Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.144-145

F-2-6

Growth and characteristics of GaNAs/GaAs MQW by molecular beam epitaxy

Katsuhiro Takao[1],Kensuke Fujii[1], Hayato Miyagawa[1], Noriaki Tsurumachi [1], Hiroshi Itoh[1], Naoto Sumida[1], Shunsuke Nakanishi[1], Hidefumi Akiyama[2], Shun koshiba[1]
[1] Faculty of Engineering, Kagawa University, Takamatsu, Kagawa 761-0396, Japan
[2] Institute for Solid State Physics, University of Tokyo, Chiba 277-8581, Japan
Phone: +81-87-864-2403 E-mail: koshiba@eng.kagawa-u.ac.jp

1. Introduction

Recently, much progress has been made on improving the material quality of GaNAs and InGaNAs compound semiconductor grown by molecular beam epitaxy (MBE) [1]~[4]. In particular, GaAs with a few percent of nitrogen has a potential for light-emitting devices of long wavelength (λ >1.3μm) region because of the large bandgap bowing. Many studies have been reported for alloys, and there are few reports for multiple quantum wells (MQWs) and superlattice (SLs).

In this article, we have studied the growth of GaNAs/GaAs MQW structures by RF-MBE. The MQW structures of alternating layers of GaNAs (well) and GaAs (barrier). In general, the N content and thickness of GaNAs are difficult to control. We have made several GaNAs/GaAs MQWs for various GaNAs layer thickness grown by MBE. The structural and optical properties of the samples are characterized by transmission electron microscopy (TEM), photoluminescence (PL), optical absorption and X-ray diffraction (XRD).

2. Experimental

The GaNAs/GaAs MQWs grown by MBE using RF plasma nitrogen radical beam source. All the layers were grown on (001)- oriented semi-insulating GaAs substrates held at asubstrate temperature of 560℃. GaNAs/GaAs MQWs were grown by using the shutter program. A steady plasma ignition and stability are very important in the growth MQW and SL.

First of all, to obtain the best condition, we did the ignition experiment of nitrogen plasma. As a result, it succeeded in plasma ignitions for every 100 times. The optimum conditions of plasma are mainly determined with parameters of the flow time of nitrogen gas (T1), and the delay time of the ignition of plasma (T2), which are controlled by Mass Flow Controller (MFC). The optimized condition is followed, (a) RF-power is 300W (b) Rate of initial flow is 6.5sccm (c) T1 is 1.8s (d) T2 is 1s, a shown in Fig. 1 .

The growth sequence was as follows: (a) a 1 μ m thick GaAs buffer layer, (b) alternating layers of GaNAs and GaAs (the MQWs region), and (c) a 5nm thick GaAs cap layer. It is designed that the period width of all MQW structures were set to about 130ML. These period structures and luminescence energies of samples were confirmed by TEM, XRD, and PL measurement. The PL was excited by second harmonic of Nd : YAG laser at 532nm.

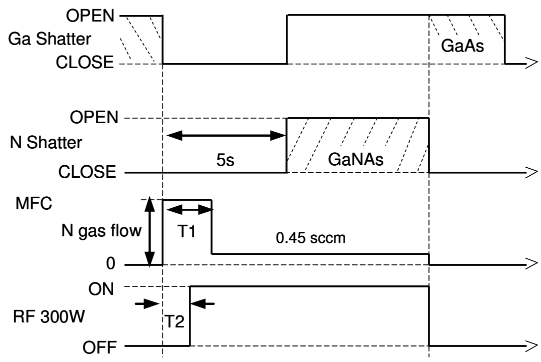

Fig. 1. A timetable of GaNAs/GaAs MQWs growth sequens.

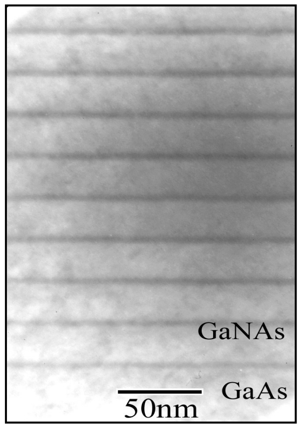

Fig. 2. Cross-sectional TEM observation of GaNAs MQWs with GaNAs (dark) and GaAs (bright) barrier layers.

3. Results and Discussion

Fig. 2 shows a cross-sectional TEM image. It is clearly observed MQWs structure with very smooth heterointerface. In this image the bright layers are the barriers GaAs, while the dark parts are the GaNAs wells. As a result of this measurement, period near the design value was indicated.

PL spectra of GaNAs/GaAs MQW structures are shown in Fig. 3. Here, we observed two samples A and B whose designed GaNAs width is 1.5nm and 3.0nm, respectively. The contents of nitrogen, both A and B were 2% by XRD analysis. The PL spectrum of sample A is measured at 10 K and that of sample B is at 77K. The peak intensity of both are normalized. The PL peak energy of A is located at 1.32eV and B at 1.11eV. The PL peak shift to the lower energy side, since the band-gap energy is getting smaller as widely of well width. Full width at half-maximum (FWHM) of PL peak is 47meV for A and 138meV for B, respectively. As compared with AlGaAs/GaAs MQW, these PL peaks are quite broad, due to the fluctuations of QW width and N composition.

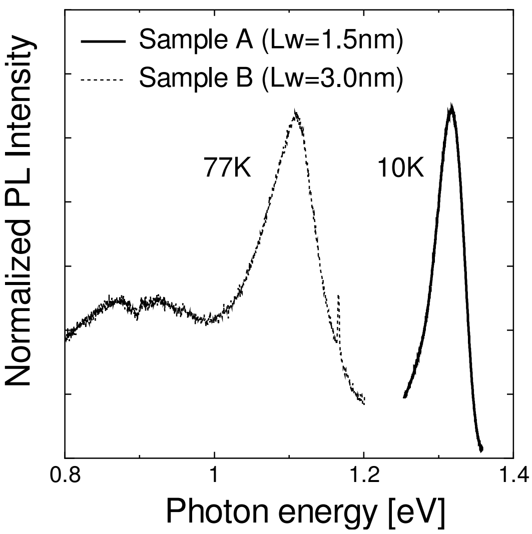

Fig. 3. PL spectra of GaNAs/GaAs MQWs sampleA (Lw=1.5nm) at 10K and sampleB (Lw=3.0nm) at 77K, here Lw means the well width, *i.e.* the thickness of GaNAs layer.

Figure 4 shows absorption spectra of sample A and B. For comparison, that of GaAs substrate is also shown. The absorption measurement was performed at room-temperature. In both the sample A and B, we observed the absorption shoulder around 1.3eV and 1.1eV, respectively. In case of GaAs substrate, we didn't observe such a shoulder below GaAs band-gap. The shoulder shifts to lower energy when well width is wide as same as the case of PL peak energy.

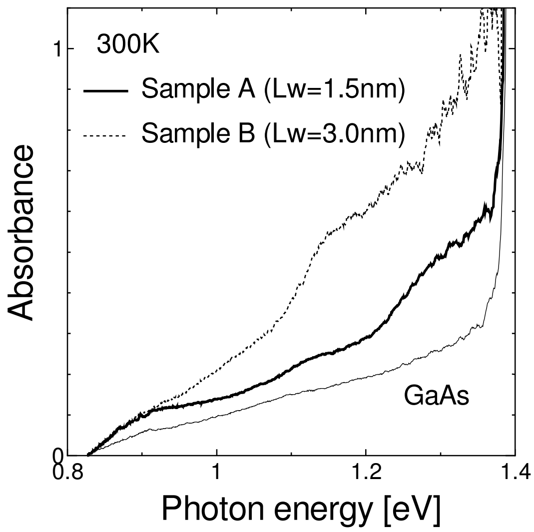

Fig. 4. Absorbance spectra of GaNAs/GaAs MQWs sampleA (Lw=1.5nm) and sampleB (Lw=3.0nm) at 300K.

4. Conclusion

Accordingly, GaNAs/GaAs MQW structures were successfully grown by RF-MBE using shutter program to flow nitrogen. The periodic structures were able to be observation by TEM and XRD, and in this experiment, the relation between PL and Absorbance spectra was obtained.

4. References

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