GaInNP:

A Novel Material for Device Applications

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Recently nitrogen-containing III-V compound semiconductors have attracted much attention for device applications; in particular, the large bandgap bowing with nitrogen incorporaton makes the GaInNAs/GaAs system suitable for long-wavelength (1.3 μm) vertical-cavity surface-emitting lasers. GaInNAs has also been used as the low-bandgap base of a heterojunction bipolar transistor with a low turn-on voltage. In this paper, we present another class of novel materials, GaInNP grown on GaP and GaAs (100) substrates, for optoelectronic and electronic applications, respectively.

All samples were grown by gas-source molecular beam epitaxy, with elemental group III sources, thermally cracked arsine and phosphine, and a RF plasma nitrogen source.

We have previously shown that incorporating a small amount of nitrogen (~0.5%) in GaP changes the indirect bandgap to direct bandgap, and thus GaNP/GaP exhibits a strong room-temperature photoluminescence at ~650 nm.[1] Double-heterostructure GaNP/GaP light-emitting diodes (LEDs) have been fabricated.[2] In that LED structure the 500 nm-thick $GaN_{0.011}P_{0.989}$ active layer is lattice-mismatched to the GaP substrate, so it shows ~15% lattice relaxation, resulting in dislocations, which would degrade the luminescence efficiency. Incorporating a small amount of indium, 2.4%, has improved the structural quality of the GaInNP layer, as shown by x-ray rocking curve measurements. Figure 1 shows the room-temperature photoluminescence (PL) spectra of $GaN_{0.015}P_{0.985}$ (solid line) and $Ga_{0.976}In_{0.024}N_{0.016}P_{0.984}$ (dashed line), and that of $Ga_{0.51}In_{0.49}P$ lattice-matched to GaAs as a reference. We see that the GaInNP PL intensity is higher than that of GaInP, and the peak energy is red-shifted. We are presently fabricating GaInNP/GaP LEDs and shall report the results later.

GaInNP is also being explored as a collector tunnel barrier in heterojunction bipolar transistors (HBTs). As in the GaInNAs/GaAs system, the bandgap lowering of GaInNP is expected to occur mainly through the lowering of the conduction band edge. Therefore, inserting a thin GaInNP in the GaAs collector region near the base would have a small conduction band barrier. Because the holes have a larger effective mass, they cannot tunnel through the thin barrier and are confined in the base, resulting in a larger gain. To prove this idea we have to first determine the band offset of GaInNP with respect to GaAs. Therefore, we grew a series of GaInNP/GaAs multi-quantum wells (MQWs) and a GaInP/GaAs MQW. Adding N to the GaInP barrier results in red shift of the QW PL peak due to lowering of the barrier. From a finite barrier model, we determine the conduction band offset of GaInNP/GaAs to be 7 meV and the valence band offset to be ~200 meV. Thus, $Ga_{0.46}In_{0.54}N_{0.005}P_{0.995}$ could be a suitable collector tunnel barrier in an HBT.

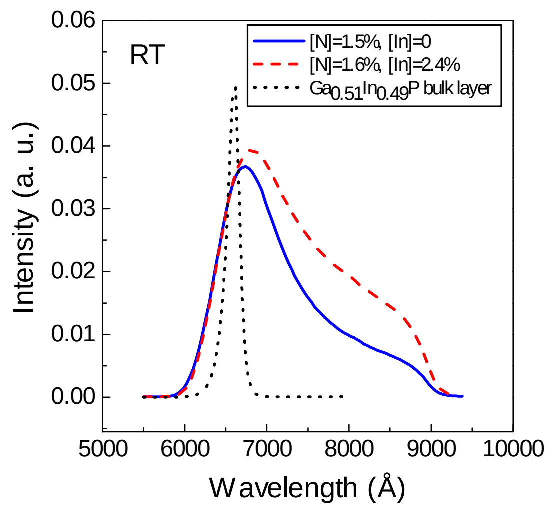

Fig. 1 Room-temperature (RT) photoluminescence spectrum of GaNP (solid curve) and GaInNP (dashed curve) grown on GaP(100) and GaInP (dotted curve) grown on GaAs(100).

1. H.P. Xin, C.W. Tu, Y. Zhang and A. Mascarenhas, Appl. Phys. Lett. **76**, 1267 (2000).
2. H.P. Xin, R.J. Welty, and C.W. Tu, IEEE Photon. Technol. Lett. **12**, 960 (2000).