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Optimization of Well Width and of N Composition on Optical Properties for GaNAs/GaAs MQW grown by RF-MBE

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1. Introduction

Recently, the GaNAs alloy have been intensively studied and it is known to very large band-gap bowing factor [1]. In particular, GaNAs has a potential to be used for light-emitting devices of a long wavelength (λ > 1.3μm) with good temperature property because of the large band offset. However, it is reported that a GaNAs on GaAs (001) substrate photoluminescence (PL) intensity decrease with increase of N content [2-3]. For increase PL intensity, many studies have been made which used tilted substrates and various anneal techniques however PL peak energy is blue-shift in the case of anneal [4-6].

So far, during the growth of GaNAs/GaAs quantum well, nitrogen plasma was kept igniting in RF-MBE. We reported novel growth technique for multiple quantum well (MQW), in which plasma is ignited only when the GaNAs layer is grown [7-8]. By this modulated N radical beam source technique, we could control the GaNAs well thickness by atomic layer scale also with fine hetero interface with GaAs barrier.

In this paper, we have investigated the effect of GaNAs well thickness and of N composition on GaNAs/GaAs MQW optical properties.

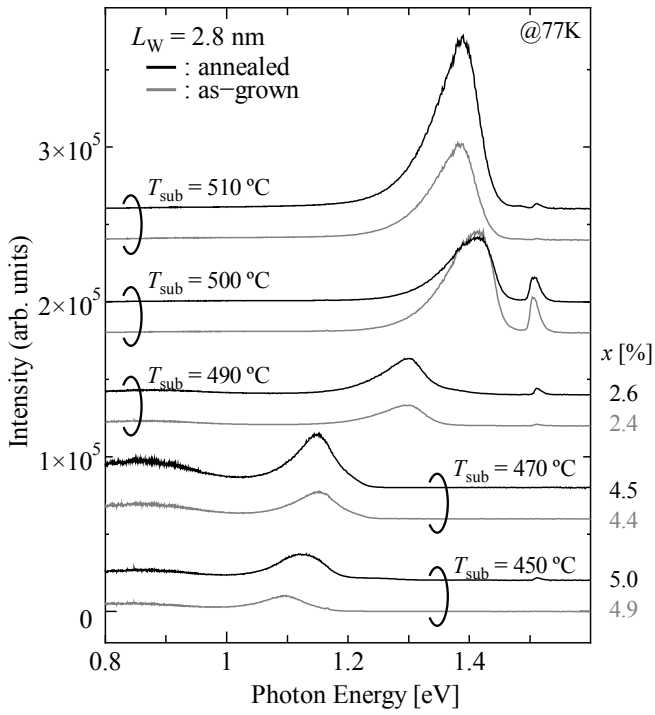

Fig. 1 Tsub and annealing dependence of PL spectra of GaNAs/GaAs MQWs structure at 77K.

2. Experiment

The GaNAs/GaAs MQWs were grown on (001) semi-insulating GaAs substrates by MBE using modulated N radical beam source (SVT, RF 4.5). All the samples were un-doped and were grown on a GaAs buffer layer of 1μm, with a GaAs cap layer of 5 nm thick. In this study, we changed GaNAs layer thickness, L_W, and surface temperature, T_{sur}. The L_Ws (T_{sur}s) were designed to be (performed at) 0.85 nm (470 ℃), 1.4 nm (450, 470 and 500 ℃) and 2.8 nm (450, 470, 490, 500 and 510 ℃). In all samples, the GaAs barrier layer thickness of MQW and number of period were fixed to 14.1 nm and 30 times, respectively. The after thermal annealing was performed at 580 ℃ for 10min under a flux of As_4 to maintain mirror-like surface morphology.

The MQW structures were examined by XRD measurements. The (00L) scattering profiles in reciprocal space were obtained by θ-2θ scan at Cu K_α. In PL measurements at 77K, the samples were excited by second harmonics of Nd:YVO4 laser at 532 nm.

3. Results and Discussion

Figure 1 shows the PL spectra of the MQW structures with designed L_Ws of 2.8 nm, where the as-grown samples and annealed ones were shown as gray lines and black lines, respectively. The N composition x of all samples except for samples grown at 500 and 510 ℃ were clearly observed by XRD, as shown in Fig. 1. From the PL spectra of the all samples, we have observed two PL peaks from each sample, one is a dominant emission from GaNAs/GaAs MQW and the other is a weak broad PL peak around 0.85 eV. The latter broad emission was observed very weak in the samples grown at 500 and

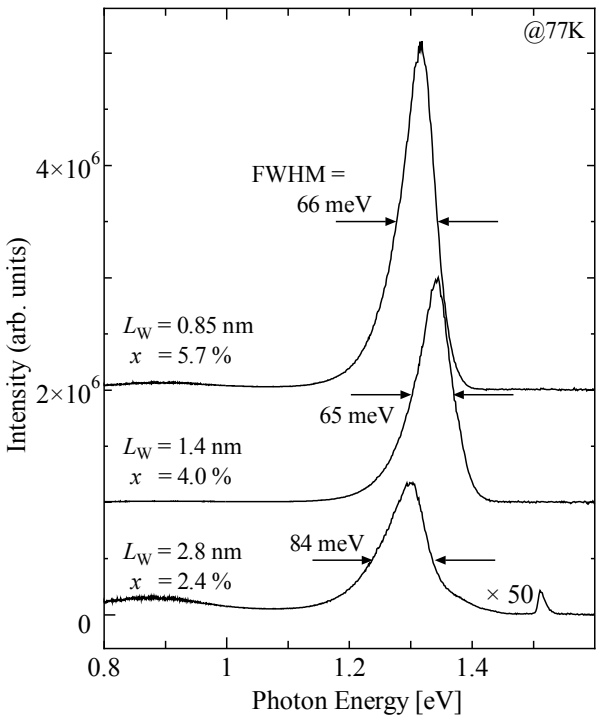

Fig. 2 PL spectra of three type GaNAs/GaAs MQWs structure at 77K.

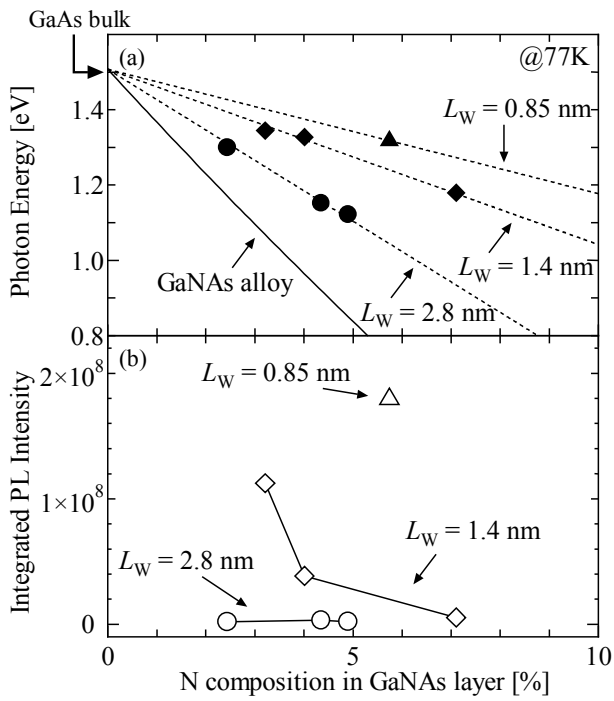

Fig. 3 N composition dependence of (a) photon energy and of (b) integrated PL intensity.

510 ℃. The origin of this broad emission was related to crystalline defect by Buyanova *et. al.* [3]. The sample of lower T_{sub} has larger N composition in GaNAs layer. By increase of N composition in GaNAs, the PL peak energies shifts lower, however, the dominant PL emission decreases, as observed in precious literature [2-3][6]. On the other hand, the PL intensities from the after annealed samples are 1.5 times stronger than that from as-grown samples. From these results, we can control the well width L_W and N composition x of GaNAs/GaAs MQW structures for optimization of their optical properties.

Figure 2 shows comparison of the PL spectra of the three annealed MQW samples, the PL peak energies of which are similar, and around 1.3 eV, although designed L_Ws and growth temperatures T_{sur}s of the samples are quite different. The designed L_W (T_{sur}) are 0.85 nm (470 ℃), 1.4 nm (470 ℃) and 2.8nm (490 ℃) starting from the top, respectively. All the dominant PL peaks are between 1.30 and 1.35 eV. The dominant peak intensity of narrow L_W (0.85 nm) sample is approximately 100 times as high as that of thick L_W (2.8 nm). This increase of PL intensity is higher in magnification than that reported by *in-situ* annealing and *ex-situ* rapid thermal annealing [4-5].

Figures 3 (a) and (b) shows the N composition dependence of the PL peak energy and the integrated PL intensity of dominant emission peak, respectively. In Fig. 3(a) the solid line and dotted line are band-gap of GaNAs alloy and fitted curve, respectively. We confirmed the red-shift of the PL peak energy of the each L_W by increasing N composition. The integrated PL intensities of the MQWs of L_W = 2.8 nm are smaller than that of the L_W = 1.4 nm samples, whose intensity decreases drastically with increase of N composition. The PL intensity of L_W = 0.85 nm sample is very high compared to those of 1.4nm and 2.8 nm samples. Therefore, QW with thinner GaNAs layer and with higher N composition will be candidate for high PL intensity.

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