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Ga-bilayer controlled AlGaN/GaN HEMT structure grown on Si by PA-MBE

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Recently, AlGaN/GaN HEMTs grown on 100 mm diameter Si using plasma assisted molecular beam epitaxy (PA-MBE) have been demonstrated [1,2]. In these structures, the growth rate is limited by the active nitrogen species available from the nitrogen plasma. Consequently, longer growth times are required to achieve thicker buffer layer necessary for the device structures. However, the narrow growth widow for the GaN layer in PA-MBE technique is affected by the fluctuation in substrate temperature and material fluxes during the long growth period.

In this study, the recovery time (the time required for the recovery of RHEED intensity) of the Ga-bilayer during the entire GaN buffer growth was monitored at equal intervals of time and the Ga-flux was adjusted correspondingly to obtain high quality layer. This technique is shown to assist in maintaining Ga-bilayer on the growing GaN surface and produce 2D-growth for the entire growth. The smooth surface morphology (RMS ~1 nm) obtained on the top surface of AlGaN/GaN HEMT structure is found to enhance the 2DEG mobility.

Good quality GaN layers can be grown under Ga-stable growth conditions by PA-MBE [3]. Under Ga-stable conditions, the adatom mobility increases due to excess Ga which wets the surface, leading to step-flow growth and the observed two-dimensional growth morphology. As a function of the growth time the GaN growth changes from 3D to 2D growth mode and Ga-bilayer forms after 60 minutes of growth (~200 nm) under 2D growth conditions. Fig 1 shows the RHEED recovery time of Ga-bilayer on the growing GaN surface which is the RHEED intensity variation induced by the Ga desorption. In this study, Ga-bilayer recovery time of 10 to 15 sec was maintained by adjusting the Ga flux. This ensures that the grown GaN layer has smooth surface morphology and good crystalline quality.

Based on the bilayer technique AlGaN/GaN/AlN HEMT structures were grown on 100 mm diameter Si substrates. The 2DEG electrical properties, XRD-FWHM and RMS surface roughness values obtained are compared in Table 1 with the data obtained using conventional growth method. The highest Hall mobility of 1180 cm²/V.sec with sheet carrier density of 1x10¹³ cm⁻² was achieved. This is the highest electron mobility value achieved for AlGaN/GaN heterostructures on Si (111) by PA-MBE. Ga-bilayer controlled GaN growth is found to be one of viable techniques to ensure smooth surface morphology, good crystalline quality and hence good 2DEG electrical properties for AlGaN/GaN HEMT structures.

Table 1. Electrical, FWHM and RMS of AlGaN HEMT structure.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Mobility (cm²/V.sec)</th>
<th>CD (10¹³ cm⁻²)</th>
<th>FWHM (arcsec)</th>
<th>RMS (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>380</td>
<td>2.2</td>
<td>2434</td>
<td>3</td>
</tr>
<tr>
<td>Ga bilayer</td>
<td>1180</td>
<td>1.0</td>
<td>1314</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Fig. 1 Ga-bilayer recovery time

References: