

Interfacial Structure of HfON/SiN/Si Gate Stacks

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Hf oxide and oxynitride are the most promising candidates for high-k gate dielectrics in next generation metal-oxide-semiconductor field effect transistor (MOSFET). Recently, we have reported that the radical nitridation of HfO₂/SiN/Si stack structure improves its thermal stability against the increase in capacitance equivalent thickness due to rapid thermal oxidation [1]. In this study, we investigated the chemical bonding structure of HfO₂/SiN and HfON/SiN stacked layers using hard x-ray photoelectron spectroscopy (HX-PES).

A SiN layer thinner than 1 nm was formed by radical nitridation of Si(001) wafers at 500°C and a 4~5 nm thick HfO₂ layer was deposited at 500°C by electron beam evaporation. Some samples were additionally subjected to radical nitridation at a N₂ partial pressure of 5×10⁻⁵ Torr at 500°C. Angle-resolved HX-PES measurements were carried out at the undulator beam line, BL47XU, of SPring-8.

Figures 1(a) and 1(b) show Si 1s spectra normalized by the Hf 4f intensity taken at various take-off angles (TOA) for HfO₂/SiN/Si before and after radical nitridation, respectively. In the HfO₂/SiN/Si sample, the binding energy difference of Si 1s bonding states between the interlayer and the Si substrate increases from 2.72 eV to 3.30 eV with decrease in TOA, which indicates that the existence of the Si-O bonding state near the HfO₂/SiN interface just after the HfO₂ deposition and that the chemical composition of N and O gradually changes in the interlayer. On the other hand, in the HfON/SiN/Si sample after radical nitridation, the binding energy of the interlayer is independent of TOA and it increases compared to that at TOA of 80° in the sample before the radical nitridation. These results suggest the occurrence of SiN interlayer oxidation by surplus O atoms from the HfO₂ layer during the radical nitridation, which leads to homogeneous distribution of Si-O and Si-N bonding states in the interlayer.

Reference: [1] R. Takahashi *et al.*, Jpn. J. Appl. Phys. **43**, 7821 (2004).

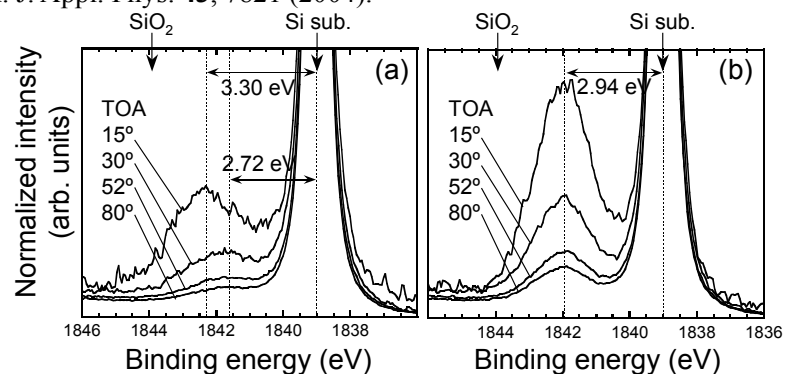


Fig. 1 Si 1s spectra taken at various TOA for HfO₂/SiN/Si (a) before and (b) after radical nitridation.