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The Effect of As_2 and As_4 Molecule Beam Species on MBE Grown GaN_xAs_{1-x}/GaAs MQW by Modulated N Radical Beam Source

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1. Introduction

Ga(In)NAs alloys with a low nitrogen content are expected to be a new compound semiconductor material for long wavelength light emission device on GaAs substrate with a high temperature performance. Many studies of GaNAs and GaInNAs have been reported for alloys and single quantum well (SQW), whereas few studies have been reported for multiple quantum wells (MQWs) and superlattices (SLs). Furthermore, during the growth of their GaNAs/GaAs MQW, nitrogen plasma ignition of RF-MBE has been performed manually.

We automated the plasma ignition before, and reported a novel MQW growth technique [1], where the nitrogen plasma is ignited only when the GaNAs layer is grown (Fig. 1). This method was able to make higher quality GaNAs/GaAs MQW structure than it had made by conventional method. Fine MQW structures originating from the precise control of the modulated N radical beam have been demonstrated as clear satellite peaks from the X-ray diffraction (XRD) measurements and sharp photoluminescence (PL) peaks.

It is known well that change to the quality of the growth membrane by the difference of the crystal growth mechanism in using a molecular beam of As_4 and As_2 when GaAs grows up. It is generally used As_4 molecular beam by MBE growth. However, As_2 has the advantage to reduce the consumption of the As material used from As_4 for the MBE growth. And there is a report that this improves an optical characteristic. Then, we investigated the influence that the effect of As_2 and As_4 molecular beam species on MBE grown GaNAs/GaAs MQW by this modulated N radical beam source.

2.Experiment and Results

The GaNAs/GaAs MQWs were grown by the RF-MBE using above-mentioned modulated N radical beam source (SVT, RF 4.5). We designed three GaNAs/GaAs MQW structures, which had different GaNAs well thickness (i.e. 5 ML, 10 ML and 20 ML), as shown in Table I. The two of samples for each structure were made, one for As_2 and the other one As_4 molecular beam species. For the As_2 molecules, we used craker cell (Veeco, VG-500V-As-IV-L) where the cracking zone temperature set at 900°C. Meanwhile in the case of the As_4 temperature was set at 600°C. All the samples were grown on (001) semi-insulating GaAs substrates held at 560°C. The growth sequence was as follows: (a) a 1-μm-thik GaAs buffer layer, (b) the MQW structure of 50 GaNAs/GaAs quantum wells and (c) a 5-nm-thick GaAs cap layer.

The periodic structures of the samples were examined by XRD. The (00*L*) scattering profiles in reciprocal space were obtained by θ-2θ scan by Cu K_α line. Figure 2 shows the XRD profiles of sample C and D. The obtained value of N composition in the GaNAs layer of sample C was 2.72%. The satellite peaks of the samples A and E with As_4 molecules clearly observed. However the satellite peaks of sample B, D and F were not observed

The PL measured at 77K using the second harmonics of Nd:YVO4 laser at 532 nm as excitation source. Fig. 3. (a) shows the PL spectra of sample C and D in the liner scale. The dominant peak of sample D show the 90 meV blue shift, compared with that of sample C. Fig. 3 (b) is same data plotted in the logarithmic scale, in order to emphasis drastic reduction of broad peak intensity. The intensity of the broad peak of sample C near by 0.9 eV decreased in sample D. Similar results were observed in the case of samples of A and B, also in the case of E and F. Full widths at half maximums (FWHMs) of the PL peaks were not changed so much for all the sample.

3.Discussion

The satellite peaks were not observed by the XRD measurements from all the samples made by As_2 molecules. However, as for all the same samples, clear PL peaks from GaNAs layers were observed.

The clear blue shifts dominant PL peaks show the reduction of N composition in the case of the As_2 molecules. This shift of 90 meV correspond to the reduction of N composition in GaNAs well by about 0.7% [2]. This reduction of N composition weakens the intensity of satellite peaks of the XRD measurement. It is thought that higher sticking coefficient of As_2 molecules reduce the incorporation of atoms N during the growth.

References

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[2]U. Tisch, E. Finkman and J. Salzman, Appl. Phys. Lett. **81** (2002) 463

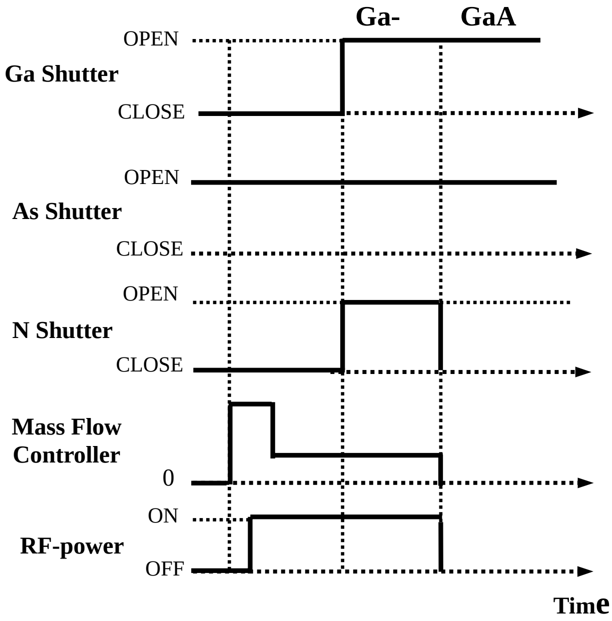

Fig. 1. Timetable of GaNAs/GaAs MQWs growth sequence by MBE using modulated N radical beam source.

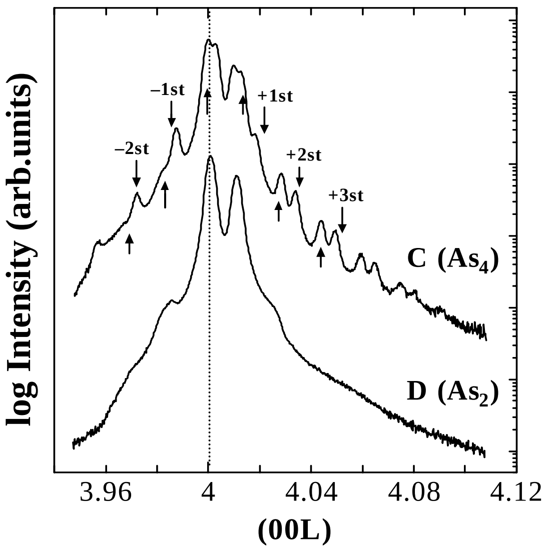

Fig. 2. XRD profiles around (004) peaks of GaNAs/GaAs MQW structures of samples C and D. The down-arrows are satellite peak of MQW structure by Cu $K_{\alpha1}$ line, and up-arrows are peak by Cu $K_{\alpha2}$ line. The satellite peaks of sample D was not observed.

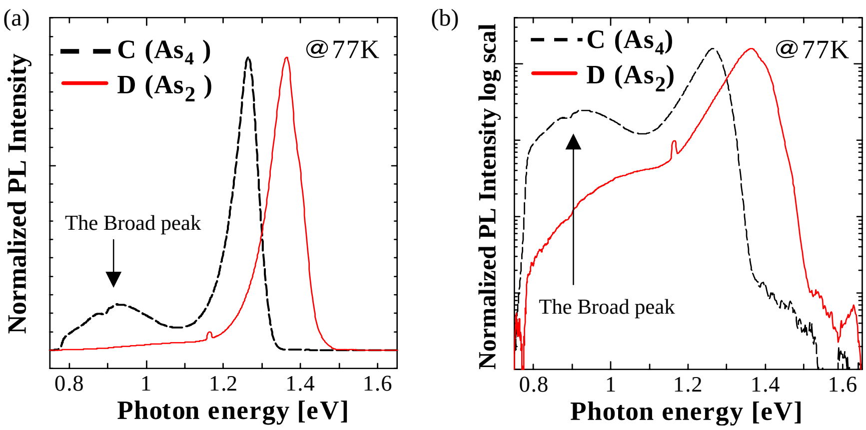

Fig.3. (a) PL spectra of GaNAs/GaAs MQW structures of sample C and D measured at 77K. Fig. 3. (b) is same data plotted in the logarithmic scale to emphasis reduction of broad peak.

Table I. Design value of MQW structure and PL measurement.

Sample	Design GaNAs/GaAs MQW structure				From PL measurment	
	As cracking cell [°C]	GaNAs [ML]	GaAs [ML]	Times N	PL peak position[eV]	FWHM[meV]
A	600 (As_4)	5	100	50	1.28	68.1
B	900 (As_2)	5	100	50	1.37	91.9
C	600 (As_4)	10	100	50	1.27	75.6
D	900 (As_2)	10	100	50	1.36	95.9
E	600 (As_4)	20	100	50	1.24	91.9
F	900 (As_2)	20	100	50	1.35	67.6