Structural and optical characterization of thick GaN films grown by direct reaction of Ga and NH_3

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Growth of bulk GaN crystal, which is the most suitable substrate for the growth of GaN epilayer, has been investigated using high-pressure synthesis method [1]. However, bulk GaN crystals are too small in size to be used as substrates at present. Recently, thick GaN grown by either hydride vapor phase epitaxy (HVPE) [2] or sublimation method [3] has been proposed to be a promising substrate for the growth of high quality GaN epilayers.

In this work, we grew thick GaN films on sapphire by the direct reaction of metallic Ga and ammonia in a conventional RF induction heated chemical vapor deposition (CVD) reactor and clarified the correlation between structural and optical properties of the films. A cylindroid graphite susceptor was designed to install both substrate and Ga on a lower part of the susceptor. The GaN films were grown on (0006) Al_2O_3sapphire substrate positioned at both a few centimeters apart from the Ga source or just above Ga source with a gap of 7 mm.

The growth of thick GaN were carried out as functions of the amount of metal Ga, growth temperature (1050 ~ 1150 ℃), distance of substrate from Ga source, NH_3 flow rate, pressure, and growth time. The structure and optical properties of the thick GaN were evaluated using XRD and PL measurements, respectively.

The structural properties of thick GaN films were investigated in terms of growth temperature by XRD measurements. The GaN film was prepared at the substrate position of 3.5 cm apart from the Ga source on the same plane. Figure 1 presents XRD patterns for Sample #1 grown at the temperature range of 1030 ~ 1150℃, respectively, with θ - 2θ scan mode. GaN(0002), Al_2O_3(0006), and GaN(0004) peaks are primarily detected at 2θ = 34.35, 41.6, and 72.85°, respectively, from all the films. Besides, small peaks associated with [$10\bar{1}0$], [$10\bar{1}1$], and [$11\bar{2}0$] diffractions are observed at 2θ = 32.443, 36.998, and 57.55, respectively. However, the ($10\bar{1}0$), ($10\bar{1}1$), and ($11\bar{2}0$) peaks were almost disappeared at 1070℃. It is interesting to see that the intensities of these small peaks are significantly influenced by the growth temperature.

Shown in Fig. 2 are room temperature PL spectra of Sample #1. Band edge luminescence is shown at 3.414 eV. Anomalous sharp peak at 3.02 eV is not induced by sample but by measurement system. Deep level related yellow luminescence is shown at 2.25 eV. Our PL measurements show that the intensity of YL increases at temperatures which grow GaN films along the [$10\bar{1}0$] and [$10\bar{1}1$] directions. This indicates that the variation of YL intensity is very similar to that of ($10\bar{1}0$) and ($10\bar{1}1$) XRD peaks.

Figure 1 and 2 shows that there is a correlation between structural and optical properties of the GaN thick films. The comparison of PL and XRD measurements was also performed for Sample #2. Figure 3 describes the intensity ratios of $(10\bar{1}0)/(0002)$, $(10\bar{1}1)/(0002)$, and $(11\bar{2}0)/(0002)$ peaks of XRD spectra as well as that of yellow/blue emissions of PL spectra as a function of the growth temperature. The intensity of the yellow emission increases with the increase of $(10\bar{1}0)$, $(10\bar{1}1)$, and $(11\bar{2}0)$ peak intensities. This demonstrates that the crystal quality has a big impact on the optical property for GaN. Since the $(10\bar{1}0)$ plane of hexagonal GaN is perpendicular to the close-packed basal plane of (0001) GaN, the growth along $[10\bar{1}0]$ direction in the wurtzite GaN might generate high density of defects or dangling bonds at the boundaries between GaN structures of different orientations. This high defect density in the GaN epilayer seems to be closely related with the yellow luminescence.

In this paper, we have intensively discussed the correlation of structural and optical properties of the thick GaN films. Based on our experimental results and the previously reported data, we concluded that YL is emitted from the deep gap state formed by Ga vacancies and impurities trapped at domain boundary with a $\{10\bar{1}0\}$and $\{10\bar{1}1\}$ atomic facet.

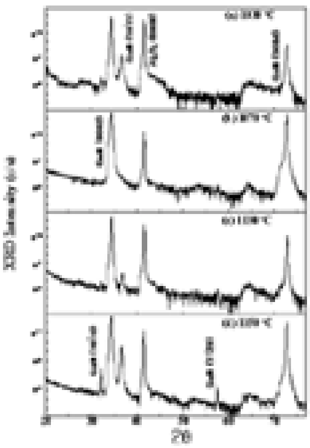

Figure 1 XRD spectra for GaN films(Sample #1) grown for 60min with 500sccm NH3 as a function of growth temperature ; (a) 1030℃, (b)1070℃, (c) 1130℃ , and (c) 1150℃

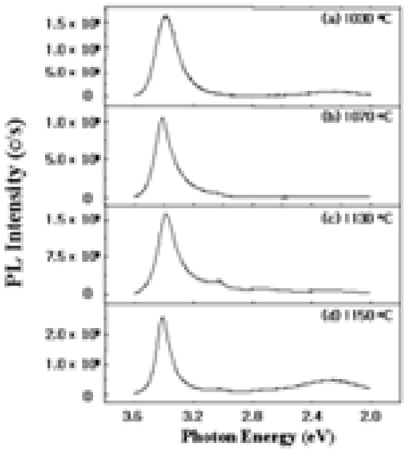

Figure 2 PL spectra measured at room temperature for sample #1 as a function of growth temperature ; (a) 1030℃, (b)1070℃, (c) 1130℃ , and (c) 1150℃

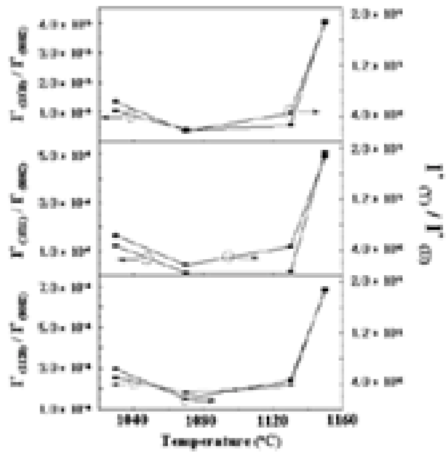

Figure 3 The normalized peak intensity ratios of YL to BL and of $(10\bar{1}0)$, $(10\bar{1}1)$, $(11\bar{2}0)$ to (0002) for sample #1 as a function of the growth temperature

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