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MOVPE Growth of GaN Layer on Titanium Thin Film

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GaN was prepared on Ti film by metal organic vapor phase epitaxy (MOVPE). The Ti film was deposited on sapphire substrate by electron beam evaporation. Scanning electron microscopy (SEM) observation revealed that the GaN layer with optically smooth and specular surface was successfully grown on the rough surface of the Ti film. The X-ray diffraction (XRD) pattern of the sample showed that a hexagonal GaN layer is well oriented in the c-axis, furthermore, the underlying Ti seems to be converted into TiN by nitridation during the GaN growth.
Key words: MOVPE, GaN, Ti, TiN, buried-electrode

1. INTRODUCTION

Gallium nitride (GaN) and related alloys have attracted tremendous attention for blue and green LEDs[1,2], ultraviolet LDs[3] and high-power electronic devices[4]. As for electrode materials of these devices, a number of elemental metals have been investigated so far. For example, Al[5], Ti[6], and their alloys as ohmic contact and Ni[7] as schottky contact have been usually used for the electrodes of n-GaN.

These electrode materials have commonly formed on the surface of n-GaN with proper pretreatments. On the other hand, Hiramatsu et al. [8] have recently proposed the schottky electrodes which were buried under GaN layer using epitaxial lateral overgrowth (ELO). In this case, the electrode was used as a mask for selective growth. GaN layer, therefore, was not grown on electrodes. The electrodes were eventually buried by lateral growth of GaN. The buried-electrode process is seen to be of technological importance for the future electronic devices based on GaN. The buried electrodes using ELO technique, however, is advantageous in terms of obtaining high-quality epitaxial layer, but disadvantageous in terms of complicating the preparation procedures.

In this study, we investigate whether GaN can be grown directly on metal or not. From the viewpoint of allowing low resistance ohmic contacts to n-GaN as low as $\sim 10^{7}\Omega\cdot cm$,[6] Ti was chosen as the buried metal. There are no reports on the ohmic electrodes which were buried with GaN.

2. EXPERIMENTAL

Ti film was deposited on sapphire substrate by electron beam evaporation. Thickness of Ti film was estimated to range from 50 to 60nm. After the sample was taken out from the evaporation chamber, it was introduced into MOVPE reactor without any pretreatments. GaN layer was grown on Ti-deposited sapphire substrate by low-pressure MOVPE with a horizontal reactor. Trimethylgallium (TMG) and ammonia (NH_3) were used as the source materials for gallium and nitrogen, respectively. The following procedures were employed in GaN growth. After Ti-deposited sapphire substrate was annealed at 600°C for ten minutes in hydrogen ambient, low-temperature GaN (LT-GaN) buffer layer was grown on that at the same temperature. Then, the substrate was ramped to 1060°C under an NH_3 ambient, and GaN growth was initiated by the introducing of TMG. The same growth sequence was performed for sapphire substrate without Ti film to compare with the GaN on the Ti film. The growth rate of the GaN was approximately 1μm/hour. The crystal structure of the GaN was determined by double-crystal X-ray diffraction (XRD) analysis. Scanning electron microscopy (SEM) was used to determine characteristics of the surface and the cross-sectional structures of the samples.

3. RESULT AND DISCUSSION

The XRD pattern of Ti film on sapphire substrate is shown in Fig.1. The diffraction peak of sapphire substrate appears at 41.7° for $Al_2O_3(0006)$ plane. The br-

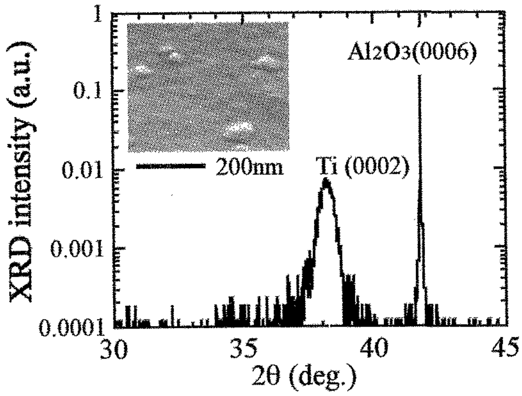

Fig. 1. XRD pattern of Ti film on sapphire substrate. Inset shows a SEM surface image of 50nm-thick Ti film.

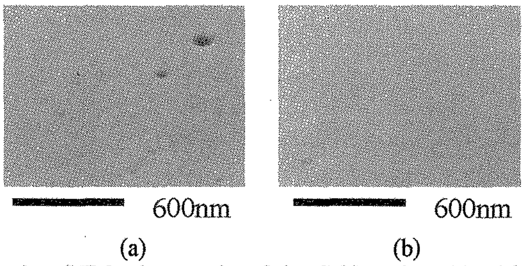

Fig. 2. SEM micrographs of the GaN surface (a) with Ti film and (b) without Ti film.

oad diffraction peak for hexagonal Ti (0002) was observed at 38.1°. The SEM micrograph for the surface of the Ti film is shown in Fig. 1 inset. Small grains are visible on top of the whole film. Typical size of these features is about 20-40nm in width.

Fig. 2 (a) shows SEM surface image of the GaN on Ti film. Optically smooth and specular GaN surface was successfully obtained despite of the rough surface of Ti film shown in Fig. 1 inset. The surface flatness of the GaN with Ti film is practically equivalent to that without Ti film, except for several pits on the surface of the GaN with Ti film.

Fig. 3 shows the cross-sectional SEM micrograph of the GaN on Ti film. GaN/Ti/sapphire interfaces can be seen clearly. A few voids exist near the interface of GaN/Ti. The interface of Ti/sapphire is relatively flat in comparison with GaN/Ti interface.

Fig. 4 (a) and (b) show the XRD patterns of GaN without and with Ti film, respectively. A hexagonal GaN layer on Ti film is well oriented in the c-axis, although the GaN (0002) peak of the sample on Ti film is weaker and broader than that without Ti film. It should be noted that a small peak appeared at 36.7°. This peak may be attributed to TiN (111) plane reflection. It

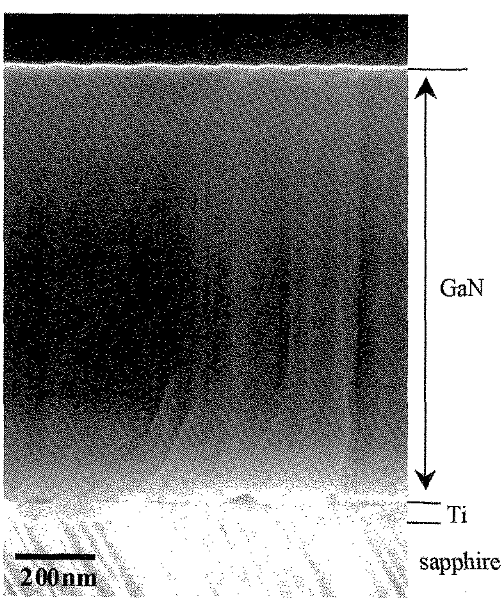

Fig. 3. Cross-sectional SEM micrograph of the GaN/Ti /sapphire structure.

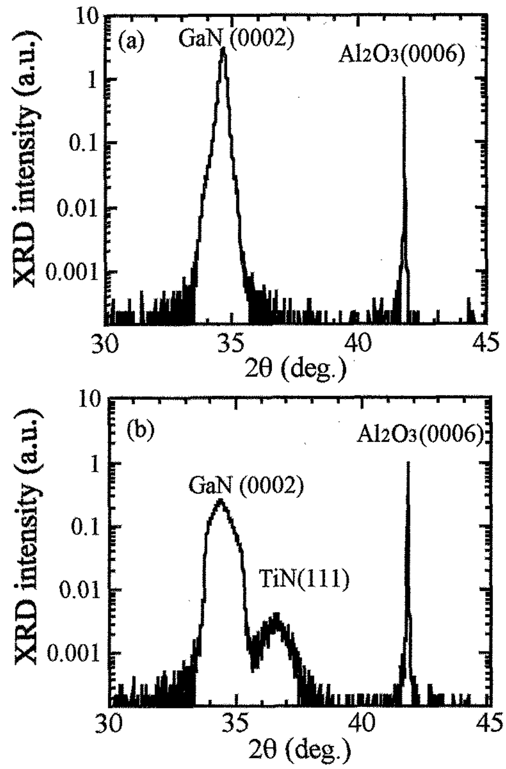

Fig. 4. XRD patterns of the GaN (a) with Ti film and (b) without Ti film.

is possible that Ti is converted into TiN by nitridation in NH_3 ambient during the GaN growth. Full-width-at-half-maximum (FWHM) of the rocking curve of the GaN (0002) peak around 34.3° is 1350arcsec. This value is about two times broader than that without Ti film. This result shows that the crystalline quality of the GaN with Ti film is poorer than that without Ti film.

4. CONCLUSION

C-axis oriented hexagonal GaN with a smooth surface can be obtained on the rough surface of Ti. To our knowledge, this is the first time such kind of direct epitaxy of GaN on metal has been reported. The crystalline quality of the GaN with Ti film, however, is poorer than that without Ti film. There is still room for improvement of crystalline quality of GaN on Ti film.

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