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InP/$In_{0.53}Ga_{0.47}As$/InP Double Heterojunction Bipolar Transistors on a GaAs Substrate Using InP Metamorphic Buffer Layer

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Double heterojunction bipolar transistors (DHBTs) have applications [1-3] in high frequency communications and radar. Though InGaAs/InP HBTs grown on InP substrates show the best high-frequency performance, InP substrates have several disadvantages compared to GaAs substrates. InP substrates are expensive and 100-mm-diameter InP substrates are extremely fragile and are readily broken during processing . Thus, several groups have recently pursued metamorphic growth of InP-based DHBTs on GaAs substrates [4].

Here we report InP-based DHBTs grown on GaAs using InP as the metamorphic buffer layer. While AlGaAsSb and InAlAs have been explored as the metamorphic buffer layers, InP metamorphic layers grown in our laboratory have substantially better measured thermal conductivity – 16.1 W/mK for InP, 10.5 W/mK for InAlAs, and 8.4 W/mK for AlGaAsSb metamorphic layers. With a typical HBT geometry and $2x10^5$ W/cm^2 dissipation, a thermal analysis indicates that use of the InP buffer layer will reduce the operating junction temperature 16-39 ^{o}C , a difference which can have substantial impact upon device reliability.

InP/$In_{0.53}Ga_{0.47}As$/InP DHBTs were grown on GaAs substrate using a Varian Gen II MBE system. The 1.5 µm thick InP metamorphic buffer layer was grown at 480°C directly on the GaAs substrate. During buffer layer growth, the reflection high energy electron diffraction (RHEED) pattern showed strong streaks, indicating two-dimensional growth, though the RHEED intensity was slightly smaller than observed with lattice-matched growth.

Triple-mesa HBTs were fabricated using optical projection lithography and selective wet etching. The emitter-base junction is 0.3 *m*m by 8 *m*m , while the base-collector junction is 1.1 *m*m x 11 *m*m . Fig. 1 shows the common emitter characteristics; ß = 27 is obtained. Current-gain and power-gain cut-off frequencies f_t =165 GHz and $f_{\max}$ = 92 GHz were measured at I_C = 7.0 mA and V_{CE}=1.5 V , as determined by a -20 dB/decade extrapolation from DC-45 GHz measurements (figure 2). These cutoff frequencies are over a 2:1 higher than prior reported results for metamorphic HBTs.

References

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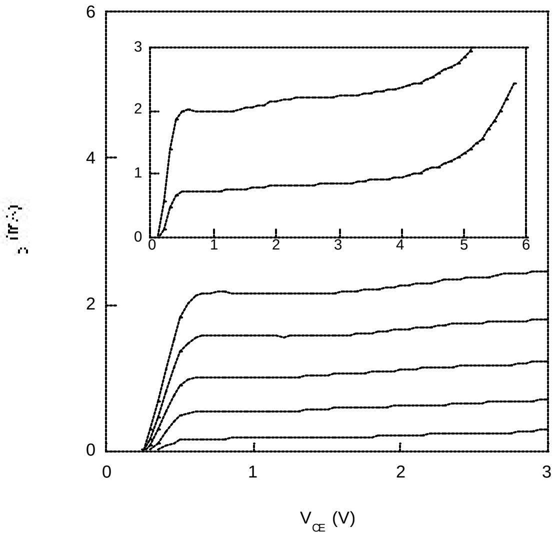

Fig. 1: Common-Emitter DC characteristics of a 0.3 *m*m x 8 *m*m emitter device. Base current steps are 20 *m*A . The inset shows the 5 V BVCEO breakdown voltage.

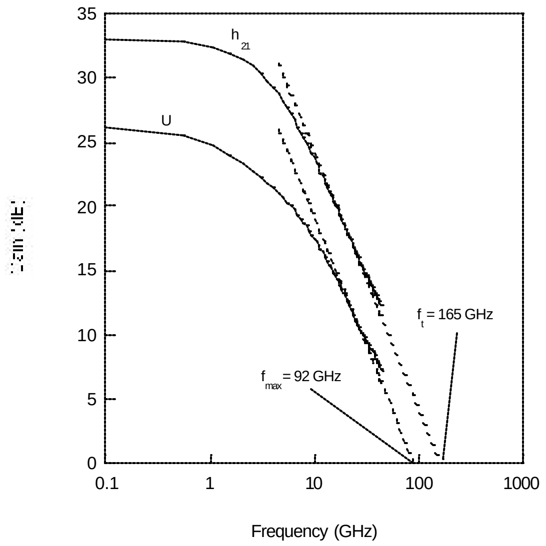

Fig. 2 : Small signal current gain and unilateral power gain vs. frequency at I_C=7.0 mA and V_{CE}=1.5 V.