Spatial Distribution of Local Schottky and Ohmic Junctions at ITO/p-GaN Interfaces Studied by Scanning Photoelectron Microscopy

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GaN-based light-emitting diodes (LEDs) are widely applied to LCD backlight, full color displays, traffic displays, etc. For further improvements of the efficiency of the GaN LED, the increment of extraction efficiency of light is required. In the conventional GaN LED, a transparent electrode such as Ni / Au is used as an electrode on Mg-doped *p*-type GaN. However, the transmittance of this electrode is only 40% and the optical absorption at the electrode is a significant problem. In order to improve the extraction efficiency of the GaN LED, it is important to develop the transparent electrode on *p*-GaN with a good ohmic contact. As the transparent electrode for Mg-doped GaN, we have adopted indium tin oxide (ITO), which is widely used as a transparent electrode, and have investigated electrical properties and chemical states of ITO / Mg: GaN interfaces. For the optimum condition, I-V characteristics show the ohmic contact between ITO and Mg: GaN while the results of x-ray photoelectron spectroscopy (XPS) measurements indicate that a finite Schottky barrier still remains. The difference between the I-V characteristics and XPS results suggests the formation of local ohmic junctions due to some defects or inhomogeneities at the ITO / Mg: GaN interface. Therefore, we have investigated spatial distribution of the electronic structures and Schottky barrier height at the ITO / Mg: GaN interface using scanning photoelectron microscopy (SPEM). SPEM measurements were carried out at NSRRC BL09A1 undulator beamline. The spatial resolution and energy resolution were set to about 200 nm and 0.3 eV at the photon energy of 650 eV, respectively.

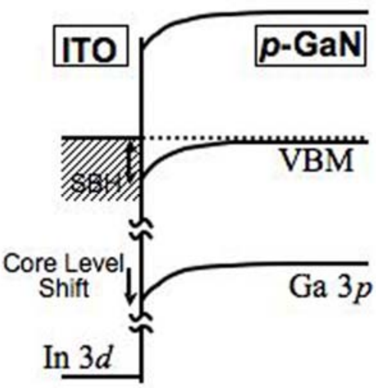

Figure 1. Band diagram at the ITO / *p*-GaN interface.

Figure 1 shows the band diagram of the ITO / *p*-GaN interface. We can determine the value of band bending and Schottky barrier height (SBH) at the ITO / GaN interface from the shift of Ga 3*p* core level spectra.

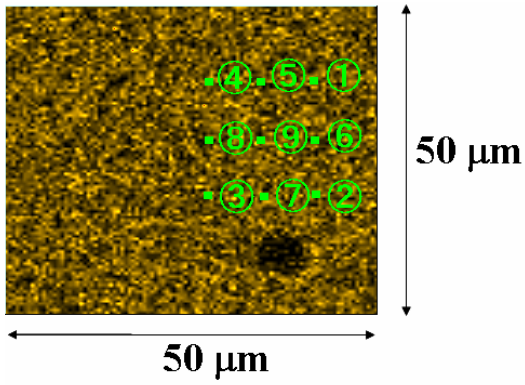

Figure 2. Ga 3*p* SPEM image of 2 nm-thick ITO thin films deposited on Mg: GaN.

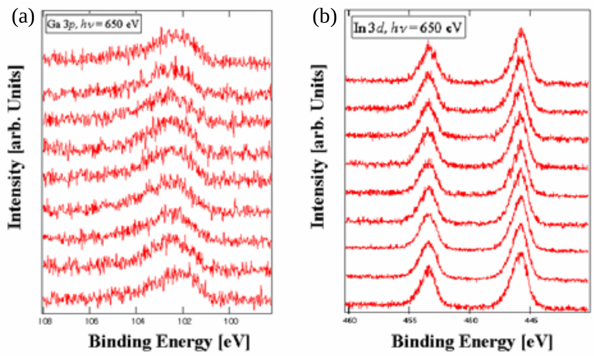

Figure 3. (a) Ga 3*p* and (b) In 3*d* spectra at several positions numbered on Fig. 2.

Figure 2 shows a Ga 3*p* SPEM image of ITO thin films on Mg: GaN. We have taken Ga 3*p* and In 3*d* spectra at several positions numbered on Fig. 2, as shown in Fig. 3. The peak energy of In 3*d* spectra does not shift at all positions within the accuracy of 100 meV, indicating that the Fermi energy of ITO does not show any modulation at all positions. On the other hand, the peak energy of Ga 3*p* are modulated in the range of ± 300 meV, suggesting the existence of local inhomogeneities of SBH. For the detailed discussion, higher spatial and energy resolution experiments are required.