Characterization of defects in InGaAsN grown by molecular-beam epitaxy

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The unique electronic properties of InGaAsN make it an attractive material for use in data communication lasers and high-efficiency multijunction solar cells. $In_xGa_{1-x}As_{1-y}N_y$ alloys with small concentrations of nitrogen ($y \leq 0.02$) can be grown which are lattice matched to GaAs when $x \approx 3y$[1]. The "giant band-gap reduction"[2-4] which results from the incorporation of low N concentrations allows tuning of the energy band gap below 1.42 eV. However, the growth of high quality epitaxial layers of this material remains a challenge. The optical properties of GaAs/InGaAsN/GaAs quantum wells and the electrical properties of InGaAsN bulk layers with varying levels of N have been studied. The effects of rapid thermal annealing on the optical characteristics of the quaternary have been examined using photoluminescence (PL).

Fig. 1 shows the blue shift of the PL peak as a function of annealing temperature for InGaAsN quantum wells with different N content levels. The blue shift indicates a quantum well intermixing process mediated by a reduction of the defects in the material due to annealing. The effect of the annealing temperature on the intensity of the PL peak is shown in Fig. 2. The optical quality of the InGaAsN quantum wells is known to decrease with increasing N content[6,7].

The electrical characteristics of InGaAsN bulk layers have been examined through Hall effect measurement. The dependence of the carrier concentration on the amount of nitrogen in as-grown silicon (n-type) and beryllium (p-type) doped InGaAsN is shown in Fig. 3. The carrier concentration of the material decreases with increasing N content, indicating that the density of electrically active defects in the material increases as more N is added. This observation is consistent with the deterioration in the optical quality of the InGaAsN. The effects of rapid thermal annealing on the electrical characteristics of the quaternary are being examined.

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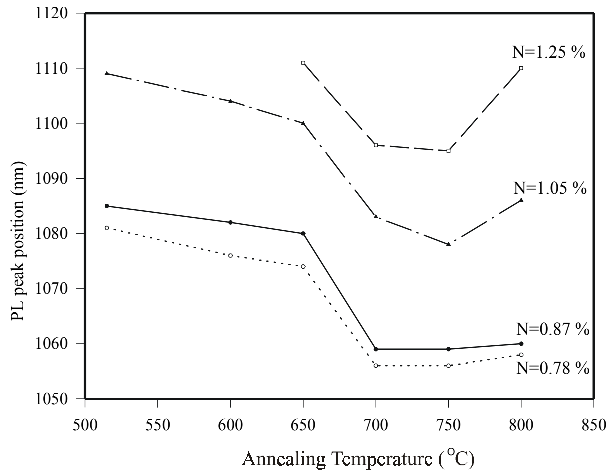

Fig. 1. The PL peak wavelength of InGaAsN quantum wells vs annealing temperature for samples with different amounts of N.

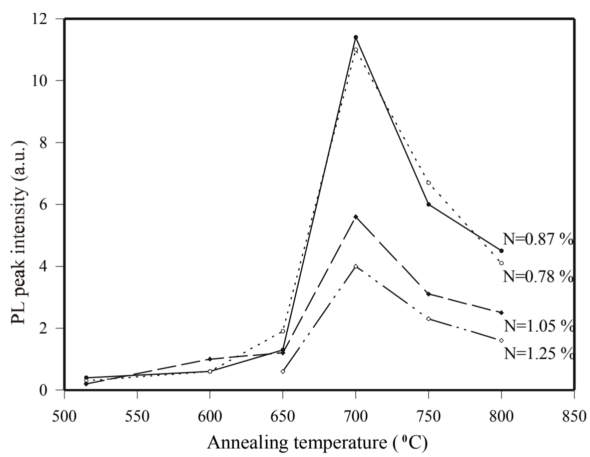

Fig. 2. The maximum PL intensity of InGaAsN quantum wells vs annealing temperature for samples with different amounts of N.

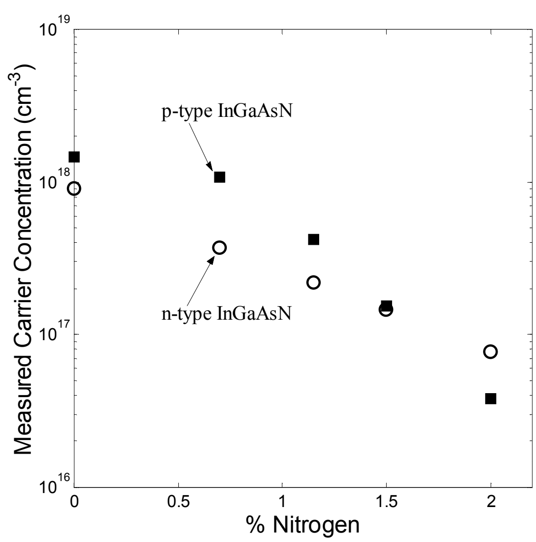

FIG. 3. Carrier concentration of as-grown InGaAsN vs N content.