Electron energy loss spectroscopy study of O K-edge at SiO_2/GaN interfaces

Higashimine, K.[1], Sato, T.[2] and Suzuki, T.[1]

[1] Japan Advanced Institute of Science and Technology, Japan, [2] Advantest Laboratories Ltd., Japan

Recently, physical properties at SiO_2/GaN interfaces have been extensively investigated, since many unresolved issues still remain for the application of GaN to MOS systems as the power devices in the future. For example, there is a report that Ga is diffused from GaN into SiO_2 film [1] and a report that a crystalline Ga_2O_3 thin layer is formed on the SiO_2/GaN interface [2], after a post deposition annealing (PDA). There are, however, few reports on the results of scanning transmission electron microscope (STEM) observations of the SiO_2/GaN interfaces made by atomic layer deposition (ALD). In the present study, using electron energy loss spectroscopy (EELS) in combination with STEM observations by the high angle annular darkfield (HAADF) method, we evaluate the O K-edge of the ALD-formed SiO_2/GaN interfaces to obtain insights into the interface structures and electronic states.

The SiO_2 thin films were formed by the ALD method on the HF-cleaned n-GaN (Si: 2×10^{18} cm^{-3}) on SiC substrates, using Tris(dimethylamino)silane as a Si source and the remote O_2 plasma at a stage temperature of 500 ° C. PDA was done at 900 ° C for 2 minutes under N_2 atmosphere. Observations were performed at a high voltage of 200 kV using JEM-ARM200F equipped with GIF Quantum. EELS measurements were carried out under a condition of the energy width 0.05 eV / ch.

As a result, the HAADF images indicate that no different structural phase was observed in the ALD formed SiO_2 films, and that the very flat SiO_2/GaN interfaces were formed by the present ALD method even after PDA. Figure 1 shows an EEL spectrum around 530 eV at the SiO_2/GaN interface of a sample before PDA. Focusing on the bottom part of the O K-edge, it is found that a small pre-edge appears and that the threshold value is shifted downward by 3 eV. This shift is believed to be due to a decrease in the number of oxygen atoms close to one oxygen atom [3]. The spectrum imaging method was applied to the rectangle area near the interface shown in a HAADF image of Fig.2. We successfully visualized the existence distributions of the oxygen atoms which are different from ones in bulk-SiO_2, as drawn with blue color in Fig.3. Furthermore, it was found that the degrees of the existence distributions were different between the interfaces before and after the PDA. That may be related to the interface state and the fixed charges.

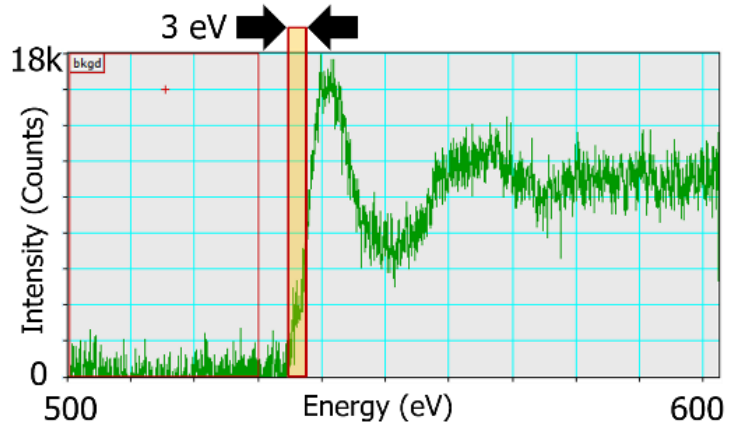

Fig.1 An EEL spectrum at the SiO_2/GaN interface before PDA. At the bottom part of O K-edge, a small pre-edge appears and the downward shift by 3 eV is clearly seen.

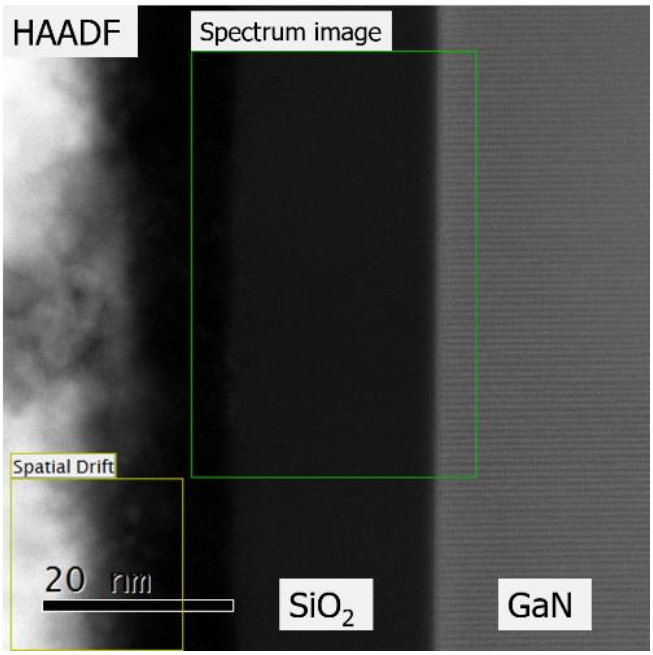

Fig.2 A cross-sectional HAADF image of the ALD-formed SiO_2/GaN before PDA. The interface at the SiO_2/GaN is very flat, and no different structural phase is observed.

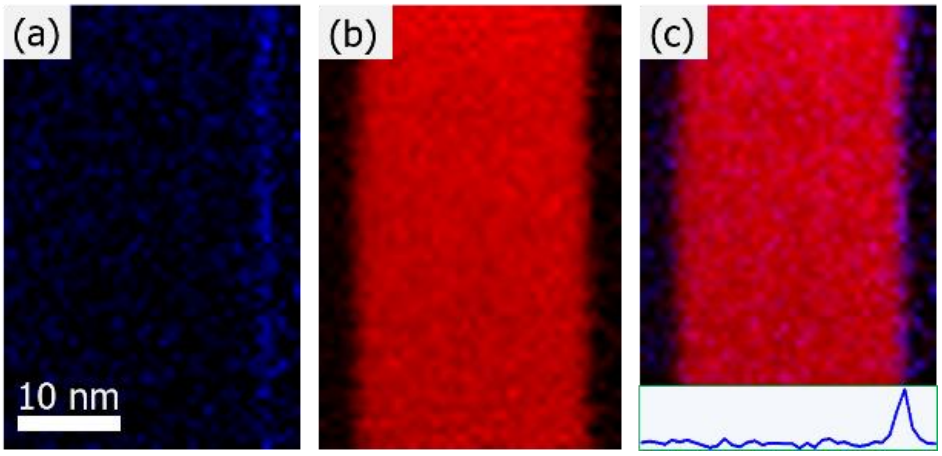

Fig.3 Spectrum images of (a) the range of the 3 eV width indicated in Fig.1, (b) the first peak of O K-edge except the range of (a), and (c) overlay of (a) and (b) with an inset of the averaged line profile of (a). Spectrum images were obtained from the rectangle area drawn with green line in Fig.2.

References

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