Diamond - Nitride Semiconductor
~ p-n junction and two-dimensional electron gas ~

Motivation
A nitride/diamond heterojunction is expected for high-efficiency, deep-ultraviolet (deep-UV) light-emitting diodes (LEDs) and high-output-power transistors, because high-efficiency p-type doping in diamond is possible and diamond has the highest thermal conductivity among materials. However, the most difficult issue has been the difference in crystal structures between nitride and diamond.

III-V Nitride semiconductor (AIN) and diamond

<table>
<thead>
<tr>
<th>Crystal structure</th>
<th>Wrutize structure</th>
<th>Diamond structure</th>
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<tbody>
<tr>
<td>Band gap</td>
<td>6.0 eV (direct)</td>
<td>5.5 eV (indirect)</td>
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<tr>
<td>Thermal conductivity</td>
<td>3 W/cm K</td>
<td>22 W/cm K</td>
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<tr>
<td>n-type doping</td>
<td>Si (250 meV)</td>
<td>P (590 meV)</td>
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<tr>
<td>P-type doping</td>
<td>Mg (630 meV)</td>
<td>B (370 meV)</td>
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Originality
NTT proposed nitride growth on the diamond (111) plane, which has a similar atomic arrangement to the nitride (0001) plane, and successfully obtained single-crystal aluminum nitride (AlN) on diamond. Using this growth technique, we demonstrated band-edge emission from an n-type AlN/p-type diamond heterojunction LED and the formation of two-dimensional electron gas (2DEG) at the nitride heterojunction on diamond.

Impact
The nitride/diamond heterostructure will lead to deep-UV LEDs and millimeter-wave power transistors. The deep-UV LEDs can efficiently decompose toxic chemicals, such as dioxin and PCBs. The millimeter-wave power transistors can improve the information-carrying capacity in broadband wireless communications.

Atomic arrangement: AlN (0001) and Diamond (111) planes

- AlN (0001)
- Diamond (111)

n-type AlN/p-type diamond heterojunction diode

- n-type electrode
- Two-dimensional electron gas (2DEG)

Nitride HEMT structure grown on diamond

- Un-doped AlGaN
- Un-doped GaN(0001)
- AlN/GaN multilayers
- Single-crystal AlN (0001) buffer
- Diamond (111)

Sheet electron density (cm⁻²)

Temperature (K)

Electron mobility (cm²/Vs)

High carrier density

High electron mobility

Diamond free-exiton (235nm)

20 mA RT

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