INDIUM PHOSPHIDE DOUBLE HETEROJUNCTION
BIPOLAR TRANSISTORS WITH T-SHAPED EMITTER
METAL FEATURES HAVING CUTOFF FREQUENCIES IN
EXCESS OF 200 GHZ

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Introduction

• Motivation
  – Improve electronic instruments for spectroscopy.
  – Develop and utilize the fastest transistors (Heterojunction Bipolar Transistors) for advancing heterodyne receivers.

• Device Development
  – Microfabrication of HBTs
  – T-emitter metal structure

• Results
  – DC and RF HBT characteristics
  – Matched HBT amplifier characteristics

• Summary

• Acknowledgments
Motivation
Motivation

Electromagnetic Spectrum

<table>
<thead>
<tr>
<th>Microwaves</th>
<th>Infrared</th>
<th>Visible</th>
<th>Ultraviolet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1cm, 1mm, 100um, 10um, 1um, 0.1um</td>
<td></td>
<td></td>
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<tr>
<td>30, 300, 3THz, 30, 300, 3000 GHz, THz, GHz, THz</td>
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Microwave/Infrared Spectroscopy
Carbon II - 1.9 THz, H2O - 7.6 THz (Organic Life)
Hydrogen deuteride - 2.7 THz (Big Crunch)

Fmax versus Critical Lithographic Dimension

Emitters Width [um]
Gate Length [um]
Device Development

- Epitaxial Structure - InP/InGaAs/InP Double HBT (DHBT)

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*Energy level versus position diagram generated with Bandprofiler of W. Frensley UTDallas*
Device Development

- Triple Mesa DHBT Microfabrication

1. Epi-wafer
2. EJ flat orientation
3. Collector etch
4. Base post
5. Collector etch
6. Collector metal
7. Collector post
8. Isolation
9. BCB deposition, planarization, etch
10. Metal 1
11. Metal 2 airbridge
Device Development

- T-Shaped Emitter Metal

T-Emitter

Standard Emitter

H. Masuda, et al. '95
H. Nakejima, et al. '99
Results

- Focus Ion Beam Cross Sections and SEMs

Dual 0.5um x 12um Emitter DHBT
Results

- DC Current – Voltage Characteristics

Optical photo of a 0.3umX9um emitter DHBT in coplanar waveguide.
Results

- The figures of merit of high speed transistors are the current gain cutoff frequency \(F_t\) and maximum frequency of oscillation \(F_{\text{max}}\).

\[
F_t = \frac{1}{2 \cdot \pi \cdot \tau_{ec}} \quad \tau_{ec} = \tau_e + \tau_b + \tau_{bc} + \tau_c
\]

\(\tau_{ec}\) is the total emitter to collector delay time of the HBT.

\[
F_{\text{max}} \gg \left[ \frac{F_t}{8 \cdot \pi \cdot R_b \cdot C_{cb}} \right]^{1/2}
\]

\(R_b\) is the effective HBT base resistance,
\(C_{cb}\) is the base to collector capacitance.
Results

- RF Vector Network Analyzer Measurements of DHBTs
Results

- RF Vector Network Analyzer Measurements of Amplifiers

**Dual 0.7um x 12um Emitter DHBT Amplifier**

**WR-10 CPW On-Wafer Measurement**
- Dual 0.7um x 12um Emitter 100GHz Amplifier
- $J_e = 3.41 \text{mA/um}^2$, $V_{ce} = 2\text{V}$

**WR-5 CPW On-Wafer Measurement**
- Dual 0.7um x 12um Emitter 180GHz Amplifier
- $J_e = 3.48 \text{mA/um}^2$, $V_{ce} = 2.16\text{V}$
Summary

- We are motivated to improve electronic components for advancing heterodyne receiver technology for future astrophysics, planetary and Earth science spectroscopy missions.
- We have demonstrated,
  - T-shaped emitter metal DHBTs with the goal of improving yield and performance.
  - Third generation emitter mesa HBTs with $F_t = 251$ GHz, $F_{max} = 288$ GHz (Second generation had $F_t = 142$ GHz, $F_{max} = 160$ GHz. First generation had $F_t = 126$ GHz and $F_{max} = 120$ GHz).
  - DHBT tuned amplifier with 3.9dB gain at 82.5GHz.
- Performance of the HBTs will improve with the minimization of parasitics (base contact and series resistances, reduction of the base metal width) and scaling of epitaxial layers.
Acknowledgments

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