Effect of Conduction Band Offset on Breakdown Voltage at SiO_2/4H-SiC (000-1) studied by Hard X-ray Photoelectron Spectroscopy

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SiC has attracted a great interest in the application of high power devices due to its wide band gap and the easiness of oxide layer formation, that is SiO_2, by thermal oxidation procedure.[1,2] However, the high-density interface states and small conduction band offset of SiO_2/SiC-based electronic devices still hamper the device performances.[3,4] In this study, we investigated the effect of conduction band offset (ΔE_c) on the breakdown voltage upon SiO_2/4H-SiC (000-1) using hard x-ray photoelectron spectroscopy (HAXPES).

We used 4H-SiC (000-1) substrate cleaned by standard RCA method to employ following thermal oxidation methods:1) wet oxidation, 2) wet oxidation followed by oxygen annealing, and 3) dry oxidation. Each oxidation was followed by Ar annealing. The oxide layers were etched with a diluted HF to obtain thicknesses of around 8 nm. HAXPES measurements were carried out at BL15XU beamline at SPring-8 with incident photon energy was 5.9 keV and energy resolution was set to be 240 meV.

The valence band offset (ΔE_v) was experimentally determined from the difference between VBM_{SiO2} and VBM_{SiC}. ΔE_c is determined from this relationship: $\Delta E_c = E_g^{SiO_2} - E_g^{SiC} - \Delta E_v$. $E_g^{SiO_2}$ were experimentally estimated from O 1s energy loss spectra while E_g^{SiC} was set to be 3.26 eV.[4] The breakdown voltage increases with the larger ΔE_c. SiO_2/4H-SiC (000-1) prepared by dry oxidation procedure exhibits highest ΔE_c, while wet oxidation procedure exhibits the lowest ΔE_c. Oxygen annealing performed after wet oxidation was effective for an increase of ΔE_c, which yields higher breakdown voltage.

Keywords: breakdown voltage, conduction band offset, SiO_2/4H-SiC (000-1), thermal oxidation

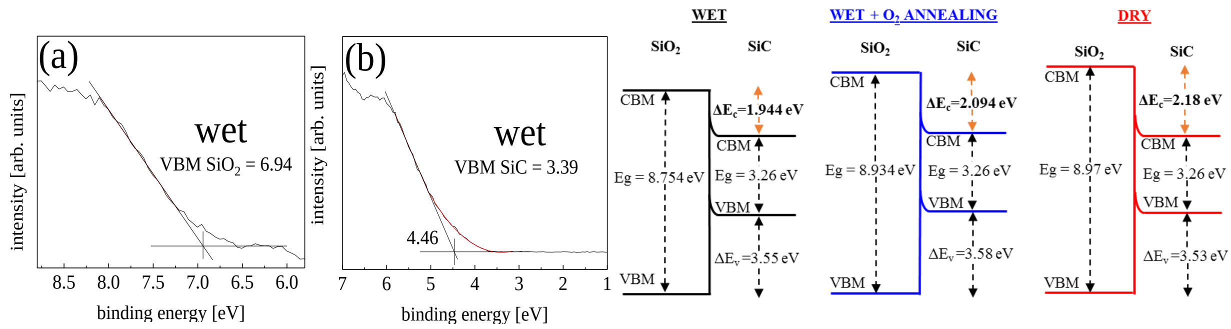

Fig. 1 (a) VBM_{SiO2} (b) valence band leading edge of SiC and VBM_{SiC} of SiO_2/4H-SiC (000-1) structure prepared by wet oxidation. Black lines depict the linear fitting to estimate both VBM_{SiO2} and valence band leading edge of SiC while red curve depicts combination of parabolic and exponential fitting of $a(x-b)^2(\exp(c(x-b)/9.7)$ to estimate VBM_{SiC}, where b and 9.7[5] represents the value of VBM_{SiC} (in eV) and electron mean free path (in nm) of SiC respectively. (c) Band offset of three different oxidation procedures. The energy origin is VBM_{SiO2} of SiO_2/4H-SiC (000-1).

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