Characterization of MOVPE InN films grown on 3c-SiC/Si(111) templates

Improved MOVPE InN films grown on 3c-SiC/Si(111) templates

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An experimental study has been made on the correlation between the fabrication conditions for 3c-SiC/Si(111) template and electrical and crystallographic properties of InN films grown on the template. The template has been prepared by C^+-ion implantation into Si(111). Although the 3c-SiC layers shows a large (170 arcmin) FWHM of XRC (111) diffraction, InN films with a considerably small (about 50 arcmin) FWHMs for (0002) and (10-10) diffraction are grown on the layers. A lower implantation dose brings a smaller XRC FWHMs for 3c-SiC and the quality of InN is improved by improving that of the 3c-SiC layer. The post implantation annealing is found to be effective to improve the quality of the 3c-SiC layer and, therefore, to improve the quality of InN films. Hall mobility is found to be markedly increased by decreasing FWHM of InN (0002) diffraction. The best data of carrier concentration and Hall mobility are 6.2×10^{18}cm^{-3} and 630cm^2/Vs, respectively.

1 Introduction

Indium nitride (InN) currently is attracting much interest because of its prominent properties and potential applications. For example, this material is revealed to have the lowest effective mass [1] and the highest electron drift velocity [2] among all III-nitride semiconductors. This means that InN is suitable for high speed and high frequency electronic device applications. However, device-quality InN films are so far still lacking because of difficulties in growing good crystals. One of the reasons for this may be the large lattice mismatch (00%) between InN and sapphire substrate. Silicon (Si) is expected as another candidate substrate for epitaxial growth of InN, because of the unique merits of Si substrate such as low cost, the higher thermal conductivity, the smaller lattice mismatch (8%) and the larger area wafer availability. In addition, Si has an advantage that optoelectronic integrated circuits (OEICs) can be fabricateed by combining III-nitride optical devices and Si electronic devices. However, the growth of InN directly on a Si substrate using MOVPE is difficult owing to the formation of amorphous SiN_x on the surface [3]. We have previously reported [4] that a single crystalline wurtzite InN is grown on the 3c-SiC/Si(111) template Such a template is prepared by the C^+-ion implantation into Si(111). Furthermore, InN films with quality comparative to that grown on the sapphire are grown by employing the nitrided 3c-SiC/Si(111) templates [5]. In this study, we show the correlation between the fabrication conditions for 3c-SiC/Si(111) template and electrical and crystallographic properties of InN films grown on the template. Hall mobility is found to be markedly increased by decreasing FWHM of InN (0002) diffraction.

2 Experimental

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Templates of 3c-SiC/Si(111) structure are prepared by carbon (C^+)-ion implantation into Si(111) and the post growth annealing. with a dose of (0.9-2)×10^{18}/cm^2 and an acceleration voltage of 180kV at a temperature 600°C. After the implantation, 3c-SiC layer is annealed at 1250°C for 2h in air atmosphere or not performed. The etching processes of upper layers just on single-crystalline 3c-SiC layer for 3c-SiC/Si(111) template has been reported elsewhere [6]. MOVPE InN films is grown at 600°C with trimethylindium (TMI) and NH_3 as sources on the 3c-SiC/Si(111) templates. First the templates were thermally cleaned at 1000℃ in H_2 atmosphere for 10min, then GaN buffer layer is grown with triathylgallium (TEG) and NH_3 at 550°C. Just before the GaN buffer growth, the template is nitrided at 900°C. The InN films are characterizes with AFM and Hall measurements. The structural analysis is performed by XRC with tilt- and twist-angle distribution.

3 Results and discussion

Table 1 summarizes FWHMs of XRC (111) diffraction for 3c-SiC layers formed by the implantation with a different dose and those of (0002) and (10-10) diffraction for InN films grown on those layers. One can see that although FWHM of (111) diffraction of 3c-SiC layers is so large, InN films with a considerably small (about 1/3 of that for 3c-SiC) FWHM values are grown on the layers. It is found that a lower dose (9.0 × 10^{17} cm^{-2}) results in smaller FWHMs for both SiC and InN layers. According to Linder et al. [7], the dose of 9.0 × 10^{17} cm^{-2} corresponds to that for the stoichiometric 3c-SiC formation. Figure 1 shows the AFM images for 3c-SiC layers formed with a different implantation dose and for InN films grown on the 3c-SiC layers. One can see that the surface morphology is dependent on implantation dose. When the total dose is low (9x10^{17} cm^{-2}), the surface of the 3c-SiC layer is seen to be porous and 3c-SiC grains seems to be coalescing each other. On the other hand, 3c-SiC grains are randomly distributed on the surface when the total dose is high (2x10^{18} cm^{-2}). In spite of the large difference in the SiC surface morphology, the InN films show no marked difference in their morphology, as seen in Fig. 1. Thus, the crystalline quality and morphology of InN are not so much influenced by those of 3c-SiC layers. This does not mean that the crystalline quality can not be improved by the improvement of 3c-SiC quality. Figure 3 shows the relationships between FWHMs of 3c-SiC (111) diffraction and those of (0002) and (10-10) diffraction for InN films. The results in Fig. 3 shows that the quality of InN is improved by improving that of the 3c-SiC layer. Data for samples prepared without the post implantation annealing (1250°C) are also shown in Fig. 3. The post implantation annealing is found to be effective to improve the quality of the 3c-SiC layer and, therefore, to improve the quality of InN films. The numbers in Fig. 3 show implantation dose. One can see that the lower dose brings higher quality of InN. Figure 4 shows the relationship between FWHM of InN (0002) diffraction and Hall mobility

Table 1. FWHMs of 3c-SiC layers with a different dose and of InN films grown on those layers.

Dose (C^+/cm^2)		**0.9 × 10^{18}**	**2.0 × 10^{18}**
3c-SiC	(111)	**167 arcmin**	**176 arcmin**
InN	(0002)	**47 arcmin**	**56 arcmin**
	(10-10)	**53 arcmin**	**66 arcmin**

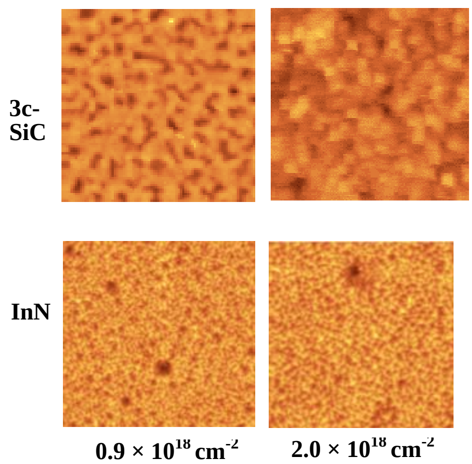

Fig. 1 AFM images (10µm × 10µm) of 3c-SiC layers formed with a different implantation dose and InN films grown on the 3c-SiC layers; (a) dose 0.9 × 10^{18} cm^{-2} (b) dose 2.0 × 10^{18} cm^{-2} .

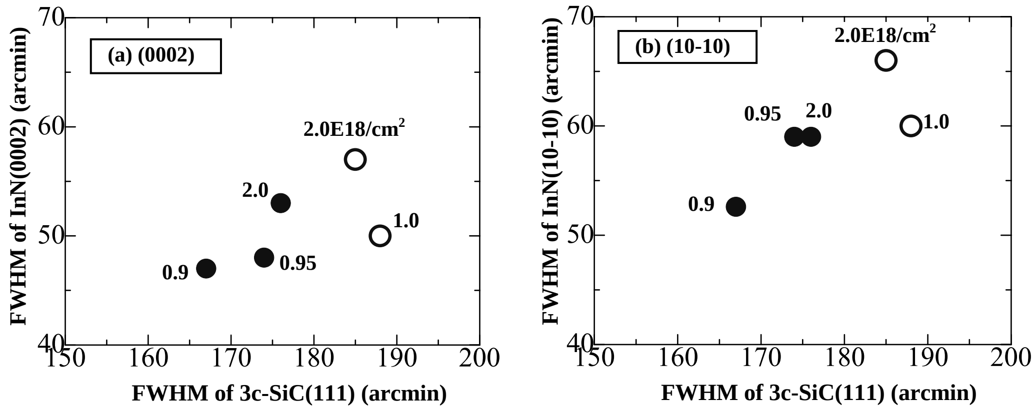

Fig. 3. The relationships between FWHMs of 3c -SiC (111) diffraction and those of (0002) and (10-10) diffractions for InN films. Data for samples prepared without the post implantation annealing (1250°C, 2h) are also shown (○: without annealing, ●: with annealing). The number in the figures shows an implantation dose.

of InN. Also shown are data for InN films grown on sapphire (0001) substrates. For samples grown on both 3c-SiC/(111) and sapphire (0001), Hall mobility is found to be markedly increased by decreasing FWHM of InN (0002) diffraction. This may indicate that screw dislocations are mainly responsible for electron scattering in InN. A clear dependence of Hall mobility on FWHM of InN(10-10) diffraction is not observed in this study. The best data of carrier concentration and Hall mobility are 6.2×10^{18}cm^{-3} and 630cm^2/Vs, respectively.

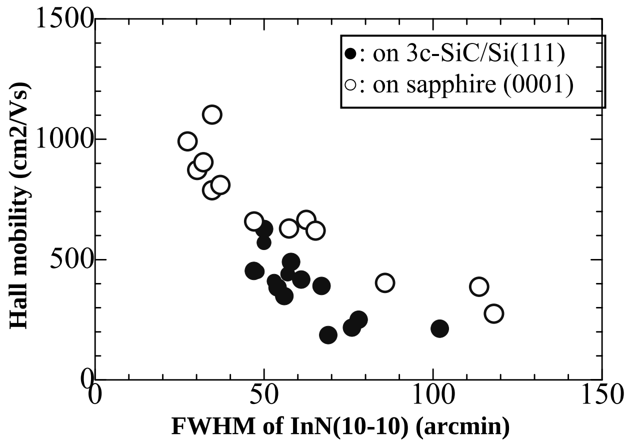

Fig. 4. The relationship between FWHM of InN (0002) diffraction and Hall mobility of InN. Data for InN films grown on sapphire (0001) substrates are also shown for comparison.

4 Conclusion

We have studied the correlation between the fabrication conditions for 3c-SiC/Si(111) template and electrical and crystallographic properties of InN films grown on the template. Although FWHM of (111) diffraction of 3c-SiC layers is so large (about 170 arcmin), InN films with a considerably small (about 50 arcmin) FWHM values are grown on the layers. A lower implantation dose (9.0×10^{17} cm^{-2}) results in smaller XRC FWHMs for both SiC and InN layers. Although the crystalline quality and morphology of InN are not so much influenced by those of 3c-SiC layers, the quality of InN is improved by improving that of the 3c-SiC layer. The post implantation annealing is found to be effective to improve the quality of the 3c-SiC layer and, therefore, to improve the quality of InN films. For samples grown on both 3c-SiC/(111) and sapphire (0001), Hall mobility is found to be markedly increased by decreasing FWHM of InN (0002) diffraction. This may indicate that screw dislocations are mainly responsible for electron scattering in InN.

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