Choice of Substrate Using Thermal Modeling of GaN Based HEMT Devices

Pankaj Kumar I. Kandpal 1, Dr. Meena I. Mishra2
1. Department of Electronic Science, Kurukshetra University, Kurukshetra, Haryana, India;
2. Solid State Physics Laboratory, Ministry of Defense (DRDO), Lucknow Road, Timarpur, Delhi, India.

Introduction: GaN plays a crucial role in what is today the most promising technology for high power, high-frequency circuits: AlGaN/GaN HEMTs. The aim here is to show and discuss results of 3D Thermal Simulation of GaN-based HEMT structures differing by substrate material.

Simulation Results: Thermal Distribution for

Materials | Thermal Conductivity (W/m.K)
--- | ---
Si | 149
Sapphire | 27.21
SiC | 360
GaN | 130

Table 1. Physical Property

<table>
<thead>
<tr>
<th>Structural Domain</th>
<th>Dimensions (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness of Metal Layer</td>
<td>2.5</td>
</tr>
<tr>
<td>Thickness of GaN Layer</td>
<td>3.5</td>
</tr>
<tr>
<td>Substrate Thickness</td>
<td>100</td>
</tr>
<tr>
<td>Total Thickness of Structure (GaN + Substrate)</td>
<td>156</td>
</tr>
<tr>
<td>Length (W) of Each Heating Finger (Total Six Fingers)</td>
<td>100</td>
</tr>
<tr>
<td>Spacing (d) between Fingers</td>
<td>42</td>
</tr>
</tbody>
</table>

Table 2. Specifications of Dimensions of Different layers of HEMT Structure

**FUTURE APPLICATION**: HEAT SINK Designing

**Conclusions**: The Temperature non-uniformity along the finger width is the most critical for the case of sapphire (highest temperature decrease from finger centre to edge among all substrates), where the substrate’s low thermal conductivity tends to confine the heat flow in the thin top GaN layer. SiC has Minimum Temperature Variation along the Finger width. So, SiC is considered to be a Best Substrate.


Figure 1. Structure of GaN HEMT

Thermal Modeling of HEMT Device: The inward heat flux of 67.42 x10^6 W/m^2 is applied on the surface of the metal layer just above the GaN layer, assuming there is a source of heat. Below the GaN layer, there is a substrate (Si, SiC or Sapphire). Heat distribution is analysed for each substrate used in GaN HEMT. The bottom of the structure consists of a Transistor Case and a Heat-Sink (kept at 300 K).

Figure 2. Structure of GaN HEMT designed for Thermal Modeling

Band Gap Energy of GaN = 3.44 eV

Table 3. Temperature Variations in Substrate used

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Temp. variation (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>273-290</td>
</tr>
<tr>
<td>SiC</td>
<td>273-277.5</td>
</tr>
<tr>
<td>Sapphire</td>
<td>273-314</td>
</tr>
</tbody>
</table>

Figure 3. Boundary Plot  Figure 4. Iso Surface Plot

Figure 5. Boundary Plot  Figure 6. Iso Surface Plot

Figure 7. Boundary Plot  Figure 8. Iso Surface Plot

Figure 9. Temperature variation along Arc Length of (a) Si (b)SiC (c) Sapphire

Figure 10. Temperature variation along Finger width of (a) Si (b)SiC (c) Sapphire