots for the non-, InGaP- and sulfur-passivated HBT's. It is found that all exhibit the nearly equal collector currents. Whereas the non-passivated devices exhibit larger base currents than those of Passivated ones. In particular, the sulfur-passivated devices even have the smallest base current as they sulfur treated after emitter metal deposition (sulfur-pass. 1). Figure 3 shows the dc current gain as a function of collector current. Note that both sulfur- and InGaP-passivated devices demonstrate very good linearity in wide range of collector (10^{-5} to 10^{-1} A).

In conclusion, we have compared characteristics and demonstrated what improvements are between sulfur-treatment and edge thinning HBT's. We will also report the effects of sulfur treatment with various processing conditions on device performances in this presentation. Moreover, InGaP passivation-layer thickness-dependent behaviors for InGaP/GaAs HBT's will be discussed to verify that sulfur-treatment seems to be another choice in commercial product.

REFERENCES

[1] N. Pan, J. Elliott, J. Knowles, D. P. Vu, K. Kishimoto, J. K. Twynam, H. Sato, M. T. Fresina, and G. E. Stillman, IEEE Electron Device Lett. **19**, 115 (1998).

[2] N. L. Wang, B. Lin, F. H. Chau, G. Jackson, Z. Chen, and C. P. Lee, Solid-State Electronics **43**, 1399 (1999).

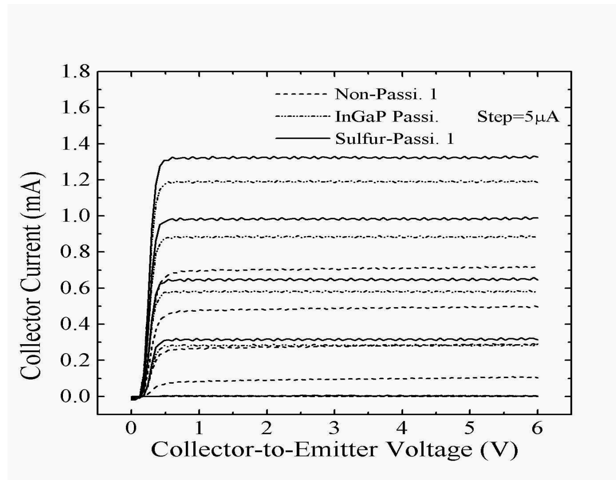

Fig. 1: The measured common-emitter characteristics for the studied HBT's with and without passivation layer.

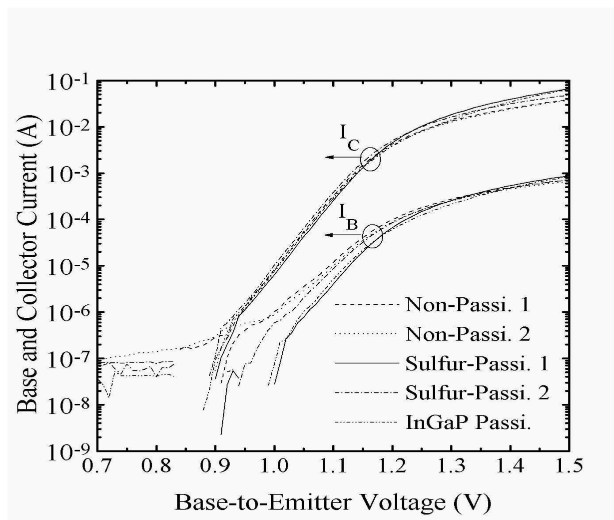

Fig. 2: The measured Gummel plots for the fabricated HBT's by edge thining technique and sulfur treatment as well as non-passivation layer.

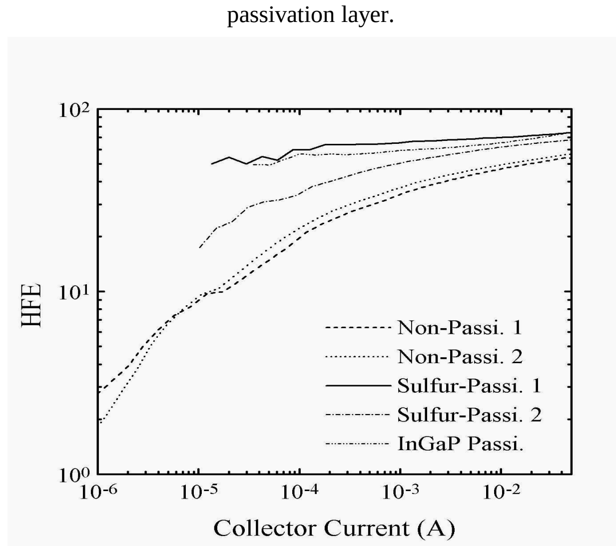

Fig. 3: The dc current gains as a function of collector current deduced from Fig.2.