Process-dependent properties of InAlN surface and ALD-Al_2O_3/InAlN interface

M. Akazawa, M. Chiba, and T. Nakano
RCIQE, Hokkaido University, Sapporo 060-8628, Japan
e-mail: akazawa@rciqe.hokudai.ac.jp

InAlN lattice matched to GaN is promising material for a barrier layer in III-nitride HEMTs[1]. However, the leakage current through the InAlN barrier is a residual problem that has not been solved. This problem can be avoided by the usage of a gate insulator[2]. Actually, using the plasma oxide layer, an InAlN/GaN MOSHEMT with a high cut-off frequency has been achieved[3]. However, the properties of the insulator/InAlN interfaces are not fully understood, especially effects of the fabrication process on the formed interface are not clarified. For the appropriate control of the insulator/InAlN interface, properties of the InAlN surface should be also investigated. We would like to present the process-dependent properties of the InAlN surface and Al_2O_3/InAlN interface formed by atomic layer deposition (ALD).

By X-ray photoelectron spectroscopy (XPS), we found that the native oxide layer on the air-exposed InAlN surface mainly consisted of hydroxide components that are not stable thermally and chemically. The existence of the surface native oxide layer implied the possibility of the uncontrolled surface oxidation during a careless device fabrication process. Actually, during high-temperature ($\geq$ 800 ^{o}C) annealing, the bare InAlN surface was oxidized by the trace contamination in a furnace even in nitrogen flow. Therefore, if the device fabrication needs the ohmic-contact annealing process at the high temperature, the InAlN surface should be protected by an insulator layer to achieve cap annealing.

To investigate the process-dependent properties of the Al_2O_3/InAlN interface, MOS diodes with ALD-Al_2O_3 layers were fabricated and tested. Here, the ALD was done at 350 ^{o}C by using TMA and H_2O. XPS for the interface between an ultrathin ALD Al_2O_3 layer and the host InAlN layer revealed that the conduction band offset should be as large as 1 eV, which indicated that the ALD-Al_2O_3 layer was suitable as a barrier for electrons. However, annealing the Al_2O_3 layer at the high temperature led to high leakage current and high interface states in the completed MOS diode. The possible reason was polycrystallization of the Al_2O_3 layer at high temperature. Therefore, ohmic-contact annealing should be carried out prior to ALD of Al_2O_3 for achieving an improved performance of the MOS diode. As the protection layer during ohmic-contact annealing, the SiN_x layer deposited by ECRCVD was found to be appropriate. Although conventional post deposition annealing at 400 ^{o}C for 1 min reduced the interface state density (D_{it}) at the Al_2O_3/InAlN interface, annealing at the high temperature (850 ^{o}C) for the initial ultrathin ALD-Al_2O_3 layer prior to the subsequent deposition of the thicker outer layer was more effective. By the appropriate formation process, D_{it} lower than 10^{12} cm^{-2}eV^{-1} was obtained in the energy range within 1 eV from the conduction band edge. We would like to stress that the Al_2O_3/InAlN interface properties are sensitive to or dependent on the fabrication process and thermal treatment.

1) J. Kuzmík: IEEE Electron. Device Lett. **22** (2001) 510.
2) G. Pozzovivo et al.: Appl. Phys. Lett. **91** (2007) 043509.
3) Y. Yue et al.: presented at IWN2012, Sapporo, Japan, Oct. 14-19, 2012.