A NEW BANDGAP NARROWING MODEL BASED ON CORRECTED INTRINSIC CARRIER CONCENTRATION

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1. Introduction

The modeling of bandgap narrowing (BGN) is crucial for bipolar device simulation. Many works [1]-[3] have been devoted to investigating this subject. The large deviation among the measured values of BGN was removed by the inclusion of minority carrier mobility [2]. However, theoretical confirmation of a BGN model has not yet been established.

A recent work [4] revealed that commonly used values [5] of intrinsic carrier concentration n_i are not correct. As shown in Fig. 1, the value of conventional n_i ($1.45\times10^{10}\text{cm}^{-3}$ at 300 K) is 1.34 times larger than that in [4]. This difference in n_i amounts to 15 meV in BGN.

Here, we present a new bandgap narrowing model derived from theoretical calculation, which is based on the corrected intrinsic carrier concentration.

2. New bandgap narrowing model

Figure 2 shows bandgap narrowing ΔE_g for measurements, theoretical calculation and the proposed model. The measured values in [2] were recalculated using the corrected intrinsic carrier concentration. Our theoretical calculation used the density of states for the impurity bands and the band tails, which included Hubbard bands [3] and a split of the degenerated impurity states. Theoretical calculation shows sufficient agreement with the measurements within a specified range of impurity concentration. We propose a new simplified expression for BGN which is suitable for device simulation ;

$$\Delta E_g = q\, V_1 \ln\left[\frac{1 + (N/N_0)^\alpha}{1 + (N/N_1)^\alpha}\right] \qquad (1)$$

where $V_1 = 25.16$ mV, $N = N_D^+ + N_A^-$, $N_0 = 4\times10^{17}\text{cm}^{-3}$, $N_1 = 3\times10^{20}\text{cm}^{-3}$ and $\alpha = 0.8$.

3. Comparison with measurements

Figure 3 shows the impurity profiles for an intrinsic region of a bipolar transistor, where the SIMS profiles for As and B are incorporated. These profiles were used for device simulation.

Figure 4 shows a comparison between the simulated and measured current-temperature characteristics, using a triangular mesh device simulator TRIMEDES [6]. The minority carrier mobility model [6] was also included in this calculation. The theoretical calculation resulted in a larger I_B, which suggests that ΔE_g for $N > 10^{20}\text{cm}^{-3}$ was overestimated in the theoretical calculation. The proposed model resulted in an excellent agreement with the measurements for both I_C and I_B.

References

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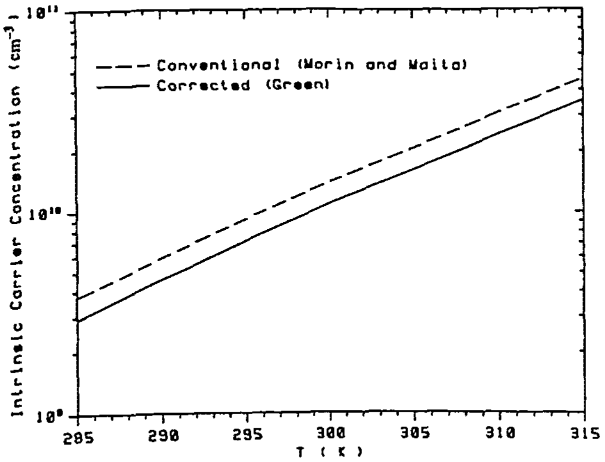

Fig. 1 Models for intrinsic carrier concentration.

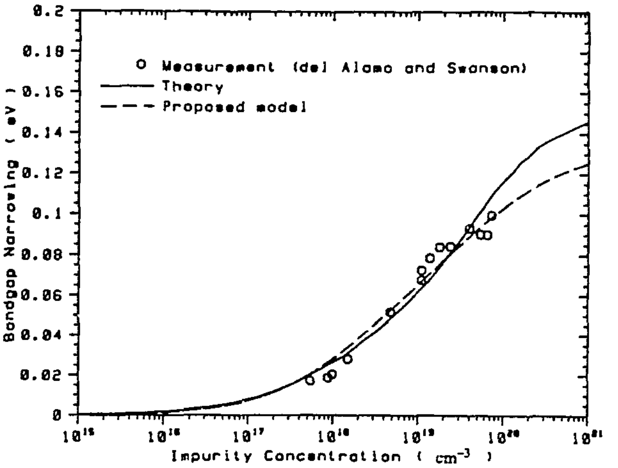

Fig. 2 Bandgap narrowing ΔE_g for measurement, theoretical calculation and proposed model.

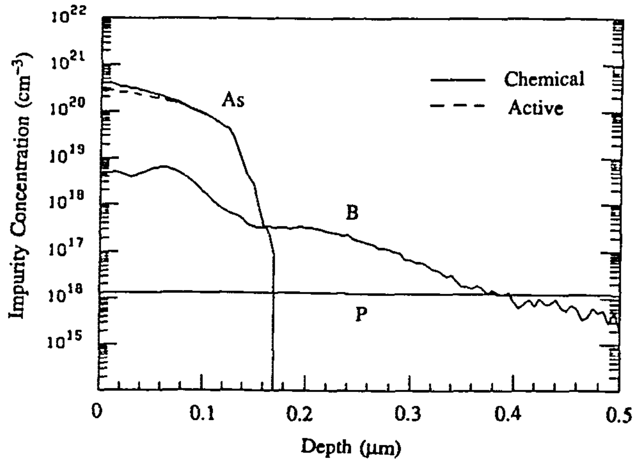

Fig. 3 Impurity profiles for intrinsic bipolar region.

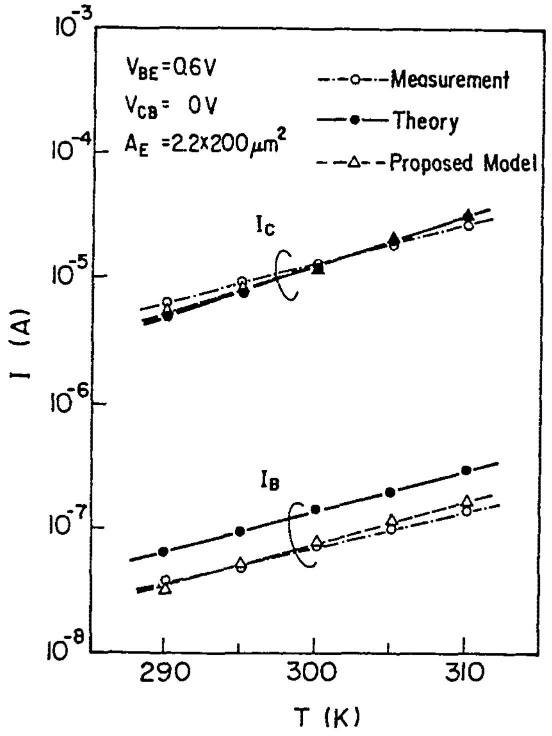

Fig. 4 Simulated current-temperature characteristics.