Extended Abstracts of the 18th (1986 International) Conference on Solid State Devices and Materials, Tokyo, 1986, pp. 765-766

Hot Electron Transistors Using InGaAs/InAlGaAs Heterostructure

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Hot electron transistors (HETs) using $In_{0.53}Ga_{0.47}As$ for the base and $In_{0.52}(Al_{0.5}Ga_{0.5})_{0.48}As$ for the emitter and collector barrier were fabricated and characterized for the first time. Common-emitter current gain was measured as 3.0 at 77K for the 1000 Å base HETs, which is about 3 times higher than that of GaAs/AlGaAs HETs.

Hot electron transistors (HETs) are attractive for use as high speed devices because they use ballistic transport of hot electrons. We have already fabricated GaAs/AlGaAs HETs and observed a common-emitter current gain of 1.0 for the 1000 Å base at 77K.[1] This relatively low current gain was due to the intervalley scattering in the GaAs base at higher injection energies of more than 0.3 eV. To achieve a higher current gain, we tried to fabricate InGaAs base HETs with a higher Γ -L separation energy.[2),3]

Figure 1 is a schematic cross section of the InGaAs/InAlGaAs HETs we fabricated. $In_{0.53}Ga_{0.47}As$ and $In_{0.52}(Al_{0.5}Ga_{0.5})_{0.48}As$ were grown on an InP substrate using pulse molecular beam methods.[4] The conduction band discontinuity at the emitter barrier and the collector barrier, as derived from the thermionic current, was measured to be 0.255 eV.[5] As we use a quaternary InAlGaAs barrier, the collector barrier can be made much lower than that of an InAlAs barrier (0.553 eV).[5] The carrier concentration in the base layer was 1 X 10^{18} cm^{-3}. Figure 2 shows the common-emitter collector current-voltage characteristics measured at 77K. The emitter-base junction area is 6 X 44 μm^2. A common-emitter current gain of 3.0 was obtained at V_{CE} = 2.0 V and I_B = 5 mA (V_{BE} = 0.6 V). This value was 3 times higher than that of GaAs base HETs.[1] The increased current gain can be attributed to the higher electron injection energy. The collector current density was 6.4 X 10^3 A/cm^2 at I_B = 5 mA and 1.7 X 10^4 A/cm^2 at I_B = 20 mA. Transconductance, g_m, was 2.75 S/mm at V_{BE} = 0.6 V. High current density and transconductance was due to the higher tunneling probability of InAlGaAs than that of AlGaAs. These results show that InGaAs HETs exhibit a large current drivability due to the lower electron effective mass of InAlGaAs than that of AlGaAs.

The relationship between the transfer ratio ($\Delta I_C/\Delta I_E$) and the injection energy in InGaAs base HETs was analized. Figure 3 shows the transfer ratio in the common-base configuration as a function of emitter voltage, V_E, at V_{CB} = 0.5 V. Note that the transfer ratio increases rapidly with increasing negative emitter voltage and takes the peak at around 0.67 V, then followed by decreased transferm ratio. The peak in the transfer ratio is considered to be due to the increased intervalley scattering of hot electrons at a higher injection energy than the Γ-L valley separation energy.(0.55 eV)[2)]

These results show that InGaAs/InAlGaAs HET devices show great promise regarding high current gain, and large current drivability.

This work was supported by the MITI's Project of Basic Technology for Future Industries.

Reference

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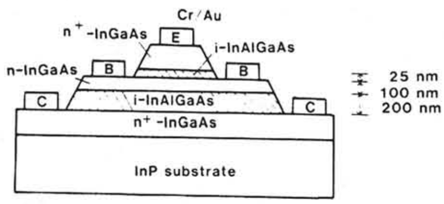

Figure 1. Schematic cross-section of an InGaAs/InAlGaAs HET

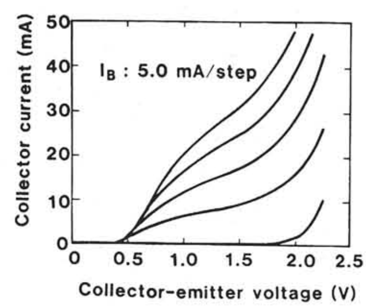

Figure 2. Common-emitter collector current-voltage characteristics measured at 77K

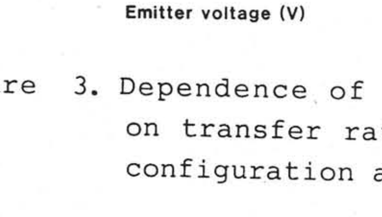

Figure 3. Dependence of emitter voltage on transfer ratio in common-base configuration at V_{CB} = 0.5 V