I-V & CCE Characterisation of Proton Irradiated 12 Micron Epitaxial GaN Detectors

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Outline

- Status of GaN as a radiation hard material
- New material + fabrication into detectors
- Material characterisation
  - I-V & CCE measurements
- CCE experimental set-up
- I-V & CCE results
- Conclusions & future work
Status of GaN

- SI GaN grown by MOCVD
- Epitaxial layer 2.5 µm thick

<table>
<thead>
<tr>
<th>Fluence (n/p/pions/x-rays)</th>
<th>Max CCE (%)</th>
<th>Voltage @ Max CCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>unirradiated</td>
<td>90</td>
<td>30V</td>
</tr>
<tr>
<td>600 Mrad X-Rays</td>
<td>90</td>
<td>30V</td>
</tr>
<tr>
<td>$10^{14}$n</td>
<td>79</td>
<td>30V</td>
</tr>
<tr>
<td>$10^{15}$n</td>
<td>7</td>
<td>22V</td>
</tr>
<tr>
<td>$10^{16}$n</td>
<td>4</td>
<td>15V</td>
</tr>
<tr>
<td>$10^{16}$p</td>
<td>13</td>
<td>50V</td>
</tr>
</tbody>
</table>

[1] A.Blue (4th RD50 Workshop)

- Increase statistics i.e. fabricate and irradiate more GaN detectors
- Need thicker material to increase amount of charge generated and (hopefully!!) collected.
New Material

- Non doped n-type GaN epilayer of 12 micron thickness grown by MOCVD on sapphire using n-GaN buffer (Lumilog Ltd.) 1 wafer (2inch)
- Non doped n-type GaN epilayer of 2.5 micron thickness grown by MOCVD on sapphire using n-GaN buffer (Tokushima University) 3 wafers (2inch)
Detector Fabrication

- Fabricated pad/guard ring structures using photolithographic techniques
- Samples 10mm by 5mm. Two Pad/guard ring structures per sample.
- Pad 1mm diameter. 50µm spacing between pad and guard ring. Guard ring 500µm thick
- Deposited 200nm Pd to make Schottky contact. 200nm Au on top of this to make bonding easier.
- Somehow needed to make a contact with buffer layer.
- Coated side of material with silver paint.

![Diagram showing the layers and dimensions of the detector structure](image)

- 12µm SI epitaxial GaN.
- N-GaN buffer
- Sapphire
- Silver paint
Detector Characterisation

- Detectors characterised pre- and post- irradiated by performing
  - I-V measurements using a Keithley 237 measurement unit
  - CCE measurements using 5.48MeV α particles from an $^{241}$Am source
- Detectors left in dark for ~ 2 hours before performing I-V’s.
CCE Measurement

- Calibrate set-up using a Si detector assumed to have 100% CCE
- From observed spectrum (below left) the energy of the α particles emitted from our americium source is taken to be 3.82MeV
- Then use SRIM simulation (below right) to calculate the amount of energy that should be deposited by an α particle with incident energy of 3.82MeV in 12µm of GaN.
- Found to be 3.707MeV
Irradiations Performed

- Detectors irradiated with 24GeV/c protons at CERN
- 5 samples from each wafer = 20 samples irradiated.
- Detectors irradiated to fluences:
  - $1 \times 10^{14}$p/cm$^2$
  - $1 \times 10^{15}$p/cm$^2$
  - $2 \times 10^{15}$p/cm$^2$
  - $5 \times 10^{15}$p/cm$^2$
  - $1 \times 10^{16}$p/cm$^2$
- Detectors stored at –20°C after irradiation
- I-V/CCE Characterisation of 12µm epitaxial GaN done first
Detectors show Ohmic/Schottky behaviour

Following slide shows I-V curves for –ve bias in more depth
I-V curves (-ve Bias only)

- -ve Bias applied
CCE Spectra

- Spectra from an unirradiated detector shown on the left and from the detector irradiated to $5 \times 10^{15} \text{p/cm}^2$ on the right.
CCE Plots

![CCE Plots](image)
## Comparison

<table>
<thead>
<tr>
<th>Material</th>
<th>D (µm)</th>
<th>Fluence (n/p/pions/cm²)</th>
<th>CCE&lt;sub&gt;max&lt;/sub&gt; (%)</th>
<th>V@CCE&lt;sub&gt;max&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiC [1]</td>
<td>100</td>
<td>unirradiated</td>
<td>60</td>
<td>650V</td>
</tr>
<tr>
<td>SiC [1]</td>
<td>100</td>
<td>10&lt;sup&gt;13&lt;/sup&gt;pions</td>
<td>50</td>
<td>600V</td>
</tr>
<tr>
<td>FZ Si [2]</td>
<td>50</td>
<td>4.5x10&lt;sup&gt;14&lt;/sup&gt; 1MeV n/cm²</td>
<td>100</td>
<td>75V</td>
</tr>
<tr>
<td>FZ Si [2]</td>
<td>50</td>
<td>8.1x10&lt;sup&gt;14&lt;/sup&gt; 1MeV n/cm²</td>
<td>100</td>
<td>200V</td>
</tr>
<tr>
<td>GaN</td>
<td>12</td>
<td>unirradiated</td>
<td>55</td>
<td>130V</td>
</tr>
<tr>
<td>GaN</td>
<td>12</td>
<td>1016p/cm²</td>
<td>25</td>
<td>320V</td>
</tr>
</tbody>
</table>

[1] W. Cunningham et al. (4<sup>th</sup> RD50 workshop, CERN)
[2] M. Bruzzi et al. (5<sup>th</sup> RD50 workshop, Florence)
Conclusions + Future Work

- Fabricated detectors on 12µm epitaxial GaN
- Unirradiated detector shows a CCE of ~55%
- After irradiation to $10^{16}$p/cm$^2$ CCE drops to ~26%

- For the future: Irradiate some 12µm epitaxial GaN with neutrons (also irradiate some 2.5µm epitaxial GaN detectors) at varying fluences.
- ICP etching of 12µm epitaxial GaN. Make a ‘proper’ contact to the buffer layer