Growth and characterization of cubic InGaN/GaN multiquantum wells on 3C-SiC by RF MBE

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Blue light emitting diodes and laser diodes using hexagonal(h-) InGaN as an active layer of quantum wells (QW) structure have been already commercialized. Cubic(c-) GaN and its alloys with aluminum and indium also hold promise for light emitting optical devices in the blue and green wavelength regions. Because the bandgap of c-InGaN is lower than that of h-InGaN with the same In composition, it is possible to achieve visible light emission with the lower InN molar fraction by using c-InGaN. Therefore, it is very important to investigate the structural and optical properties of c-InGaN alloys and its QWs. In addition, the comparison between h-InGaN with piezo-electric field and c-InGaN without it is an important issue from the viewpoint of basic physics. For the cubic metastable nitrides, non-equilibrium growth method such as MBE is promising. We have already obtained high quality c-AlGaN and c-AlN epilayers [1] using 3C-SiC substrates by RF-MBE. 3C-SiC substrates are also expected to have several advantages for the c-InGaN growth from the viewpoint of lattice matching between substrates and epilayers, and thermal stability. We have already tried to grow c-InGaN epilayers on 3C-SiC substrates [2]. In this study, we attempted to grow c-InGaN/GaN multiple QW(MQW) on 3C-SiC substrates by RF-MBE, and the structural and optical properties of c-InGaN QW regions were investigated by photoluminescence (PL) and high resolution X-ray diffraction (HRXRD).

The InGaN QWs were grown on 3C-SiC (001) substrates with low temperature (LT) GaN buffer layer process by RF MBE. Prior to the growth, heat treatment of 3C-SiC substrates was carried out at 900℃ for 10 min to obtain clean surfaces. Following the heat treatment, a 10 nm thick LT-GaN buffer layer and a 300 nm thick GaN epilayer were grown at 550℃ and 760℃, respectively. Subsequently, InGaN/GaN MQW layers were grown at 640℃. The InGaN/GaN MQW samples were composed of 5 periods. The thicknesses of InGaN well layers and GaN barrier layers were 0.6～10nm,and 10nm, respectively. The InGaN layers were supposed to be strained, because the critical thickness of c-$In_xGa_{(1-x)}N$($x<0.2$) epilayers on GaN were found to be larger than 200nm.[2] Therefore, the InN molar fraction of these samples were estimated by using experimental equation: $d=4.5+0.8x+1.6x^2$.[2] The XRD measurement was done by using a Phillips X'pert MRD system and the PL measurements were carried out at 4.2K by using a 325nm line from a 30mW He-Cd laser.

Figure 1 shows an XRD pattern by omega-2theta scan for the (002) diffraction of a $In_{0.1}Ga_{0.9}N$ MQW layer grown on thick GaN layer. In/(In+Ga) flux ratio during the growth was 0.6. The c-GaN diffraction peak was observed at 20.0° and several satellite peaks from InGaN MQW were clearly observed. The period of the superstructure was determined to be 15nm from the positions of the satellite peaks. This result agrees well with the period estimated from the growthrate. In our knowledge, this is the first report showing the satellite peaks from cubic InGaN MQW structures by XRD.

Figure 2 shows the well width dependence of the PL peak energy for $In_{0.1}Ga_{0.9}N$ MQWs. The PL peak energy for the wells larger than 5nm agrees well with the calculated value using effective mass: $m_e^*=0.18$, $m_h^*=0.9$.[3]. The blue shift associated with the quantum confinement effect was observed for the small width wells. For the large width wells, the PL peak energy was almost constant. This result is contrast to the case of h-InGaN MQWs, where the piezoelectric field along (001) direction exists and has a large influence on the emission energy.

Figure 3 shows the well width dependence of the PL emission intensity for $In_{0.1}Ga_{0.9}N$ MQWs. The PL emission intensity was drastically increased with the decrease of the well width. However, te PL peak width was nearly 220meV for all the InGaN MQW samples.

In summary, we successfully grew c-$In_{0.1}Ga_{0.9}N$ MQWs on 3C-SiC substrates. For these MQW structures, several satellite peaks were observed by XRD For the first time. The PL emission intensity from these c-InGaN MQWs was drastically increased with the decrease of the well width. In the presentation, the comparison between the cubic InGaN

MQW and the hexagonal one will be discussed.

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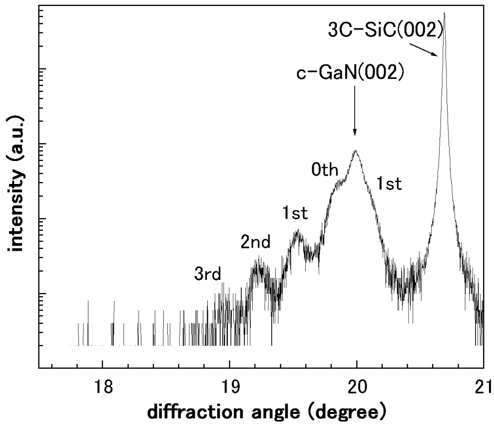

Figure.1 HRXRD omega-2theta profile for a 5 periods c-$In_{0.1}Ga_{0.9}N$ /GaN MQWs grown on a 3C-SiC substrate. The MQW layers was grown at 640℃ with the flux intensity ratio In/(Ga+In)=0.6. The diffraction peak from the c-GaN layers, and several satellite peaks from the c-InGaN MQW layers were observed.

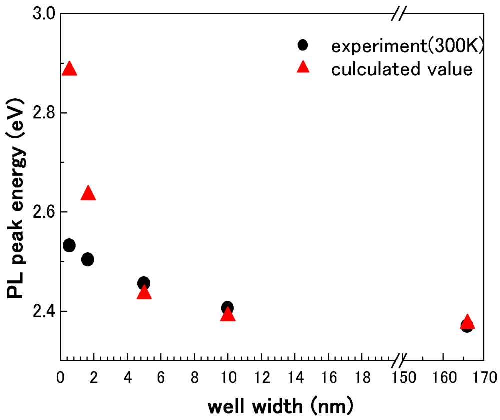

Figure.2 Well width dependence of the PL peak energy for the c-$In_{0.1}Ga_{0.9}N$/GaN MQW layers.

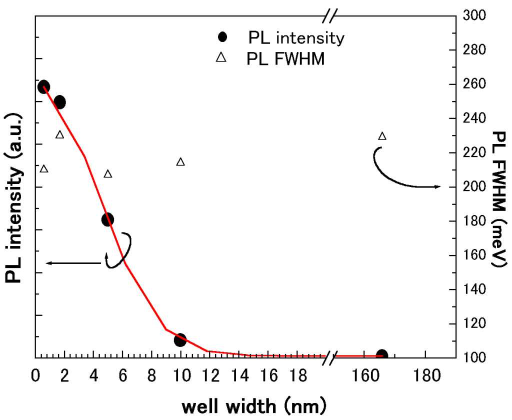

Figure 3 Well width dependence of the PL emission intensity per unit thickness for the $In_{0.1}Ga_{0.9}N$/GaN MQW layers