Influences Of Thermal Oxidation On Properties Of Indium Nitride Films

T. Araki[1], R. Yoneda[1], K. Yorozu[1], H. Naoi[2], A. Suzuki[3] and Y. Nanishi[1]
[1]Dept. of Photonics, [2]Center for Promotion of The 21st COE Program, [3]Res.Org.of Sci & Eng.,
Ritsumeikan University
1-1-1 Noji-Higashi, Kusatsu, Shiga, 525-8577, Japan
E-mail:tara@se.ritsumei.ac.jp

Since it was found that the optical band-gap energy of InN is around 0.7 eV rather than the accepted value of 1.9 eV, the research on InN has attracted much bigger attentions. However, there are very few reports on thermal stability of InN. In this paper, we study on thermal oxidation of InN and discuss influences on chemical properties of the surface and structural and optical properties of the films.

InN films were grown on sapphire (0001) substrates by RF-MBE. Sapphire substrates were thermally cleaned at 800°C and a nitridation process was carried out at 550°C. After deposition of low-temperature InN buffer layers, InN films were grown at 550°C. Before and after oxidation, we investigated the surface properties and crystalline quality of the InN films by X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM) and X-ray diffraction (XRD), respectively. In addition, the optical properties of InN were characterized by optical absorption, Raman scattering and photoluminescence (PL).

First, thermal oxidation of InN in the vacuum was investigated. After cleaning the surface by exposure to H*, the samples were oxidized by exposure to O_2 with the range of 1,000 L to 200,000 L (1 L = 1.0×10^{-6} Torr ×1 s). The sample temperature during oxidation process was varied from 370°C to 530°C. Figure 1 shows the In4d peaks obtained for the InN film with the oxidation of 100,000 L. The peak at the binding energy of In-N shifted gradually to the energy of In-O as the temperature increased. This result shows that the chemical bond on the surface of InN films changed from In-N into In-O, suggesting the formation of In_2O_3 at the surface. SEM results also confirmed that triangular grains of In_2O_3 appeared on the InN surface after oxidation process. In addition, XRD peak corresponding to In_2O_3(222) was observed together with the InN(0002), indicating that the formation of In_2O_3 by the oxidation was mainly occurred only at the surface of InN films.

Secondly, the thermal oxidation of InN in the air for 60 min was investigated. The annealing temperature was varied from 400°C to 500°C. It is found that even after the annealing at 400°C the strong XRD peak of InN(0002) was observed like that observed before annealing, indicating that InN was thermally stable for the annealing below 400°C for 60 min. Figure 2 shows the annealing temperature dependence on optical absorption spectra of the InN films. The absorption edge shifted from near 0.7 eV into near 3.4 eV as the annealing temperature increased. The absorption edge of InN annealed at 500°C almost corresponds to an absorption edge of In_2O_3 [1], suggesting formation of In_2O_3 by this annealing. These results confirmed that optical properties of InN films were strongly influenced by the annealing probably due to the formation of In_2O_3.

In summary, influences of thermal oxidation of InN on the chemical properties of the InN surface and the structural and optical properties have been investigated. The oxidation of the InN films was confirmed to promote the formation of In_2O_3, which had a remarkable influence on optical properties of the InN films.

Acknowledgements

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References

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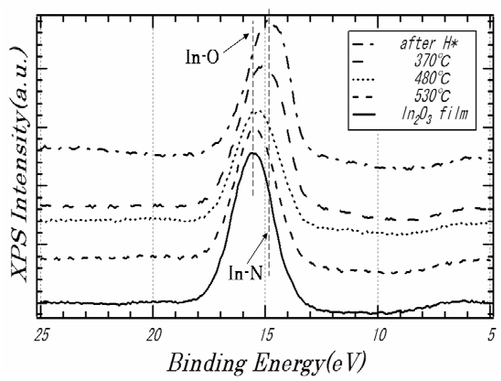

Fig. 1 In4d XPS spectra of the InN films with oxidation of 100,000 L

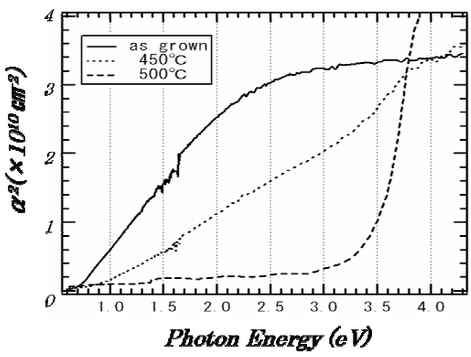

Fig. 2 Optical absorption spectra of InN before and after annealing at 450°C and 500°C