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GaN-Rich Side of GaNAs Grown by Gas Source MBE

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1. Introduction

Recently, CW operation of InGaN/AlGaN laser diodes (LDs) were successfully demonstrated[1]. However, the growth of InGaN active layer is not so easy because of the large difference in the lattice constant and optimum growth temperature. GaN-GaAs and GaN-GaP alloy system can cover the wide wavelength range for the small lattice constant difference as shown in Fig.1. Several authors reported the growth of only GaAs or GaP-rich side of GaAsN or GaPN [2-4]. In this paper, we report on the gas source MBE growth of GaN-rich side of GaNAs and GaNP, and the comparison of their composition variation of the band gap energies.

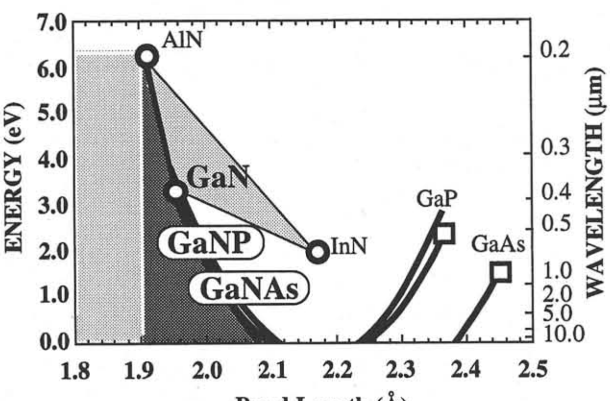

Fig.1 Energy gap dependence on bond length

2. Experimental

GaN-rich side of GaNAs and GaNP layers were grown on sapphire substrates after the high temperature growth of GaN buffer layers (thickness : 0.3μm) by gas source MBE with removed ECR (electron cyclotron resonance) radical cell for nitrogen source. Advantage of the use of ion-removed cell was demonstrated by the observation of (2x2) RHEED patterns during growth of GaN[5]. The ion removal efficiency by ion removal magnets in this ECR radical cell was over 99%. Elemental Ga, radical N_2 and thermally cracked AsH_3 and PH_3 were used as group III and group V sources. The flow rate of N2 was 1.5 SCCM. The AsH_3 and PH_3 flow rate were varied from 0.1 to 1.0 SCCM. The substrate temperature was 750°C.

3. Results and discussions

We have grown GaN-rich side of GaNP and observed the red shift of near band edge PL emission. The dependence of the band gap energy on the P composition x of $GaN_{1-x}P_x$ agreed with the theoretical calculation by Baillargeon et al[2] and Sakai et al[6], suggesting the existence of large-bowing bandgap[7,8]. We have also succeeded to grow GaN-rich side of GaNAs. In the growth with high AsH_3 flow rate of 1.0 SCCM, the phase separation into GaN-rich GaNAs and GaAs-rich GaAsN was observed, as shown in Fig.2 (X-ray diffraction (XRD) rocking curve). Two peaks are observed around 34.6° : one comes from high temperature grown GaN buffer layer and the other from GaNAs alloy layer (As composition=0.26%). The full width at half maximum (FWHM) of GaNAs (0002) peak was 464.4 arc sec.

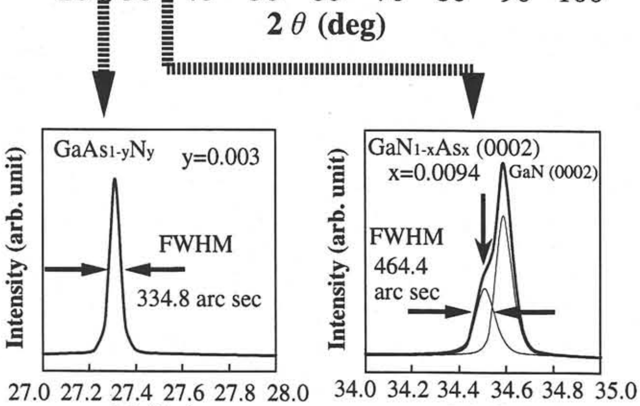

Fig.2 XRD rocking curve from the high AsH_3 flow rate (1.0 SCCM) grown-$GaN_{1-x}As_x$ on sapphire substrate.

This phase separation was also confirmed in the RHEED pattern during GaNAs growth. Figure 3 shows the dependence of alloy compositions of GaNP and GaNAs on AsH_3 and PH_3 flow rates. The composition of GaNAs saturated at lower value than that of GaNP.

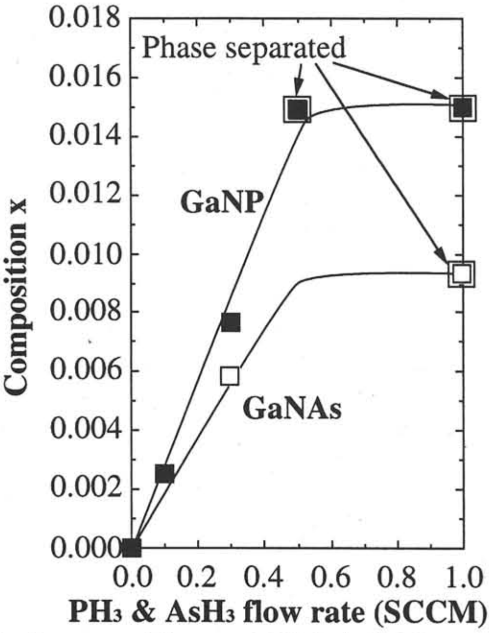

Fig.3 composition x vs PH3 & AsH3 flow rates. Saturation of composition occur at around PH_3 & AsH_3 flow rates of 0.5 SCCM.

77K photoluminescence (PL) emission was observed from the non-phase-separated $GaN_{1-x}As_x$ layer (x=0.0026) as shown in Fig.4. The higher energy peak of 3.473eV comes from high temperature grown GaN buffer layer and the other (3.425eV) comes from the GaNAs alloy layer (As composition=0.0026)

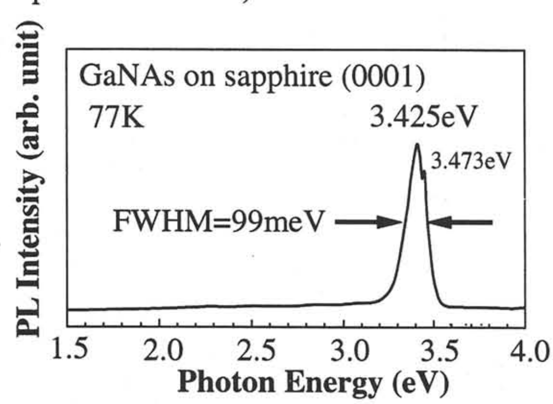

Fig.4 Photoluminescence spectrum of $GaN_{1-x}As_x$ (x=0.0026) grown on sapphire (0001) substrate.

4. Conclusion

The relation between the band gap energy and the As composition x of $GaN_{1-x}As_x$ is plotted in Fig.5 and we estimated the bowing parameter of GaNAs from this experimental result as 19.6eV. This value agrees well with that for the GaAs-rich side of GaAsN reported by M.Kondow et al[3]. It is much larger than that of GaNP.

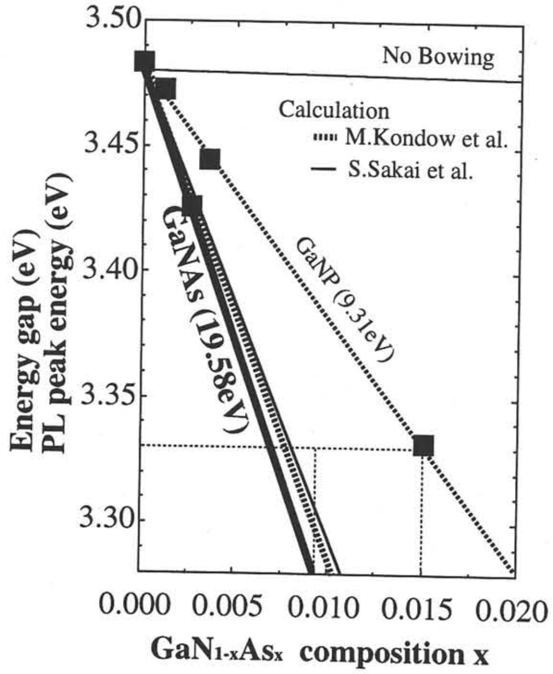

Fig.5 Energy gap dependence on $GaN_{1-x}As_x$ composition x.

In the conference, we will discuss on the advantage and disadvantage of GaNAs over GaNP.

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