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High Quality Cubic GaN Growth on GaAs (100) Substrates by Metalorganic Vapor Phase Epitaxy

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1. Introduction

GaN-based III-V semiconductors have recently attracted extensive attention because of their potential application to optoelectronic devices operating in blue and ultraviolet spectral regions. Due to its large ionicity, GaN usually crystallizes in hexagonal (wurtzite) phase at thermal equilibrium. Intensive attention so far has been focused on hexagonal GaN grown on sapphire and SiC and significant progress has been made.

On the other hand, It has been demonstrated that cubic GaN can be grown under suitable growth conditions[1]. Cubic GaN is theoretically expected to possess superior electronic properties for some device applications[2]. The epitaxially grown cubic GaN films can be cleaved along with the substrate facet, which enables us to prepare cavity mirrors for laser diodes easily. Despite these possible advantages, the research on cubic GaN falls behind that on hexagonal GaN. One reason for the imbalance of research between the two phases is the difficulty to obtain good quality cubic GaN. The inferior quality of cubic GaN is mainly caused by the co-existence of hexagonal GaN, high density of planar defects and impurities.

Here we report on the high temperature (900°C) growth of cubic GaN on GaAs (100) substrate by metalorganic vapor phase epitaxy (MOVPE). For cubic GaN, improved crystal quality can be expected as increasing temperature, provided the decomposition of GaAs substrate at high growth temperature is avoided.

2. Experiment

Cubic GaN films were grown on semi-insulating GaAs (100) substrates by MOVPE. Trimethylgallium (TMG) and 1,1-dimethylhydrazine (DMHy) were used as the precursors of Ga and N, respectively. The use of DMHy enabled us to grow cubic GaN at a small V/III ratio below 50. After the deposition of a 20nm-thick buffer layer at 575°C, an about 1 μm-thick GaN layer was deposited at 900°C. The buffer layer was found to lead to a two-dimensional growth and to protect the GaAs substrate from decomposition at relatively high growth temperature. The flow rate of TMG was set at 18μmol/min, resulting in a relatively fast growth rate of about 3μm/h. The crystal quality of cubic GaN was determined by scanning electron microscope (SEM), X-ray diffraction and photoluminescence (PL) measurements.

3. Results and Discussion

Figure 1 shows an SEM photograph of the surface and cross section of a cubic GaN film grown on GaAs (100) substrate by MOVPE. It can be seen that this sample has a smooth surface free from cracks. However, small undulations can also be observed from this photograph. The undulations may be resulted from the stretches of substrate roughness caused by nitridation. It has been reported that the nitridation of GaAs substrate can roughen the surface and thus results in the appearance of (111) facets. Although we did not nitride the GaAs substrate intentionally, there may be some nitridation effects before and during the growth of the buffer layer. The full width at half maximum (FWHM) of the X-ray rocking curve of the (002) diffraction from a 1μm-thick cubic GaN is approximately 30min. This value for cubic GaN is significantly smaller than that of 60min (4μm-thick c-GaN/Si)[3], 96min (0.4μm-thick c-GaN/GaAs)[4] and 43min (1μm-thick c-GaN/MgO)[5].

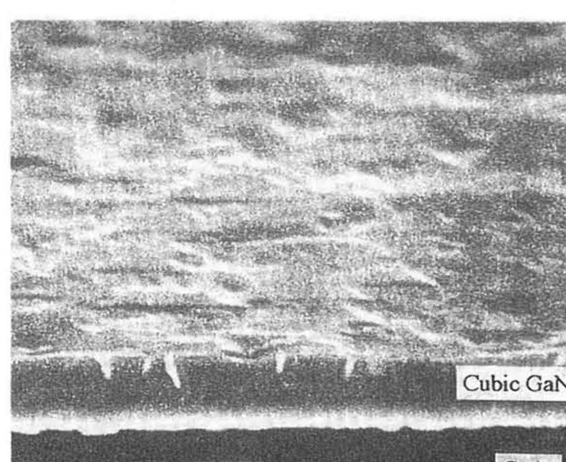

Fig. 1 SEM photograph of the cubic GaN grown on GaAs (100) substrate by MOVPE.

Figure 2 shows the photoluminescence spectrum at 6K for a cubic GaN film grown by MOVPE. This spectrum exhibits strong near-band emissions. The excitonic emission at 3.274eV, which has the full width at half maximum (FWHM) at 6K of 15meV, shows the strongest intensity in this spectrum. The donor-acceptor pair recombination at 3.178eV is weak even at low temperature (6K), indicating the relatively high quality as well as substantially high purity of the cubic GaN film. Moreover, two features can be observed from this spectrum. The first is that the intensity of deep-level emission around 2eV is very weak comparing with that of near-band emissions. The second feature is that this spectrum exhibits no emission signals above 3.30eV, which corresponds to hexagonal GaN. Because the hexagonal GaN crystallizes in better crystal quality easily than cubic GaN, the transitions from hexagonal GaN are often observed in the luminescence spectra of cubic GaN.

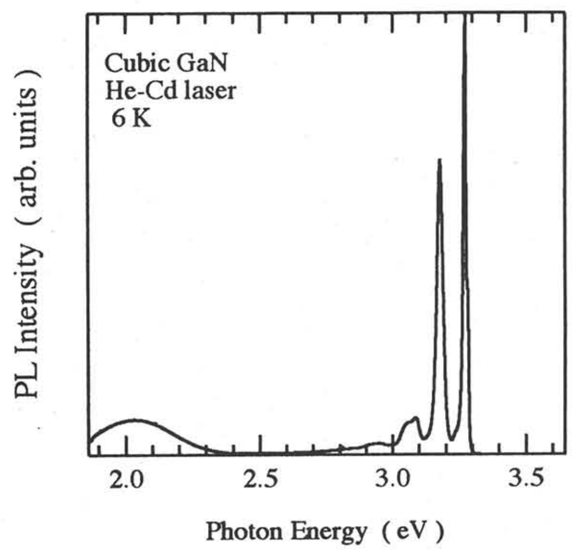

Fig. 2 Photoluminescence spectrum at 6K for a cubic GaN film grown by MOVPE.

Figure 3 shows the PL spectrum of cubic GaN measured at 300K. This spectrum is dominated by the excitonic transition at 3.216eV that has a FWHM value of 73meV. This is the best value to date for cubic GaN at room temperature. Much smaller than that reported recently by Menniger *et al.*[6] (108meV from microcrystal and 143meV from cubic GaN layer) and by As *et al.*[7] (117meV from a cubic GaN layer).

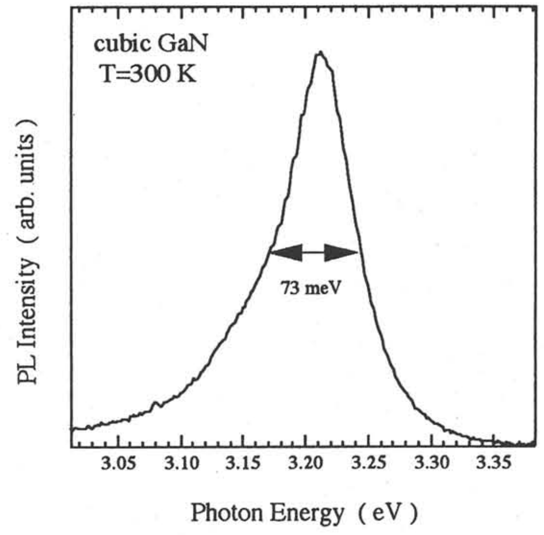

Fig. 3 Photoluminescence spectrum of cubic GaN at 300K.

4. Conclusions

In summary, we have grown cubic GaN films on GaAs (100) substrates by MOVPE at relatively high temperature. SEM measurement and X-ray diffraction showed the high crystal quality of these cubic GaN films. The PL spectra are dominated by the excitonic transition at 3.274eV at low temperature (6K). An excitonic emission at 3.216eV with FWHM value as small as 73meV was observed at 300K.

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