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Fabrication and Properties of GaN-Based Quantum Well Structure for Short Wavelength Light Emitter

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This paper represents fabrication and properties of GaN-based multi-quantum well (MQW) structure. Well-controlled MQW structures with GaInN well and GaN barrier were fabricated by metalorganic vapor phase epitaxy on the sapphire substrate. It is found that photoluminescence intensity of the MQW with their well width less than 3nm is more than one order of magnitude higher than that of the bulk GaInN layer at room temperature.

1. INTRODUCTION

Today, special attentions have been paid by plenty of III-V researchers to GaN and related semiconductors. Discovering acceptor impurities which form high-efficiency blue-luminescence centers in nitrides[1], breakthrough of high-quality thin film growth and realizations of p-type nitrides[2,3], high-quality alloys and their heterostructures resulted in the fabrication of super-bright UV/blue[4], blue[5] and blue-green[6] light emitting diodes of which efficiencies in excess of 1%, although they contains high-density dislocations in excess of $10^{10}cm^{-2}$.[7]

For the fabrication of laser diode (LD) based on GaN, high-efficient active layer which shows strong emission originated from band-to-band related transition is indispensable. Free exciton lifetime (τ_{ex}) of GaN increases with increase of temperature, and it reaches maximum of about 70ps at 10K. However, τ_{ex} decreases at much higher temperature.[8] These results indicate that non-radiative recombination is dominant at high-temperature. It may also be true for GaInN. In case of GaInN, another critical issue is the alloy fluctuation. It is also important, although we do not mention about it in this paper. Therefore, to realize high-efficient pure active layer, reduction of non-radiative recombination center is necessary. In other words, high-quality and less impurity group-III nitride is eagerly demanded.

Another way of reducing the effect of non-radiative recombination in such a non-perfect and non-pure crystal is to reduce the crystal size. If the dimension of the crystal size is reduced, great enhancement of the photoluminescence (PL) efficiency will be anticipated because of the increase of oscillator strength of exciton, thus decrease of the effect of non-radiative recombination center.

In this paper, we report the dependence of the well width on the PL properties of GaInN/GaN multi-quantum well (MQW) structure. In this case, the dimension of the crystal reduced from only three to two. Nevertheless, great improvement of the PL efficiency is observed for the first time.

2. EXPERIMENTS

GaInN/GaN MQW's were fabricated by metalorganic vapor phase epitaxy (MOVPE) on the sapphire (0001) substrate using low-temperature deposited AlN as a buffer layer. TMGa, TMAl and TMIn were used as group-III source gases, while NH_3 was used as nitrogen source gas, respectively. All the samples were nominally undoped. Structures of MQW were schematically illustrated in Fig.1. Five different structures were grown on GaN layer 1.8μm thick.

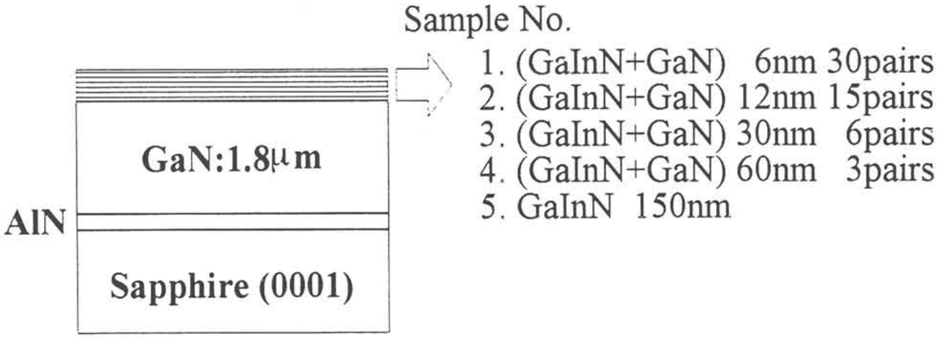

Fig.1 Schematic structure of 5 samples. Sample No.5 is used as a reference.

Samples from No.1 through No.4 have MQW structure. Total thickness of MQW part was fixed to 180nm for all the samples. Thickness of one period of each sample is depicted in the figure. Thickness ratio between GaInN well and GaN barrier is about 1:3. Sample No.5 has thick single GaInN layer, which is used as a reference. InN molar fraction of GaInN layer is about 0.07 for all the samples.

Fig.2 shows the cross sectional TEM photograph of sample No.2. MQW structure can be clearly observed. Dislocation density is about $2 \times 10^{8} cm^{-2}$.

PL measurement was performed at room temperature (RT) using He-Cd laser as an excitation source.

3. RESULTS

Bandedge emission is dominant in the PL spectrum of all the samples at RT. Figure 3 shows the dependence of the PL bandedge emission intensity as a function of thickness of one pair. The PL efficiency increase with decrease of one pair thickness, and it tends to saturate at one pair thickness of about 12nm, which corresponds to the GaInN well width of about 3nm. Therefore, it can be said that 3nm is sufficient as well width to confine carriers.

The AlGaN/GaInN single quantum well with well width of about 7.5nm was fabricated on the 6H-SiC substrate. Optically pumped stimulated emission and laser action can be observed at RT under pulsed nitrogen laser excitation. The threshold for stimulated emission is about $40 KW/cm^{2}$, which is the lowest to date in nitride.

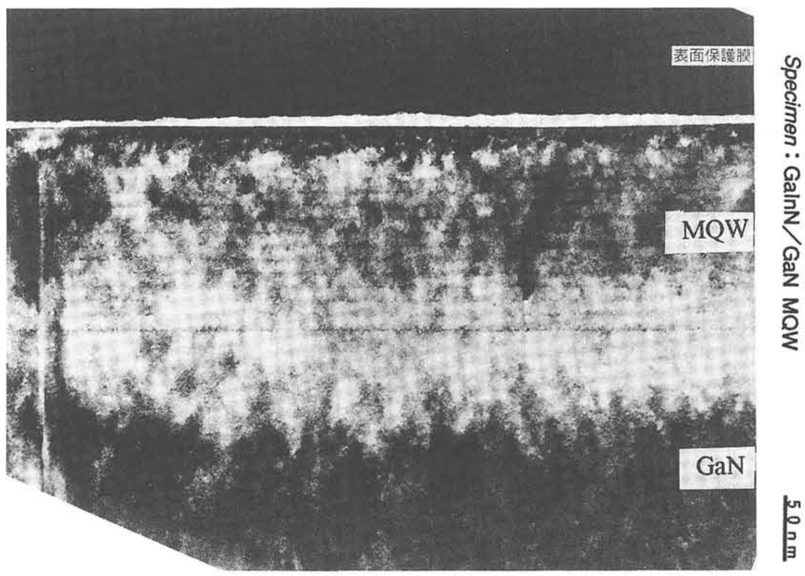

Fig.2 Cross sectional TEM photograph of sample No.2. GaInN wells are seen as the dark lines in MQW.

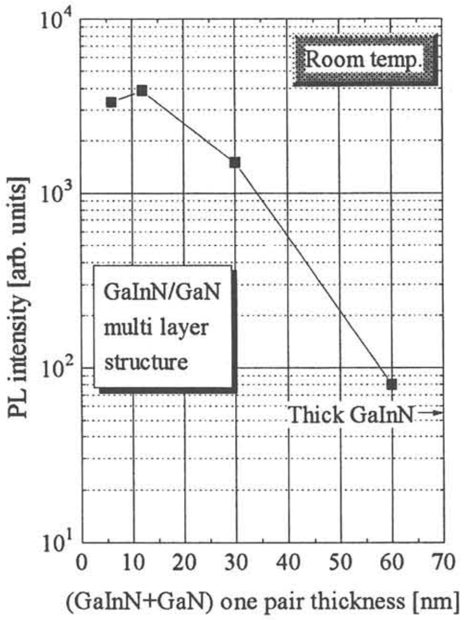

Fig.3 Dependence of the PL band edge emission intensity at RT as a function of one pair thickness in MQW. That of thick GaInN layer is also shown for comparison.

4. SUMMARY

Well width dependence of the PL efficiency was investigated for GaInN/GaN MQW structure. PL efficiency shows strong well width dependence, which is indicative of the reduction of the effect of non-radiative recombination. We believe that this results is suggestive for the realization of laser diode based on group-III nitride system.

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