Influence of interface state and band bending on In and N polar InN from Angle-resolved XPS

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Indium nitride (InN) has a smallest bandgap and a largest mobility among III-V nitride semiconductors [1]. However, the epitaxially grown InN layer contains a surface-charge-accumulation-layer, in which the Fermi-level is pinning at an energy position sufficiently higher than the conduction band minimum, resulting in a degradation of device performance [2]. The surface-charge-accumulation-layer induces a band bending and subsequent influences on the electrical properties in the surface region [3]. In this paper, surface band bending in In and N polar InN films was observed using angle-resolved X-ray photoelectron spectroscopy (AR-XPS) to discuss the surface states.

In and N polar InN layers were grown on (0001)GaN templates and free-standing (000$\bar{1}$)GaN by RF-MBE. AR-XPS (JEOL, JPS9000) spectra were observed using a Mg K_α line (1253.6 eV) as an excitation source. The binding energies in the spectra were corrected using the C1s core level emission peak. The background intensities based on a white noise were considered. The observation was performed at RT. Before the observation, the surface oxides on the samples were removed using a HCl solution. The AR-XPS spectra near the valence band maximum at detection angles of 0 and 40 degrees are shown in Fig. 1 (a) and (b). Both figures are normalizing the spectrum. Both spectra are similar to those in a previous report [4], but slightly changed each other. Difference in between the spectra is shown in inset. The observed angle is defined as the tilt angle from the normal direction of the detector and is related to the average excitation depth in XPS. The result shows that the band bending is downward on the surface. Here, "downward" means that some holes in a bulk region move to its surface states [2]. The XPS spectra around the valence bands (VBs) of In-and N-polar InN layers are shown in Fig. 1 (c) (d). The tailing states are observed around the VBs, which will be due to the surface states occupied by electrons.

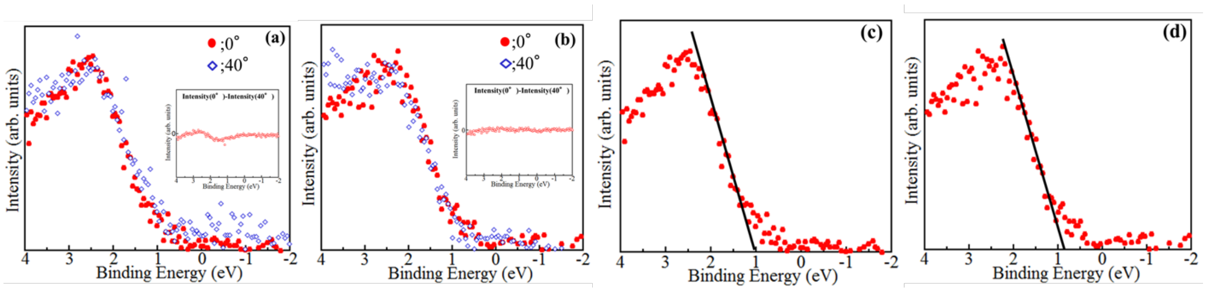

Fig. 1. (a) AR-XPS spectra of a typical In-polar InN layer and their differential spectrum (inset of figure), (b) Those of a typical N-polar InN layer and their differential spectrum, (c) XPS spectra around the valence bands of In polar InN, and (d) Those of N-polar InN.

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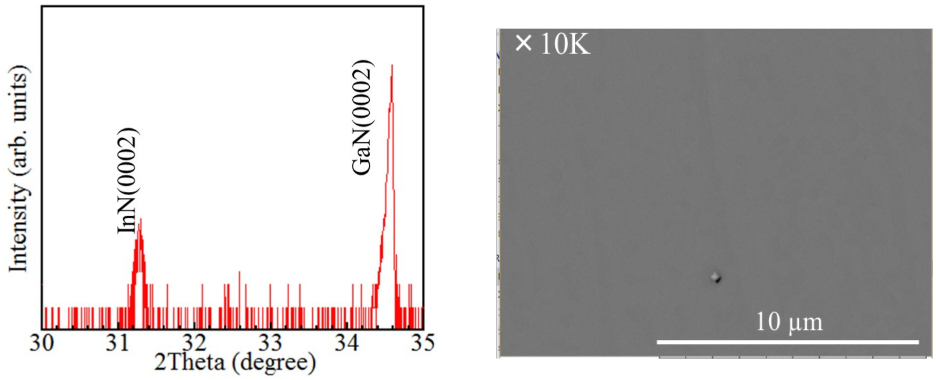

Fig. 2 The typical surface morphology and x-ray diffraction pattern in In polar InN

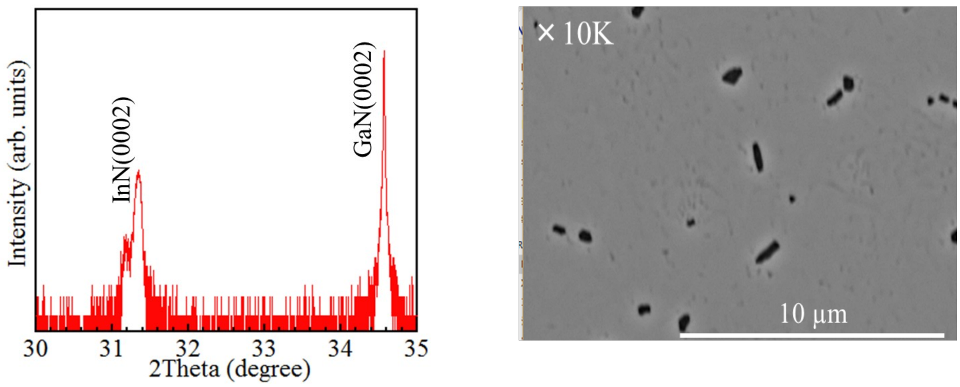

Fig. 3 The typical surface morphology and x-ray diffraction pattern in N polar InN

The InN layers were grown by RF-MBE. In the growth, DERI method was adopted [5]. The typical surface morphologies and x-ray diffraction patterns are shown in Figs. 2 and 3.

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