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MOVPE Growth of High Quality GaN/InGaN Single Quantum Well Structure Using Misoriented SiC Substrate

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High quality GaN/InGaN single quantum well (SQW) structure has been successfully grown using the misoriented 6H-SiC substrate by low pressure metalorganic vapor phase epitaxy (MOVPE). From the TEM analysis, the dislocations in the GaN films grown on the misoriented substrate bent perpendicular to the c-direction. For the InGaN films grown on the misoriented substrate, only the sharp band edge emission, whose FWHM was 92.3meV, was obserbed at 385nm in the PL spectrum at 77K. The dislocation density in the InGaN film on the GaN film grown on the misoriented substrate was as nearly half as that using the (0001) substrate (~$5 \times 10^8 cm^{-2}$).

1. Introduction

Recently, III-V nitrides have been used for short wavelength optical devices, such as blue light emitting diodes and blue~ultraviolet laser diode. In these devices, the GaN/InGaN quantum well structures have been grown on sapphire substrates[1, 2, 3]. On the other hand, the 6H-SiC substrate is more useful for the III-V nitrides epitaxial growth, because a-axis lattice mismatches of GaN and AlN to the (0001)-oriented 6H-SiC are relatively small as +3.4% and +0.9%, respectively, compared with the sapphire substrate. Furthermore, as the 6H-SiC substrates can be cleaved and have high conductivity, the laser diodes with higher performance can be produced. However, there are few reports about the epitaxial growth of the GaN/InGaN quantum well structures on the 6H-SiC, and especially no reports using the misoriented SiC substrates. In this paper, we have investigated the InGaN MOVPE growth on both the (0001) 6H-SiC substrates and the misoriented 6H-SiC substrates, and successfully grown a high quality GaN/InGaN SQW structure using the misoriented substrate for the first time.

2. Experiment

The GaN, InGaN films were grown by low pressure MOVPE on the (0001) 6H-SiC substrates or on the misoriented substrates, whose faces are tilted from (0001) toward $[11\bar{2}0]$ by 3.5°. These films were grown at 1000°C and 680°C, respectively, under a pressure of 9.3 kPa, after the AlN buffer layer was grown at 1090°C. The (0001) 6H-SiC and the misoriented substrates were simultaneously grown at the same growth conditions. Trimethylgallium (TMGa), trimethylindium (TMIn), trimethylaluminum (TMAl) and ammonia (NH_3) were used as the source materials, and hydrogen (H_2) as the carrier gas. The thicknesses of InGaN, GaN and AlN were 0.12μm, 1.5μm and 0.18μm, respectively. The films were characterized by photoluminescence (PL) excited by He-Cd laser (325nm) at 77K, photoreflectance at RT and transmission electron microscopy (TEM). The PL excitation power was 1.1W/cm^2.

3. Results and discussion

Figure 1 shows the photoluminescence spectra of the GaN films on the (0001) substrate and the misoriented substrate. For the misoriented substrate the band edge emission at 360nm, which shows high quality of the film, was dominant compared with the D-A pair emission at ~380nm and the deep emission at ~550nm, while for the (0001) substrate the band edge emission was not dominant.

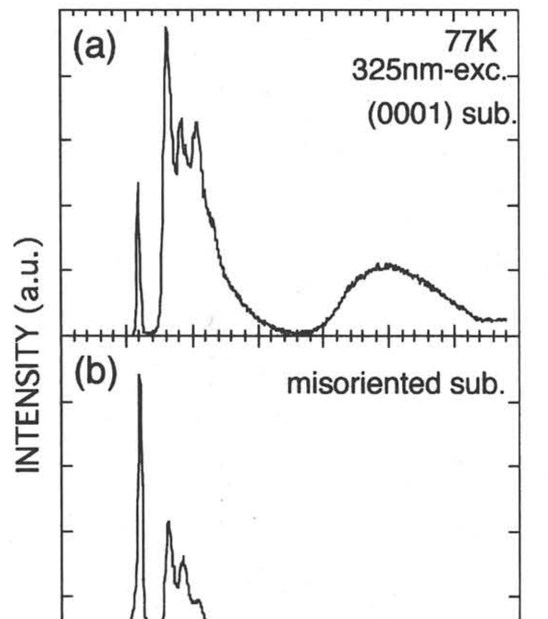

Fig.1 Photoluminescence spectra at 77K of the GaN films on the (0001) 6H-SiC substrate (a) and the 3.5° off (0001) substrate toward $[11\bar{2}0]$ direction (b).

Figure 2 shows the photoluminescence spectra measured at 77K for the InGaN films grown on the GaN films. The band edge emission peak of the InGaN film on the misoriented substrate was shorter than that on the (0001) substrate. The photoreflectance spectra of the InGaN films indicate that the absorption edges for the films using the (0001) substrate and the misoriented substrate were 410nm and 383nm, which means 16% and 7% in the In content, respectively. The values of the In contents evaluated from the photoreflectance measurements were also consistent with those from the X-ray analysis. These results indicate that the incorporation efficiency of In in InGaN films on the (0001) substrate is higher than that for the misoriented substrate. In Fig.2, the full width at half maximum (FWHM) of the band edge emission for the InGaN film using the misoriented substrate was 92.3meV, indicating that the film has almost the best quality in the case of using sapphire substrates. In the spectrum using the misoriented substrate, the luminescence from deep levels at around 600nm was not observed, which shows high quality of the InGaN film. Since the difference of the InGaN crystalline quality is supposed to be originated from the dislocations in the GaN or InGaN films, the cross sectional TEM photographs were observed. Figure 3 shows the TEM photographs of the InGaN/GaN/AlN/SiC films grown on the (0001) 6H-SiC substrate (a) and the 3.5° off (0001) substrate toward [11$\bar{2}$0] direction (b). The dislocations in the GaN films using the (0001) substrate were along the c-direction, while those using the misoriented substrate bent perpendicular to the c-direction in the GaN films. The dislocation density, which was estimated from TEM photographs, in the InGaN films grown on the misoriented substrate was about 5×10^{8} cm^{-2}, which was as half as that using the (0001) substrate.

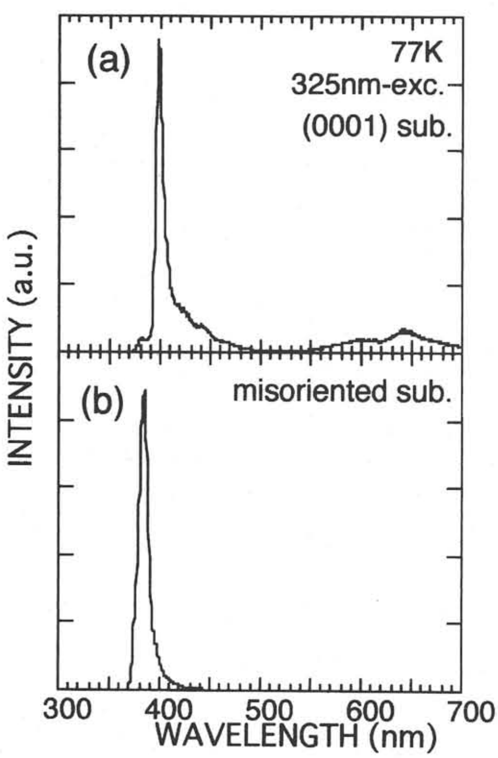

Fig.2 Photoluminescence spectra at 77K of the InGaN films on the GaN films using the (0001) 6H-SiC substrate (a) and the 3.5° off (0001) substrate toward [11$\bar{2}$0] direction (b).

Figure 4 shows the TEM photograph for the GaN/InGaN/GaN SQW structure using the misoriented substrate. The thicknesses of each layer in the GaN/InGaN/GaN SQW were 0.35μm, 70Å and 1.35μm, respectively. No dislocations were observed at the abrupt interfaces between the GaN and InGaN films. Furthermore, there were no cracks on the surface.

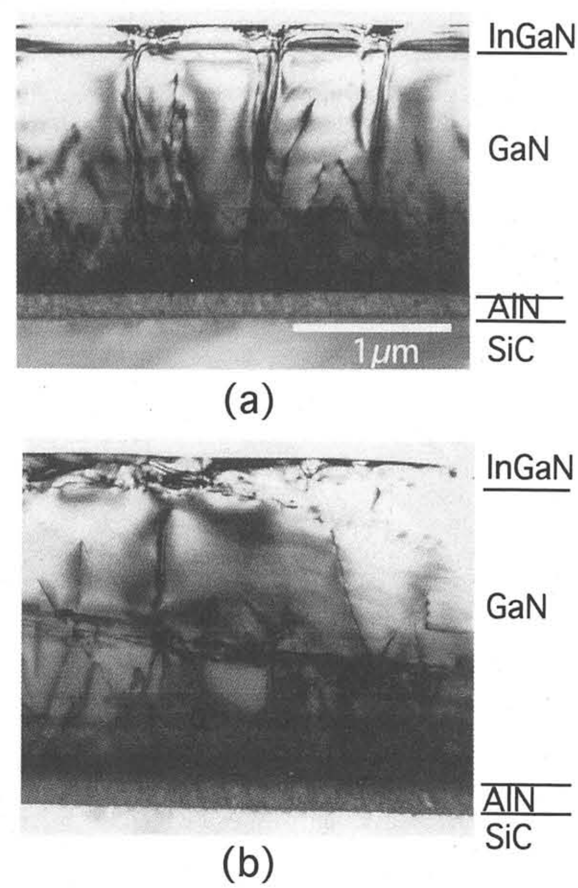

Fig.3 TEM photograph of the InGaN/GaN/AlN/SiC films using the (0001) 6H-SiC substrate (a) and 3.5° off (0001) substrate toward [11$\bar{2}$0] direction (b).

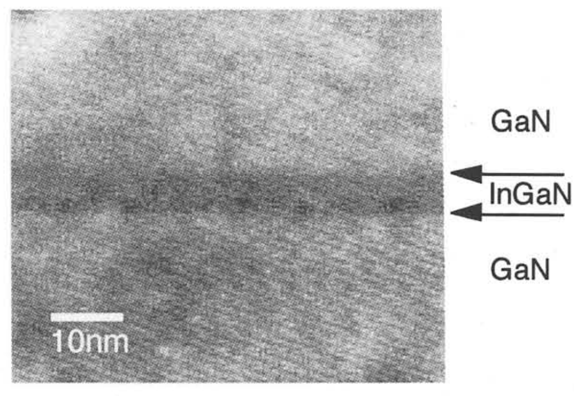

Fig.4 TEM photograph of the GaN/InGaN/GaN SQW structure using the 3.5° off (0001) substrate toward [11$\bar{2}$0] direction.

The photoluminescence spectra of the GaN/InGaN/GaN SQW structures are shown in Fig. 5. In the only case of using the misoriented substrate, the very strong and narrow luminescence was observed. The peak energy and FWHM of the luminescence were 385nm and 24.3meV, respectively, indicating the luminescence from a high quality SQW.

4. Conclusion

In summary, we have found the improvement of the optical properties of the InGaN, GaN films using the misoriented 6H-SiC substrate, in addition to the In content change between the (0001) and the misoriented 6H-SiC substrate, and successfully grown a high quality GaN/InGaN SQW structure. These results suggest a possible application of the SQW structures on the misoriented 6H-SiC substrates to the laser diodes.

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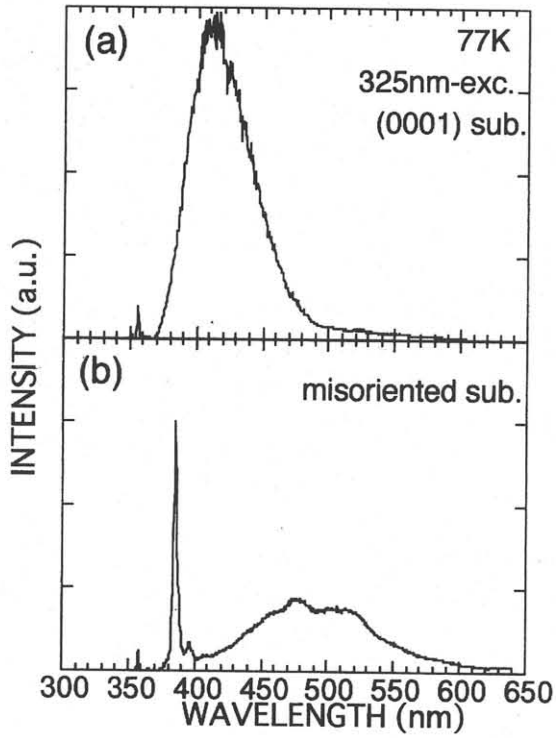

Fig.5 Photoluminescence spectra at 77K of the GaN/InGaN/GaN SQW structures using the (0001) 6H-SiC substrate (a) and the 3.5° off (0001) substrate toward [11$\bar{2}$0] direction (b).