MOCVD-Grown Carbon Doped InP/InGaAs SHBTs and DHBTs

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InP-based heterojunction bipolar transistors (HBTs) are being considered as the technology of choice for 40Gbps lightwave circuits. The HBT devices come in two flavors: A single heterojunction InP/InGaAs/InGaAs bipolar transistor (SHBT) and a double heterojunction InP/InGaAs/InP bipolar transistor (DHBT). The technology offers simultaneous high-speed and high-breakdown by employing InP as the collector in the DHBT; and lattice-matched InGaAs allows for monolithic optoelectronic integration using the SHBT. The principal material growth technology to produce such InP HBT layers is molecular beam epitaxy, which employs beryllium or carbon doping in the InGaAs base. Carbon doping has been shown to improve device reliability compared to Be-doping by reducing the diffusion of the base dopant into the wide bandgap emitter during device operation at high current densities.[*] We believe that the development of carbon-doped InP/InGaAs HBTs grown by metal-organic chemical vapor deposition (MOCVD) will accelerate the insertion of InP into reliable circuits in a cost-effective manner.

Towards this end, we are developing InP HBT technology with high base doping and adequate DC current gain for reproducible and manufacturable SHBT and DHBT devices suitable for 40Gbps lightwave technology. The HBT layers were grown using low pressure MOCVD in an Aixtron 2400 multiwafer production system. The DC gain β at $J_C = 1$ kA/cm^2 as a function of the base sheet resistance R_{sb} for a series of HBTs is plotted in Fig. 1. All of the Kopin data are on SHBTs except for a single point for a DHBT. Data from the literature are also included for comparison. The R_{sb}-squared dependence of the gain indicates Auger processes as the dominant recombination mechanism in the base. Secondary ion mass spectroscopy (SIMS) measurements indicate hydrogen incorporation remains at a manageable level, increasing from 5×10^{18} to 2×10^{19} cm^{-3} when the *active* doping level in the base is increased from 1×10^{19} to 3×10^{19} cm^{-3}. The SIMS data are consistent with the measured base sheet and thickness. Figure 2 shows DC data on small-area devices from a SHBT structure with a 50nm thick base doped at 1.0×10^{19} cm^{-3} and a 200nm thick collector. The inset shows the common-emitter characteristics. The device was fabricated in a process designed for *preliminary* RF characterization and an f_T of 80 GHz was measured at a modest current density of ~5×10^4 A/cm^2. The current gain versus frequency at 5×10^4 A/cm^2 is shown in Fig. 3. Measurements on large-area SHBT and DHBT devices with a base doping of 3×10^{19} cm^{-3} show excellent DC characteristics and are in process for RF characterization. We will present detailed RF data on both SHBTs and DHBTs with 3×10^{19} cm^{-3} base doping fabricated in a process designed for 40Gbps performance.

[*]Bahl, S.R. *et al.*, "Be diffusion in InGaAs/InP heterojunction bipolar transistors," *IEEE EDL*, vol. 21, pp. 332-334, July 2000