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B—3—1 Monolithic Hot Electron Transistors in Silicon with F_T > 1 GHz

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Monolithic Hot Electron Transistors[1] (MHET) offer the potential of a high frequency performance far superior to that of a bipolar transistor[2]. This arises because of the unipolar nature of current transport up to high current densities and the use of a degenerate base region with a small base resistance. Furthermore, fundamental difficulties in hot electron structures related to phonon scattering and quantum mechanical reflections at potential barriers are minimised because of continuity in the electronic structure throughout the device.

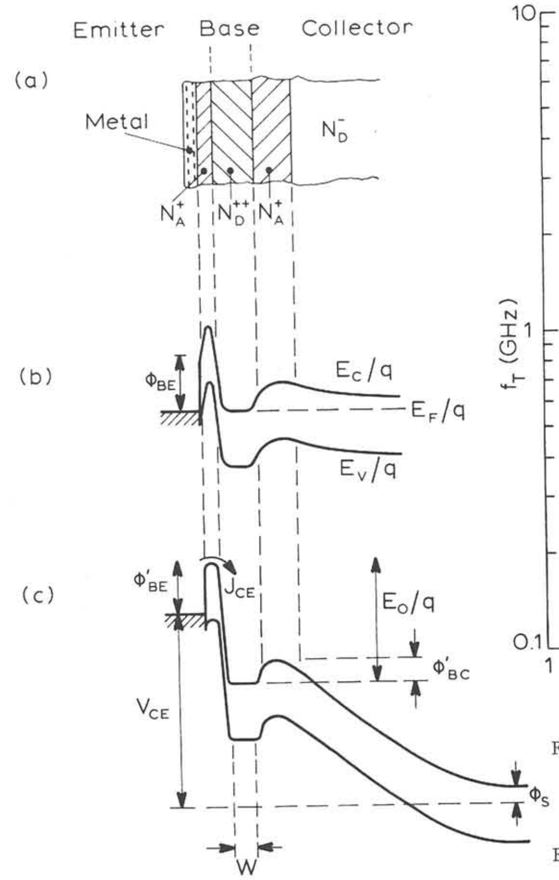
MHET structures containing two potential barriers[2], one for the emission and one for the collection of hot electrons (Figure 1) have been made using dopant implantation at low energies[3] (<25 keV). Following implantation of As and BF_2 into single crystal <100> material the structures are annealed at low temperatures to avoid diffusion and form narrow, highly doped metastable layers. Electrical and SIMS measurements have shown that there is little movement of the arsenic in these structures (<50 Å), the peak concentration being $\sim 2 \times 10^{20}$ cm^{-3} at a distance ∿150 Å from the surface. The active base width is ∿250 Å. The quality of the camel collector barrier[3], however is degraded by the presence of electrically active tails on the boron profiles formed during the implant. As expected the effective height of the collector barrier can be controlled simply by changing the concentration or energy of the BF_2 implant. The emitter barrier is formed using a boron implant with mean range ∿50 Å.

Electrical measurements have been made on simple planar devices with 4 μm interdigitated base and emitter fingers on 3 μm <100> epitaxial layers. It is found that transistor action can occur for V_{EB} as low as 0.2 V. Collector leakage can be negligible but, as expected, a high collector barrier ϕ'_{BC} reduces the gain because of the larger rate of energy loss due to optical phonon scattering at the high energies required to overcome the barrier. Current gains of ∿20 have been measured on structures with $\phi'_{BC} \sim 0.45$ eV and $V_{EB} \sim 1$ volt giving low frequency power gains of ∿20 dB. S-parameter measurements showed that F_T corrected for DC gain was >1 GHz when operated with an emitter current of >5 mA (Figure 2). The s-parameter measurements have been analysed in the context of an equivalent circuit for a MHET and compared with calculated parameters based on transistor geometry and doping profiles. Good agreement is found between measured and calculated[2] parameters which suggests that a major improvement in performance should occur with this geometry when using a more optimally designed hot-electron emitter.

1 J.M. Shannon, IEE J. Solid State & Electron Devices, 3 (5), p.142 (1979).

2 J.M. Shannon, IEE Proc. Vol. 128, Pt.1, No.4, p.134 (1981).

3 J.M. Shannon, J. Nuclear Instrum. & Methods, 182/183, p.545 (1981).



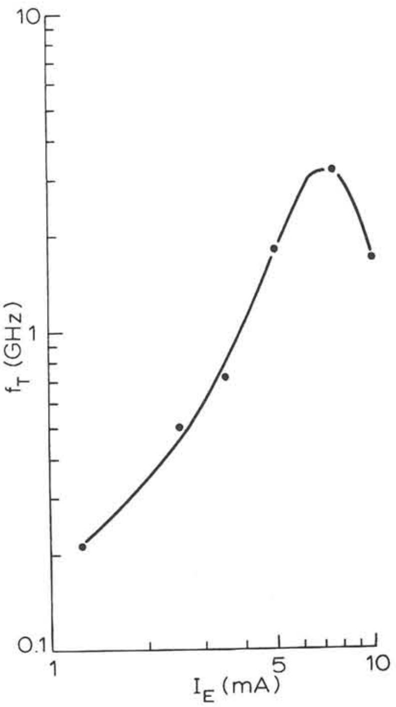


Fig. 1 MHET with metal-semiconductor emitter (a) structure, (b) band diagram in thermal equilibrium and (c) with applied bias.

Fig. 2 F_T measured on a planar silicon device made using ion implantation.