Numerical simulation of ballast resistor behavior in HBTs

R. Stenzel[1], C. Pigorsch[1], W. Klix[2], H. Leier[3], H. Blanck[4]

[1]University of Applied Sciences Dresden, Friedrich-List-Platz 1, D-01069 Dresden, Germany
[2]University of Technology Dresden, Mommsenstr. 13, D-01062 Dresden, Germany
[3]DaimlerChrysler AG, Research and Technology, Wilhelm-Runge-Str. 11, D-89081 Ulm, Germany
[4]United Monolithic Semiconductors GmbH, Wilhelm-Runge-Str. 11, D-89081 Ulm, Germany

Abstract

Power heterojunction bipolar transistors (HBT) require the use of parallel combined multiple emitter elements which are susceptible to thermal instabilities. The use of emitter ballast resistors is one approach to avoid the thermal collapse in multifinger HBTs by reducing the thermally induced voltage drop across the base-emitter junction under high current conditions [1]. Systematic simulations of AlGaAs/GaAs-HBTs and GaInP/GaAs-HBTs with GaAs and AlGaAs ballast regions of different thickness and doping have been carried out to determine the current dependence of the ballast resistors, which should be independent of current alterations. For the HBT modeling we used our 2D/3D program SIMBA [2,3] which is based on a self-consistent solution of a drift-diffusion model. The energy balance equations, the heat flow equation and the Schrodinger equation can be included optionally. The calculation of the ballast resistors is done by applying the potential distribution within the ballast region obtained by the numerical simulation at different currents. AlGaAs/GaAs-HBTs show a significant dependence on collector current (Fig. 1) due to the conduction band discontinuity and the carrier injection into the low-doped ballast region. A nearly constant ballast resistor can be achieved by GaInP/GaAs-HBTs with GaAs ballast regions because of the absence of conduction band discontinuities.

[1] G. Gao, M.S. Ünlü, H. Morkoc, D.L. Blackburn:
Emitter ballasting resistor design for, and current handling capability of AlGaAs/GaAs power heterojunction bipolar transistors.
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[2] R. Stenzel, J. Würfl, E. Richter, C. Pigorsch, W. Klix:
Simulation of influence of heat removal on power gains of heterojunction bipolar transistors.
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[3] http://www.iee.et.tu-dresden.de/~klix/simba/

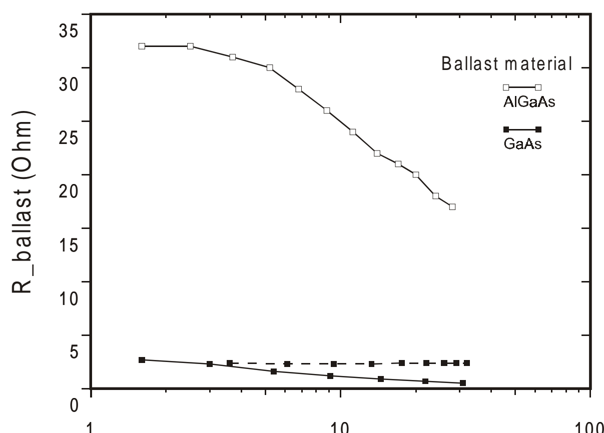

Fig. 1
Ballast resistor versus collector current for different ballast materials of a AlGaAs/GaAs-HBT (solid) and a GaInP/GaAs-HBT (dashed)
Emitter area: 2x30 µm^2, V_{CE} = 6 V
Ballast doping: $2 \cdot 10^{16}$ cm^{-3}, thickness: 300 nm