Tiny-but-tough: Nanoelectronics for Space Exploration

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Why Explore Venus?
Potential for Life on Venus

Limaye et al., Astrobiology (2018)
Material Properties of Semiconductor Materials

<table>
<thead>
<tr>
<th>Property</th>
<th>GaN</th>
<th>6H-SiC</th>
<th>AlN</th>
<th>Diamond</th>
<th>Silicon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting Point (°C)</td>
<td>2500</td>
<td>2830</td>
<td>2470</td>
<td>4000</td>
<td>1420</td>
</tr>
<tr>
<td>Energy Gap (eV)</td>
<td>3.4</td>
<td>3.0</td>
<td>6.2</td>
<td>5.6</td>
<td>1.12</td>
</tr>
<tr>
<td>Critical Field (×10^6 V/cm)</td>
<td>5.0</td>
<td>2.5</td>
<td>10</td>
<td>5.0</td>
<td>0.25</td>
</tr>
<tr>
<td>Thermal Conductivity (W/cm-K)</td>
<td>1.3</td>
<td>5.0</td>
<td>1.6</td>
<td>20</td>
<td>1.5</td>
</tr>
<tr>
<td>Young’s Modulus (GPa)</td>
<td>390</td>
<td>450</td>
<td>340</td>
<td>1035</td>
<td>190</td>
</tr>
<tr>
<td>Acoustic Velocity (x10^3 m/s)</td>
<td>8.0</td>
<td>11.9</td>
<td>11.4</td>
<td>17.2</td>
<td>9.1</td>
</tr>
<tr>
<td>Yield Strength (GPa)</td>
<td>-</td>
<td>21</td>
<td>-</td>
<td>53</td>
<td>7</td>
</tr>
<tr>
<td>Coeff. of Thermal Expansion (°C ×10^-6)</td>
<td>3.7</td>
<td>4.5</td>
<td>4.0</td>
<td>0.8</td>
<td>2.6</td>
</tr>
<tr>
<td>Chemical Stability</td>
<td>Good</td>
<td>Excellent</td>
<td>Good</td>
<td>Fair</td>
<td>Fair</td>
</tr>
</tbody>
</table>

Material properties of GaN, SiC, AlN, diamond and Si.

→ GaN is a thermally stable, mechanically robust, ultraviolet sensitive and radiation hardened semiconductor.
Gallium Nitride (GaN)

- **Power & RF**
- **LEDs**
- **Sensors**
- **Solar Cells**
- **RF Resonators**
- **Nanostructures**
GaN’s Electron Transduction (2DEG Formation)

Spontaneous polarization

Image credit: http://en.wikipedia.org/wiki/Wurtzite_crystal_structure

Piezoelectric polarization

Image credit: M. Lindeborg et al., UCSB, 2011.

Image credit: C. Chapin, Stanford University, 2015.
GaN High Electron Mobility Transistor (HEMT)

Image credit: Dr. Hans Stork, ON Semiconductor, 2018
GaN Transistor at 600°C (in Air)


ISSRDC 2019
GaN-on-Si “IoT” Sensing Platform

Pressure Sensor [1] (Chapin, 2017)

UV Photodetector [2] (Satterthwaite & Yalamarthy, 2018)


Thermoelectrics [4] (Yalamarthy, 2018)

Weathering & Exposure Testing

Weathering of GaN, SiC and sapphire material samples in the Venus Chamber at NASA Glenn Research Center

Funding Source: NASA Hot Operating Technology (HOTTech) Program
Nanocrafts/ChipSats for Space Exploration

Image Credit: Prof. Zac Manchester & Starshot Breakthrough Initiative
Graphene/GaN UV Photodetectors

In the metal-semiconductor-metal (MSM) architecture, electrodes and semiconductors are typically considered back-to-back Schottky barriers.

Graphene Transparent Electrodes

Light passes through exposed active area

Photogenerated current under applied bias
Graphene/GaN Under Proton Irradiation

SEM image of microfabricated graphene photodetector element on GaN thin film on sapphire.

1.) H. C. Chiamori et al., SPIE DSS, 2015.
Ready, Set, Launch!

GaN Sensor Payloads on the KickSat II Mission

Credit: Prof. Zac Manchester

Payload w/ GaN Sensor (Stanford XLab)

KickSat II cubesat passed shock and vibe! LEO mission completed!
Thank You!
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#lookup #venus #sisterplanet