Study of Dopant-Dependent Band Gap Narrowing in Compound Semiconductor Devices

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Band gap narrowing is one of the crucial heavy-doping effects to be considered for bipolar devices. In case of HBTs, where discontinuities in the energy levels appear, the correct modeling of the energy barriers has basic importance for studying the device performance. Using the physically-based approach from [1], we present a new band gap narrowing model which considers the semiconductor material and the dopant species for any temperature. As a particular example we present in Fig. 1 the results for Si-doped GaAs and P-doped Si. Note the stronger band gap narrowing at 77K, caused by higher degeneracy. Neglecting this effect results in an error of about 50%.
As a particular example we studied with MINIMOS-NT, our two-dimensional device simulator with approved capabilities of simulating devices with complex structure the electrical behavior of graded composition Si/SiGe HBT and AlGaAs/GaAs HBT using a hydrodynamic transport model. Our investigations were performed in a comparative way for different dopant species and temperatures, using the new band gap narrowing model and old ones, which neglect differences in the dopant species. In Fig. 2 we present the Gummel plots for Si/SiGe HBT at 77K and 300K obtained with the model of Slotboom et al.[2] (Mod.1) and with our new model (Mod.2). Note the significant difference in the current density values at 77K, resulting for Mod.2 in higher current gain, which is confirmed by experiments.
In summary, a new band gap narrowing model is presented and its impact on the HBT device performance is studied.

References

[1] G. Kaiblinger-Grujin, H. Kosina, and S. Selberherr. Monte Carlo Simulation of Electron Transport in Doped Silicon. In *High Performance Computing on the Information Superhighway – HPC Asia '97*, pages 444–449, Seoul, Korea, 1997. IEEE Computer Society Press.

[2] J.W. Slotboom and H.C. de Graaff. Measurements of Bandgap Narrowing in Si Bipolar Transistors. *Solid-State Electron.*, 19:857–862, 1976.

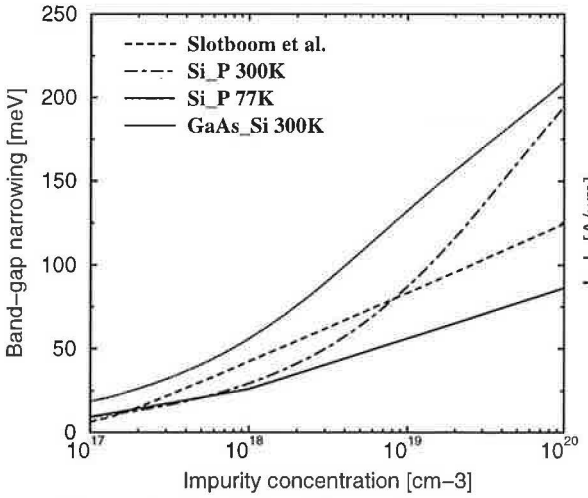

Figure 1: Band Gap Narrowing vs. Impurity Concentration

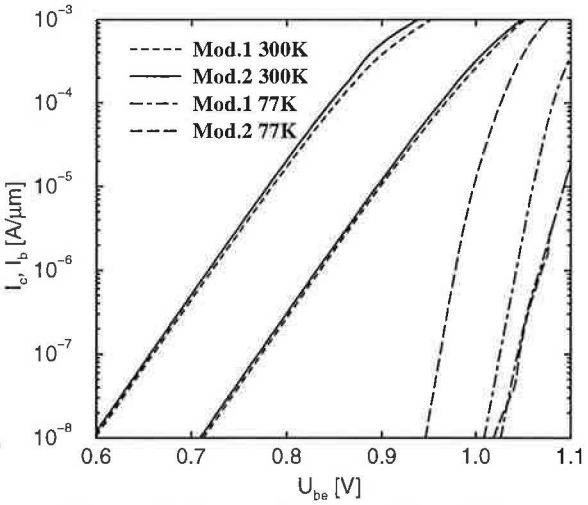

Figure 2: Gummel Plots at $V_{ce} = 2V$ Mod.1 and Mod.2