Increasing f_{MAX} for InP/GaInAsSb transistors

ETH-Zurich fabricates GaInAsSb DHBTs with record f_{MAX} of 636GHz.

Researchers at ETH-Zurich have used quaternary gallium indium arsenide antimonide (GaInAsSb) in the p-type base region of a double heterostructure bipolar transistor (DHBT) to improve performance over devices using GaAsSb or graded GaAsSb/GaInAsSb [Ralf Flückiger et al, IEEE Electron Device Letters, v35, p166, 2014].

Radio-frequency measurements gave a maximum oscillation frequency (f_{MAX}) of 636GHz and cut-off (f_T) of 424GHz at a collector current density of 8.8mA/cm^2 and collector emitter voltage of 1.6V. The researchers comment: "The present transistors offer the highest f_{MAX} to date for GaInAsSb DHBTs and match the highest f_{MAX} of any Sb-based DHBT."

DHBTs with graded bases have achieved balanced f_T/f_{MAX} performance of 480/420GHz and unbalanced performance of 670/185GHz. ETH-Zurich has previously produced GaAsSb devices with f_T/f_{MAX} of 428/621GHz (2013) and 365/501GHz (2011).

The addition of indium to GaAsSb is expected to increase minority electron mobility, reducing base transit time and thus improving the frequency response.

The epitaxial structure (Table 1) was produced on semi-insulating indium phosphide (InP) using metal-organic vapor phase epitaxy (MOVPE). The 20nm $Ga_{0.94}In_{0.06}As_{0.59}Sb_{0.41}$ base layer had a sheet resistance of 1070Ω/square.

The sheet resistance value is considered relatively low considering the low doping concentration. Part of the explanation is given by the high hole mobility of 40cm^2/V-s. A similarly doped GaAsSb layer with ~0.6 As fraction had a sheet resistance of 1140Ω/square and hole mobility of 31cm^2/V-s.

The DHBTs were fabricated using a triple-mesa process. The emitter area was 4.4μm x 0.3μm. Base/collector contact area was 5.0μm x 0.8μm.

With 0V bias across the base-collector junction, peak DC gain was 23. The researchers estimate that a GaAsSb base device with similar sheet resistance would have a gain of about half of this. The open base common emitter breakdown voltage was 4.75V.

The small-signal model for the optimum RF bias point (Figure 1) has total base resistance of 123Ω-μm (10% lower than ETH-Zurich's 2013 GaAsSb-base DHBT). ■

Material	Doping (cm^{-3})	Thickness
$Ga_{0.25}In_{0.75}As$	Si : 3.8×10^{19}	5 nm
$Ga_{0.47}In_{0.53}As$ → $Ga_{0.25}In_{0.75}As$	Si : 3.8×10^{19}	10 nm
$Ga_{0.47}In_{0.53}As$	Si : 3.8×10^{19}	20 nm
InP	S : 3.0×10^{19}	130 nm
InP	Si : 4.3×10^{16}	5 nm
$Ga_{0.10}In_{0.9}P$ → InP	Si : 4.3×10^{16}	10 nm
$Ga_{0.10}In_{0.9}P$	Si : 4.3×10^{16}	5 nm
$Ga_{0.94}In_{0.06}As_{0.59}Sb_{0.41}$	C : 7.3×10^{19}	20 nm
InP	S : 1.3×10^{17}	125 nm
InP	S : 2.2×10^{19}	50 nm
$Ga_{0.40}In_{0.60}As$	Si : 3.0×10^{19}	20 nm
InP	S : 2.2×10^{19}	300 nm
InP semi-insulating 2-inch substrate		350 μm

Table 1. Epitaxial layer structure for ETH-Zurich DHBT with InP collector, GaInAsSb base, and GaInP/InP emitter.

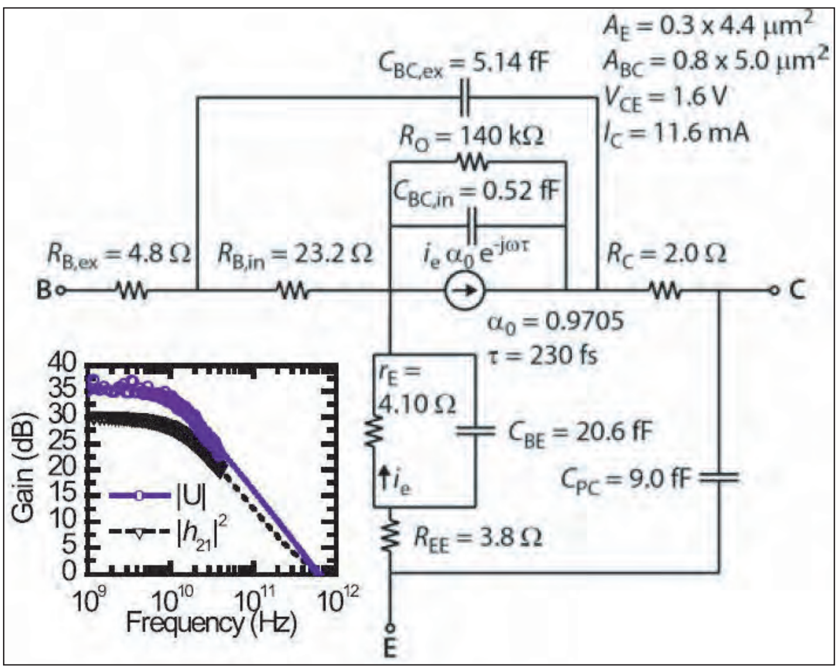

Figure 1. Small-signal equivalent circuit with component values extracted from S-parameter measurements at V_{CE} bias of 1.6V and I_C at 11.6mA. Inset: measured $|h_{21}|^2$ and U (symbols) with corresponding simulated small-signal data (lines).

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