Efficiency Enhancement in AlGaN Deep-UV LEDs Using High-Reflectivity Al-based p-type Electrode

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Background

External Quantum Efficiency of AlGaN DUV LED

η < sub > ext </sub > = η < sub > int </sub > × η < sub > inj </sub > × η < sub > a </sub >

η < sub > ext </sub > = External Quantum Efficiency (EQE)
η < sub > int </sub > = Internal Quantum Efficiency (IQE)
η < sub > inj </sub > = Light Emission Efficiency (LED)
η < sub > a </sub > = Light Absorption Efficiency

EQE of AlGaN DUV LED is still low.

η < sub > ext </sub > = 0.43 × 25% × 8% = 25%
247nm 1.8% = 250nm 0.43 = 25%

Further improvement is necessary.

Approach

Improvement of Light Extraction Efficiency in DUV LED

High-reflectivity Al p-type electrode

η < sub > ext </sub > increases by 1.3 times by using Al-electrode

Thin p-GaN contact layer

η < sub > ext </sub > increases by 3 ~ 4 times!

High-reflectivity Al p-type electrode

η < sub > a </sub > decreases by low TDD AlN

η < sub > inj </sub > increases by using high-reflectivity Al p-type electrode and thin p-GaN layer.

Fabrication process

- The samples were grown on sapphire (0001) substrates by MOCVD
- p-type activation anneal for 30 minutes at 800°C under the nitrogen atmosphere.
- Ni/Au Electrode
- Using thin Ni to suppress the photoabsorption
- Al-based Electrode
- Using the thin Ni to suppress the photoabsorption
- Non-anneal processing

Analysis of reflectivity

Reflectivity of variety of Ni/Al thickness
(Ni/Al was deposited on transparent sapphire substrate.)

Al electrode shows high reflectivity compared with conventional Ni/Au electrode.

Transmittance of p-GaN

Reflectivity of Al-electrode

Table: Reflectivity of Ni/Al thickness

<table>
<thead>
<tr>
<th>Ni/Al [nm]</th>
<th>0/10</th>
<th>1.5/10</th>
<th>2/10</th>
<th>2/10</th>
<th>0/25/Au:150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflectivity [%]</td>
<td>250nm</td>
<td>91.1</td>
<td>46.3</td>
<td>63.1</td>
<td>51.3</td>
</tr>
<tr>
<td>270nm</td>
<td>91.9</td>
<td>47.5</td>
<td>63.7</td>
<td>31.9</td>
<td>30.5</td>
</tr>
</tbody>
</table>

LEE increase by use of thick Al-electrode

Structure:

AlGaN-QW DUV-LED with MQB-EBL

- p-GaN: 10nm
- p-electrode: Ni(1nm)/Al(100nm)

Max output power: 15.6mW, highest EQE: 2.75%

Summary

- High LEE was obtained by using high-reflectivity Al p-electrode and thin p-GaN contact layer.
- High EQE 270nm DUV LED was achieved.
  highest EQE: 2.75% , Max CW power: 15.6mW, Output power: 2.2mW @ 20mA