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Optical properties of isoelectronically P-doped GaN Epilayers Grown by Gas Source Molecular Beam Epitaxy

F. S. Juang, Y. G. Hong[a], M. H. Kim[a*], and C. W. Tu[a], W. C. Lai[b] and J. Tsai[b]

Department of Electro-optics Engineering, National Huwei Institute of Technology, Huwei, Yunlin, Taiwan, Fax: 886-5-6328863, E-mail: fsjuang@seed.net.tw

[a]Department of Electrical and Computer Engineering, University of California at San Diego, 9500 Gilman Drive, La Jolla, CA 92093, USA

[b]South Epitaxy Corporation., Tainan Science-based industry Park, Tainan County, Taiwan

1. Introduction

The GaN-rich side of GaP_xN_{1-x} alloy exhibits a potentially large bandgap bowing with only a small amount of P incorporation. As a result, there could be interesting device applications. In this work, GaN:P layers were grown by molecular beam epitaxy (MBE) on GaN template layers grown by metalorganic chemical vapor deposition. GaP was used as the phosphorus source, P_2, and the N_2 plasma as the nitrogen source. The growth temperature was 640 or 740 °C for two groups of samples, respectively.

The P_2 flux has a surfactant effect on GaN growth and can improve the epitaxy quality. 2x4 RHEED patterns can be easily obtained with a P_2 flux. Without P_2 the growth of undoped GaN has 1x1 or very weak 2x4 patterns, which easily become dim or spotty. The GaN:P epilayers (0.4 *um* thick) grown with a large enough P_2 flux have smaller FWHM values in X-ray rocking curves and smaller RMS roughness in AFM measurements than those grown with less P_2 flux.

2. Results and Discussions

P isoelectronic impurity in GaN may introduce P-related shallow donor levels and deep acceptor levels. Figure 1 shows the comparison of room temperature PL for low (4.5E-5) and high (1.0E-3) P_2/N samples on a template that does not have YB emission, the dashed curve shown in the bottom of Fig. 1. The low P_2/N sample: has a strong blue emission peak at 430 nm (spectrum width between 400 and 480 nm). The high P_2/N sample has a broader emission spectrum between 400 and 600 nm. The low-P_2/N sample has a strong blue emission peak centered at 430 nm (2.88eV), which is consistent with those observed in P-implanted GaN films [1,2]. The 2.88 eV energy corresponds to an impurity-induced level at 0.54 eV above the valence band maximum. This result is similar to Mattila and Zunger's theory for GaN:P with a deep electronic gap level induced by isovalent P impurity in GaN [3,4]. As-doped GaN has been reported to exhibit blue emission which is suggested to be from As atoms occupying the gallium vacancies [5] The situation could be similar with P-doped GaN.

In Fig.1, the high P_2/N samples have a broader peak between 400 and 600 nm. The broadened spectra may come from the blue band emission combined with the enhanced YB luminescence. A high P_2 flux will let more P atoms incorporated into the lattice so the atom size mismatch will lead to large lattice relaxation and generate more dislocations in the epilayers, which give rise to an enhanced YB emission.

Figure 2 shows the PL spectra at selected temperatures for GaN doped with low P_2/N flux ratio. For the light P-doped sample the main line shifts to 420 nm with respective to the room temperature spectrum at 430 nm.

For the high P_2/N sample, the PL spectra at various temperatures are shown in Fig.3. In the 14K spectra, the strong peak at 378.5 nm is attributed to DAP transition. As the temperature is increased to be higher than 160K, this DAP peak gets thermally quenched easily as expected for the DA pair transition. The quenching is attributed to the thermal release of electrons from deep donor to the conduction band. There are satellites on the long wavelength side at 388 and 398.5 nm that are assigned as the first (DAP-1LO) and second (DAP-2LO) phonon replica, respectively. The separation between two consecutive peaks is about 80 meV.

Figure 4 shows the X-ray diffraction curves for another group of GaPN samples grown at lower temperature about 640 °C. It is found that it is easier to grow the GaN-rich GaP_xN_{1-x} alloys at lower temperature. The optical properties were also studied in this work.

3. Conclusions

The GaNs were successfully doped with P isoelectronic impurity by MBE at low and high P_2/N flux ratios. The deep electronic gap levels induced by isolated P impurity in GaN were observed in the PL measurements. Higher amount of P in GaP_xN_{1-x} alloys can be obtained at lower growth temperature.

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References

[1] H. Y. Huang, C. H. Chuang, C. K. Shu, Y. C. Pan, W. H Lee, W. K. Chen, W. H. Chen and M. C. Lee, Appl. Phys. Lett. 80, 3349 (2002).
[2] T. Ogino and M. Aoki, Jpn. J. Appl. Phys. 18, 1049(1978).
[3] T. Mattila and Alex Zunger, Phys. Rev. B 58, 1367(1998).
[4] T. Mattila and Alex Zunger, Phys. Rev. B 59, 9943(1998).
[5] C. G. Van de Walle, J. Neugebauer, Appl Phys. Lett. 76, 1009(2000).

*permanent address: Depart. of Materials Sci. and Eng., Kwangju Inst. of Sci. and Tech., Kwangju, Korea

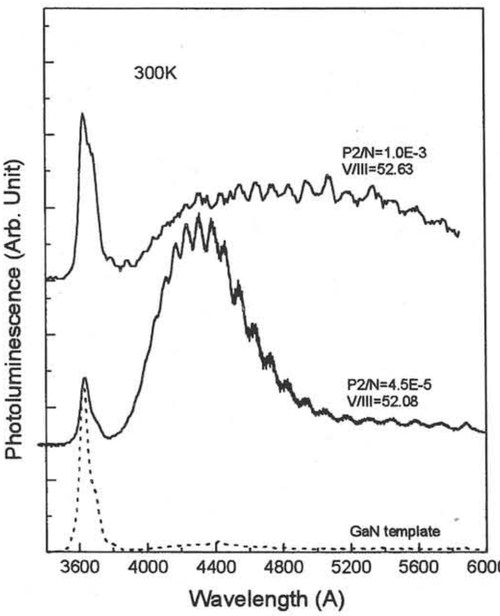

Fig.1 PL spectra at 300K for GaN doped with low and high P_2/N flux ratios

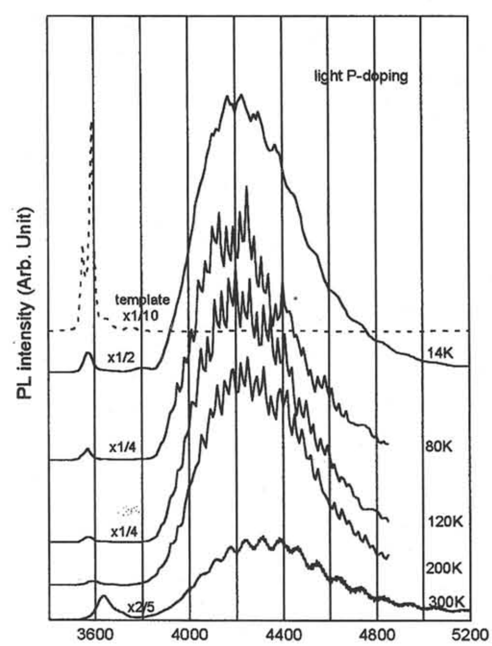

Fig.2 PL spectra at selected temperature for GaN doped with low P_2/N flux ratio

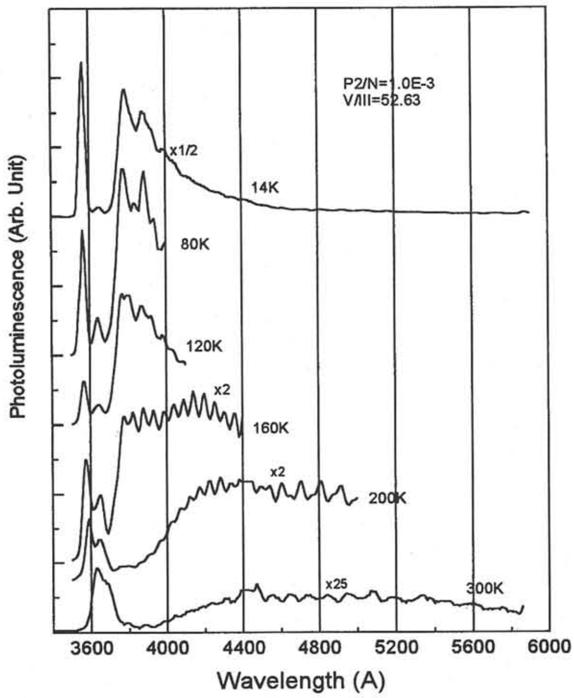

Fig.3 PL spectra at selected temperature for GaN doped with high P_2/N flux ratios

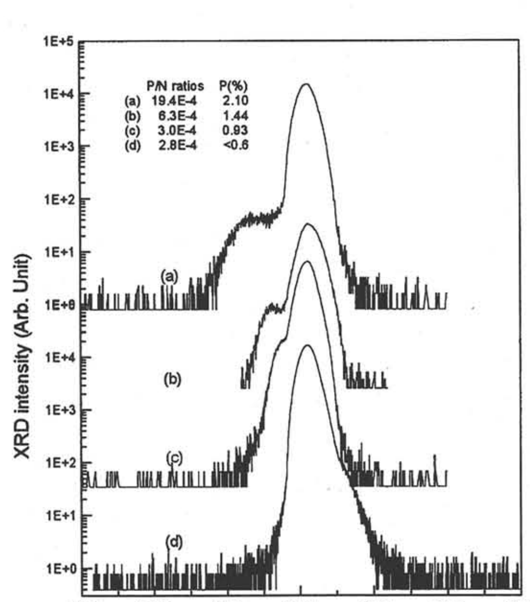

Fig.4 X-ray diffraction curves for GaPN sample grown at lower temperature about 640 °C.