**E-4-3**

**A Novel HBT with Composite Collector for Power Amplifier Application**

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1. **Introduction**

AlGaAs/GaAs and InGaP/GaAs Heterojunction bipolar transistor (HBT) has been widely used for high-speed, analog/microwave, and analog-to-digital conversion applications. It is also known that the Double Heterojunction bipolar transistors (DHBT) become more and more important HBT devices, owing to the use of a wide-bandgap material in the collector. DHBT provides higher breakdown voltage, lower Offset voltage and suppress the recombination current, which increases the current gain ($\beta$) and reduces the charge storage time, therefore increasing the speed of the transistor switching application. [1] In addition, narrow-band-gap material provides high electron mobility, which can reduce the on-resistance and transit time. In this work, we use a composite collector combines with wide-bandgap (AlGaAs/InGaP) and narrow-bandgap (GaAs) material to implement the HBT. At first, the simulation is done by two-dimensional simulator (MEDICI), and then the conventional (non self-aligned) process technology was used for the HBT device.

2. **Device Structure and Fabrication**

The Epi-structure of a novel composite collector HBT is shown in Fig.1. A 200 Å undoped GaAs and a 200 Å high n-type doping AlGaAs layer were used to reduce the conduction band barrier at base-collector junction, which can increase the electron tunneling probability through the barrier [2][3]. The breakdown voltage (BV$_{CBO}$) with different thickness of GaAs in collector was simulated and shown in Fig.2, and Fig.3 shows the simulated RF performance with different GaAs thickness. According to the simulation and experiment results, the novel composite collector HBT shows the benefits of higher breakdown voltage (wider operation range for power amplifier) and lower offset voltage, lower on-resistance (thus increasing power-added-efficiency).

3. **Result and Discuss**

The novel composite collector HBT, which collector thickness are AlGaAs 500Å and GaAs 3500Å had been fabricated and characterized (Sample A). Another composite collector HBT (InGaP/GaAs:500/3500Å) had also been fabricated and characterized (Sample B). Fig.4 shows the common-emitter I-V characteristics of sample A. Using a wide bandgap material (InGaP) in the collector, the results are also as we expected. The novel Epilayer structure of InGaP/GaAs composite collector HBT is shown in Fig.5. The Measured I-V characteristics for all devices are shown in Fig.6. The power performance of sample B is shown in Fig.7. A novel AlGaAs/GaAs composite collector (d=3500 Å) HBT, has the results of $\Delta V_{CB}=0.12$ V, $BV_{CBO}=17.35$ V, $f_t=18$ GHz, $f_{max}=20$ GHz. Another novel InGaP/GaAs composite collector (d=3500 Å) HBT, has the results of $\Delta V_{CB}=0.12$ V, $BV_{CBO}=18$ V, $f_t=30$ GHz, $f_{max}=24$ GHz. The power performance of sample B are 21.8 dBm for $P_{out_{max}}$ and 48.2% for $PAE_{max}$. The total results are summarized in Table(I),(II).

4. **Conclusion**

The novel composite collector HBT, which combines with wide-bandgap (AlGaAs or InGaP) and narrow-bandgap (GaAs) material in collector, have been simulated and fabricated. The improvement in on-resistance is attributed to the high electron mobility from GaAs. The trade-off between Breakdown Voltage and Cut-off frequency can be designed depending on circuit application. The higher BV, $f_t$, $f_{max}$ of sample B are benefit for device RF power performance.

**References**


Table (I) Novel AlGaAs/GaAs with Composite Collector HBT

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<thead>
<tr>
<th>AlGaAs composite Collector</th>
<th>SHEET</th>
<th>NEW DHBT</th>
<th>DHBT</th>
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<tr>
<td>V_{CEO} (V)</td>
<td>0.15</td>
<td>0.03</td>
<td>0.12</td>
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<tr>
<td>I_{CBO} (mA)</td>
<td>15.7</td>
<td>26</td>
<td>17.35</td>
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<td>I_C (12 Hz)</td>
<td>22.3</td>
<td>16.5</td>
<td>18</td>
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Table (II) Novel InGaP/GaAs with Composite Collector HBT

<table>
<thead>
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<th>InGaP Composite Collector</th>
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<th>DHBT</th>
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<td>R_{ON} (Ω)</td>
<td>17.5</td>
<td>20.5</td>
<td>24.4</td>
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<td>R_P+R_C (Ω)</td>
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<td>I_{CBO} (mA)</td>
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<td>I_C (12 Hz)</td>
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<td>31</td>
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Fig.1 Epi-structure of AlGaAs/GaAs novel composite collector HBT

Fig.2. $E_{max}$ for AlGaAs/GaAs DHBT with different thickness of GaAs in collector (simulated)

Fig.3. The cutoff frequency with different GaAs thickness (simulated)

Fig.4. The Measured I-V characteristics (Sample A, $A_e=80\times80\mu m^2$)

Fig.5. The novel Composite collector (InGaP/GaAs) Epi-structure

Fig.6. Measured I-V characteristics of three different InGaP/GaAs HBT ($A_e=80\times80\mu m^2$)

Fig.7. Measured Pout, PAE vs Pin (Sample B)