Effect of Nitridation on Properties of AlN/β-Ga_2O_3 Composite Structures

National Institute of Information and Communications Technology[1], Tamura Corporation[2]

°Lingaparthi Ravikiran[1], Yoshiaki Nakata[1], Akito Kuramata[2], Shigenobu Yamakoshi[2], Masataka Higashiwaki[1]

E-mail: lravikiran@nict.go.jp

We expect that AlN/β-Ga_2O_3 heterostructures would produce high-density two-dimensional electron gas (2DEG) at the interface due to the spontaneous polarization in AlN. In this work, we performed heteroepitaxial growth of AlN thin films on β-Ga_2O_3 ($\bar{2}01$) substrates by plasma-assisted molecular beam epitaxy (PAMBE) and studied structural and electrical properties of the AlN/Ga_2O_3 composite structures.

Two different samples having the same AlN(5 nm)/Ga_2O_3 ($\bar{2}01$) structure were prepared by PAMBE to study effects of Ga_2O_3 surface nitridation on structural and electrical properties of AlN/Ga_2O_3 composite structures. For one sample, the Ga_2O_3 surface was nitrided at a substrate temperature of 300 °C prior to the AlN growth, and there was no nitridation process for the other one. As shown in Fig. 1, grain-type surface morphology with a root-mean-square (RMS) roughness of 1.9 nm was observed for the sample without nitridation by atomic force microscopy. On the other hand, the sample with nitridation showed smaller grains and a smoother surface with an RMS roughness of 0.8 nm, compared to the sample without nitridation.

Figure 2 shows a cross-sectional view of metal-oxide-semiconductor (MOS) capacitors fabricated using the AlN/Ga_2O_3 structures for capacitance–voltage (C–V) measurement. A 20-nm-thick Al_2O_3 layer was formed on the AlN by atomic layer deposition to suppress leakage current. The backside Ti-based cathode electrode exhibited a good ohmic contact.

The sample without the nitridation process showed an almost constant capacitance, independent of the forward and reverse biases (Fig. 3). However, the sample with nitridation revealed accumulation and saturation behaviors in capacitance with increasing voltage in the forward bias range and depletion followed by saturation in the reverse bias range. When compared these experimental results with simulated C–V curves for Al_2O_3/AlN/Ga_2O_3 MOS capacitors with and without 2DEG at the AlN/Ga_2O_3 interface (an assumed n_s=7×10^{12} cm^{-2}), it is clear that 2DEG is absent at AlN/Ga_2O_3 interface for both samples.

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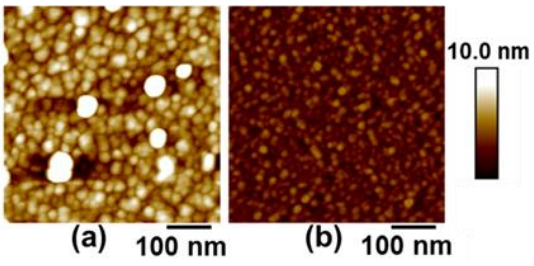

Fig. 1 AFM surface morphology of AlN/Ga_2O_3 composite structures (a) without and (b) with nitridation.

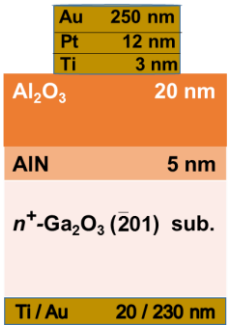

Fig. 2 Cross-sectional view of Al_2O_3/AlN/Ga_2O_3 MOS structure.

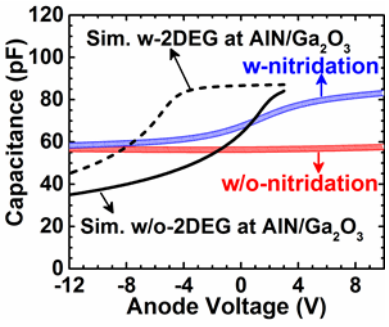

Fig. 3 Measured and simulated C–V plots for Al_2O_3/AlN/Ga_2O_3 MOS capacitors.