Epitaxial Growth of InN on Nearly Lattice Matched $(Mn,Zn)Fe_2O_4$ Substrates at Low Temperatures

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It is well known that InN epitaxial films suffer from formation of high-density crystalline defects, which stem from the large mismatches in the lattice constants and the thermal expansion coefficients. To solve this problem, the use of a nearly-lattice-matched substrate and the decrease of the growth temperature have been highly requested. $(Mn,Zn)Fe_2O_4$ (111) is quite attractive as substrates for InN because it has a three-fold rotational symmetry and possibly gives a small lattice mismatch of 1 % with InN if we assume an ideal in-plane alignment. Recently, we have found that the room-temperature (RT) epitaxial growth of AlN and GaN films is possible with the use of pulsed laser deposition (PLD) and nearly lattice matched substrates [1-3]. In this presentation, we will discuss the possibility of room temperature InN epitaxial growth on $(Mn,Zn)Fe_2O_4$ (111) at low temperatures.

The KrF excimer laser pulses (λ=248nm, τ=20ns) ablated an In metal target (99.9999%) with an energy density of about 3 J/cm^2. During the film growth, an rf-nitrogen plasma (350W, 1.5×10^{-5} Torr) was used as a nitrogen source. The substrate temperature was varied from RT to 550 ºC. We investigated the structural properties of InN with atomic force microscope (AFM), reflection high-energy electron diffraction (RHEED), X-ray diffraction (XRD), glazing incidence X-ray diffraction (GIXD), and glazing incidence X-ray reflectivity (GIXR).

From the RHEED observations and the XRD measurements, we have found that InN c-plane grows epitaxially at substrate temperatures ranging from RT to 400 °C. On the other hand, formation of polycrystalline InN was confirmed at a substrate temperature of 550 °C. The FWHM values of InN 0002 rocking curves of the films grown at RT, 150 ºC, 400 ºC, and 550 ºC were 0.028°, 0.028°, 0.70° and 0.73°, respectively. This result indicates that the crystalline alignment of InN along c-axis is degraded with the increase of the growth temperature. The in-plane relationship between InN films and the substrates have been also investigated. Figure 1 shows the typical GIXD curves for InN films grown at RT and 400 °C. We found that the in-plane alignment of InN films grown at RT with ferrite is [11-20]InN//[11-2]$(Mn,Zn)Fe_2O_4$, which makes the lattice mismatch as small as 1%. On the contrary, the in-plane alignment for GaN grown at 400 ºC is [10-10] InN // [11-2] $(Mn,Zn)Fe_2O_4$, which is rotated by 30° from the ideal in-plane alignment.

Figures 2 (a) and (b) show AFM images for the films grown at RT and 550 ºC. It was found that the surfaces of InN films grown at low temperatures below 150 ºC are quite smooth and the root mean square (rms) values are approximately 0.4 nm. In addition, the step-like structure for the RT grown film was observed as shown in Fig. 2 (a). On the other hand, the surface of InN films grown at 550ºC was quite rough and the rms value was 41 nm. These results indicate that the crystalline quality and the surface flatness of InN film are improved by the decrease of the growth temperature, which is probably attributed to the suppression of the interfacial reaction between InN and $(Mn,Zn)Fe_2O_4$. GIXR measurements revealed that the thickness of the interfacial layer is reduced from 8.4 nm to 15 nm with the decrease of the growth temperature from 550 ºC to RT.

These results indicate that the low temperature PLD growth on $(Mn,Zn)Fe_2O_4$ (111) solves the two major problems with epitaxial growths of InN; mismatches in the thermal expansion coefficients and in the lattice constants.

References

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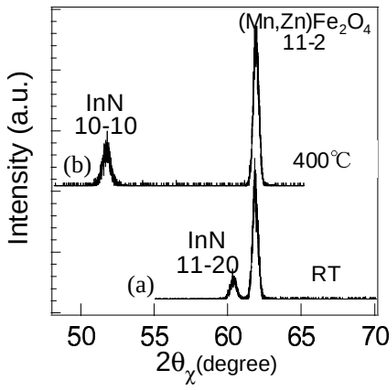

Fig. 1 The GIXD curves for InN films grown at (a)RT and (b)400 °C.

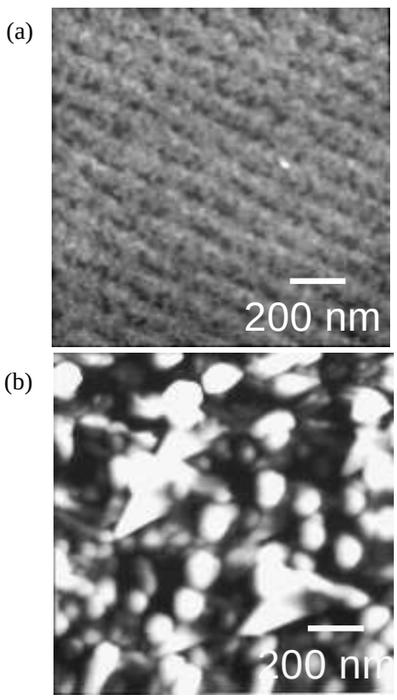

Fig. 2 AFM images for the InN films grown at (a) RT and (b) 550 ºC.