

# TRANSFERRED SUBSTRATE HETEROJUNCTION BIPOLAR TRANSISTORS FOR SUBMILLIMETER WAVE APPLICATIONS

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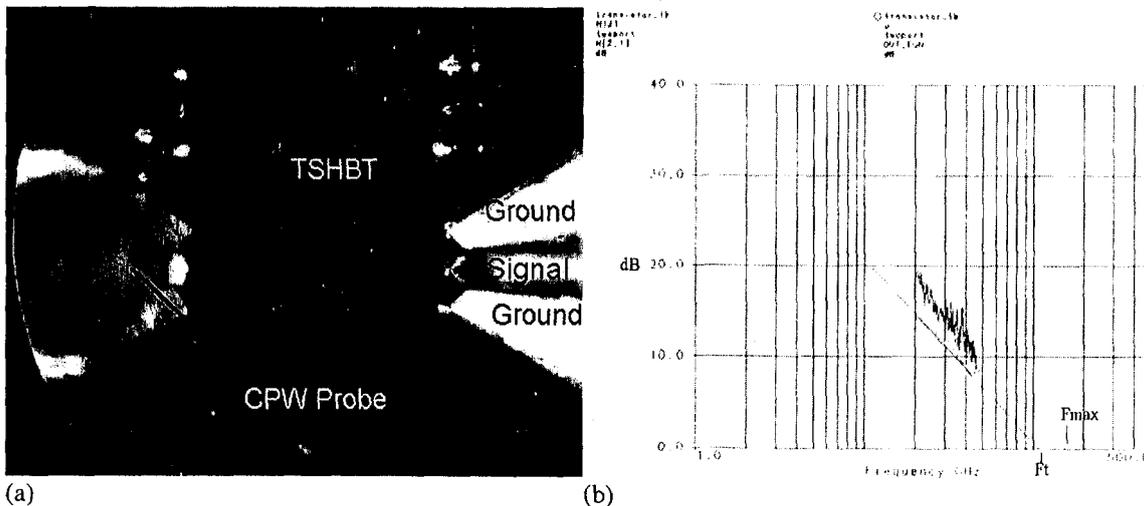
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## ABSTRACT

We present ongoing development work towards the realization of submillimeter wave transistors with goals of realizing advanced high frequency amplifiers, voltage controlled oscillators, active multipliers, and traditional high-speed digital circuits. The approach involves fabrication of indium phosphide heterojunction bipolar transistors in a low parasitic transferred-substrate process, with the necessary requirements in uniformity and reliability for eventual space-borne applications. Transferred Substrate Heterojunction Bipolar Transistors (TSHBTs) have previously demonstrated record  $>20$  dB measured unilateral power gain at 100 GHz, and high power gains in the 140-220 GHz band<sup>1</sup>, in part due to device scaling, and in part due to negative-resistance effects in the collector drift region. Single-transistor amplifiers have shown 6.3 dB gain at 174 GHz<sup>2</sup>. Scaling to  $< 200$  nm emitter junction width should result in significant power gain in the 220-330 GHz band, and perhaps at higher frequencies. Thus far we have completed a first generation of TSHBT with large emitter stripes of  $0.8 \times 6 \mu\text{m}^2$ . S-parameter measurements resulted in an extrapolated power gain cutoff frequency ( $F_{\text{max}}$ ) of 150 GHz and current gain cutoff frequency ( $F_t$ ) of 110 GHz, at an emitter current density of  $94 \text{ kA/cm}^2$  and collector-emitter bias voltage of 1.25V (Figure 1). Future generations of TSHBTs will target enhancements in speed, uniformity and reliability, through improvements in epitaxial material quality and semiconductor layer structure design, reduction in transistor geometry size, and refinements in fabrication procedures.



(a) (b)  
Figure 1. (a) Optical photo of a first generation TSHBT with wafer probes. The CPW probe pitch is  $100 \mu\text{m}$ . (b) Mason's unilateral gain and current gain, H21, versus frequency for extrapolating  $F_{\text{max}}$  and  $F_t$ , respectively.

<sup>1</sup> M. Rodwell, et al., IEEE Trans. Electron Devices, vol. 48, Nov. 2001.

<sup>2</sup> M. Urteaga, et al., Proc. IEEE GaAs IC Symp., Oct. 2001.