Effect of intermediated layers in $Al_{0.65}Ga_{0.35}N$/GaN multiple quantum wells

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Intersubband transition (ISBT) in AlGaN/GaN multiple quantum wells (MQW) is expected to be applicable to high-speed optical switches because of the very short relaxation time, which is estimated to be 200 fs [1]. However, the growth of the MQWs is crucial, because lattice mismatch at the interface between the well and the barrier is large. So far, we have grown MQWs that consisted of a total of 200 wells, and demonstrated that the intersubband relaxation time is less than 150 fs at a wavelength of 4.6 μm [2]. This MQW structure included intermediated layers. In this work, we compare two structures, one with intermediated layers and the other without, and discuss the effect of the intermediated layers on the crystalline quality and ISBT.

The growths were carried out by atmospheric pressure MOCVD. As shown in Fig. 1, the layers were grown on an undoped GaN (1.7 μm) layer deposited on a (0001) Al_2O_3 substrate. After that, MQWs consisting of four sets of 50 $Al_{0.65}Ga_{0.35}N$ (2 nm)/GaN (4 nm) QWs, and undoped GaN intermediated layers (400 nm) were grown in turns (sample A). The well layers were doped with Si at 1 x 10^{19} cm^{-3}. The growth temperature of the intermediated layers and MQWs was approximately 1100℃. The other sample, sample B, consisted of 200 wells without GaN intermediated layers.

Fig. 2 shows the transmittance spectrum obtained by FTIR. The intersubband absorptions were observed at a wavelength of about 4.6 μm in both samples. Sample A is stronger in the intensity of the intersubband absorption than sample B. The intermediated layers cause an increase in the intersubband absorption. To investigate the reasons, we examined the crystalline quality for both samples using X-ray analysis. Fig. 3 shows the results of X-ray diffraction (2θ/ω–scan). The ±1 and −2 order satellite peaks are narrower for sample A than for sample B. This indicates that sample A has better periodicity than sample B. Thus, it is considered that the intermediated layers improve the periodicity of MQWs. In Fig. 4, the reciprocal space maps (RSM) around GaN (11-14) for sample A and sample B are shown. The intensity maxima of the MQWs and the GaN layer are aligned vertically, parallel to the q_z-axis, for both samples. This indicates that the MQWs are coherently grown on GaN. In sample B, the peaks are more extended in the q_{x-y} direction. Sample A, on the other hand, has a major peak and a minor peak with very weak intensity located at a larger value in the q_{x-y} coordinate. This suggests that MQWs are strained more uniformly in sample A than in sample B. Since the growth rate is related to the strain, the periodicity of MQWs is better in sample A than in sample B. This leads to the stronger intersubband absorption.

In conclusion, we grew an $Al_{0.65}Ga_{0.35}N$/GaN quantum well structure that consisted of 4 MQWs (50 wells) and intermediate layers, and studied the effect of the intermediated layers on the crystalline quality and the intersubband absorption. With the intermediated layers, the intersubband absorption was stronger. It is considered that the periodicity of the MQWs was maintained because the strain uniformity was improved. The intermediated layer is effective for growing MQWs with a large lattice mismatch.

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References

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[2] N. Iizuka, *et al*, CLEO2000, CWP2, San Francisco (2000).

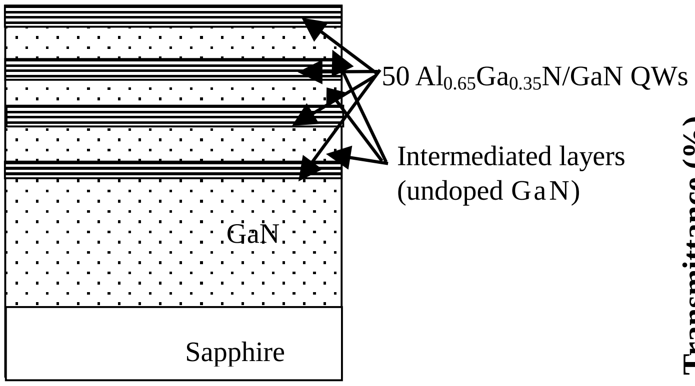

Fig.1 Cross-sectional image of sample A. The structure consists of 4-MQWs (50 wells) and the intermediated layers.

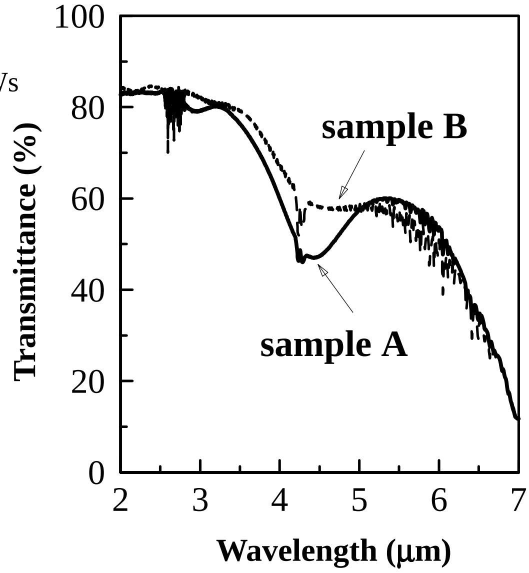

Fig. 2 Transmittance spectrum. Absorption of ISBT is around 4.6um.

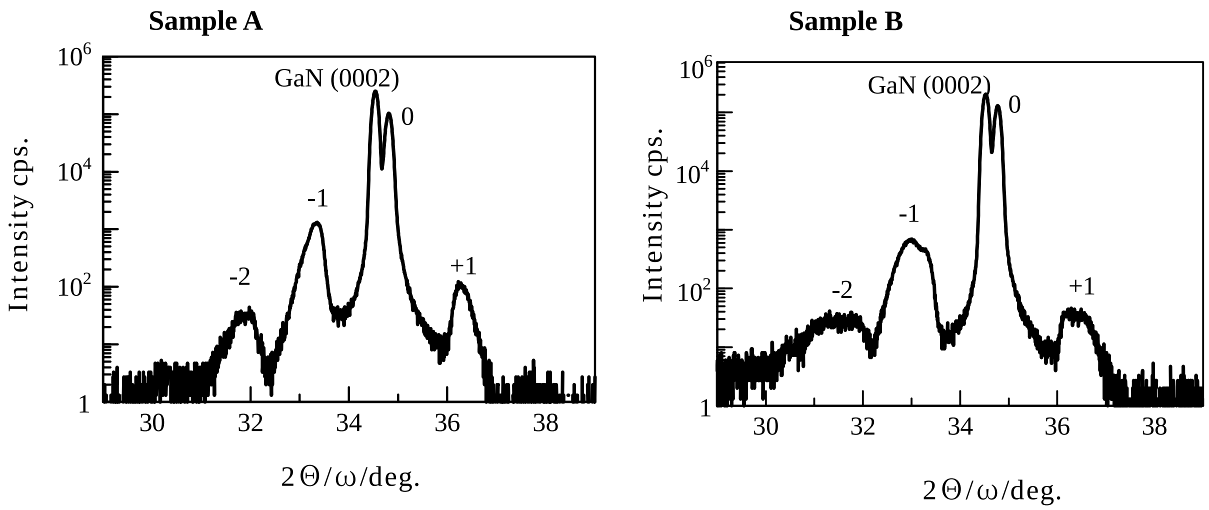

Fig.3 The 2θ/ω–scan profiles of X-ray diffraction

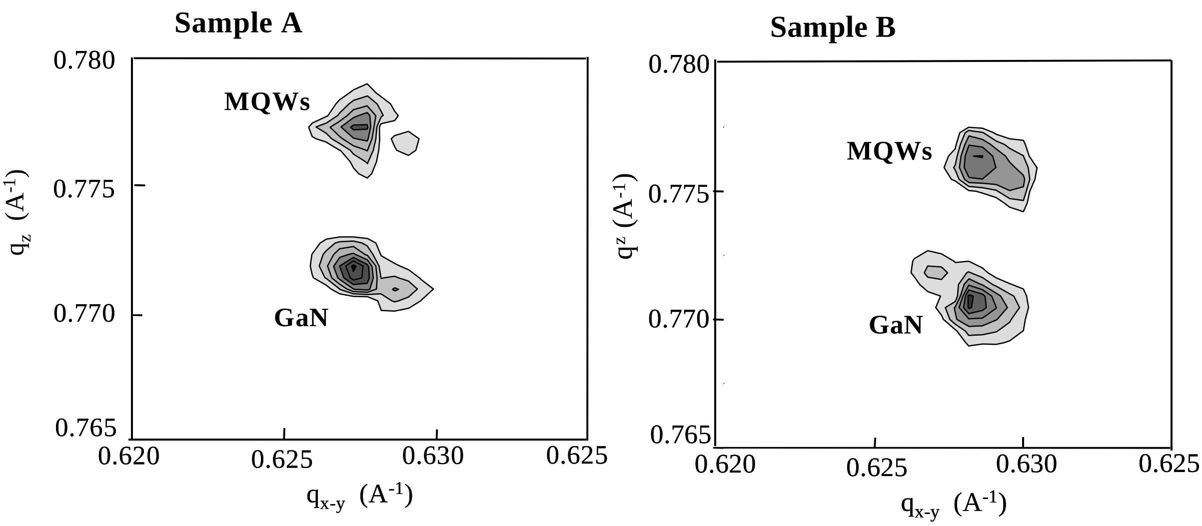

Fig.4 The reciprocal space maps (RSM) around GaN $(11\bar{1}4)$