Thermal-oxidation-induced Lattice Distortion at 4H-SiC (0001) Surface and Its Recovery by Ar Annealing

Recent studies have revealed that thermal oxidation of SiC wafer can induce macroscopic lattice distortion due to the formation of SiOx/4H-SiC interface [1]. This distortion is believed to result from changes in the electrical structure of 4H-SiC interface. In this work, we examined the lattice distortion at the surface of 4H-SiC (0001) and its recovery by post-oxidation Ar annealing, characterized by in-plane X-ray diffractometry (XRD).

[Experimental] N-type (4° off-axis) 4H-SiC (0001) Si-face wafers covered with 5 μm epitaxial layers were used as substrates. Dry oxidation processes were performed at 1300 °C for various time. Post-oxidation Ar annealing processes were then performed at 1150 and 1300 °C for various time after oxide removal in diluted HF. NO annealing (in 33% NO diluted by N2) was also performed at 1150 °C for 2 hr. The samples were characterized by in-plane XRD to determine the interspacing of lattice planes perpendicular to the wafer surfaces.

[Results and discussion] SiO2 layers with thicknesses of 12, 29, and 44 nm were thermally grown by performing dry oxidation for different time. Fig. 1(a) shows the relationships between d_{(1\bar{1}0\bar{0})} interplanar spacing and X-ray penetration depth for the oxidized 4H-SiC with different SiO2 thickness. d_{(1\bar{1}0\bar{0})} of the sample was higher in shallow area, and lower in deeper area. Furthermore, a larger d_{(1\bar{1}0\bar{0})} value was observed from the samples with thicker oxide layers, which indicated that a longer oxidation time induced larger lattice distortion [4], due to the larger amounts of generated defects. Next, post-oxidation Ar annealing was performed to clarify the possibility of lattice distortion recovery. Fig. 1(b) shows the effects of Ar annealing time on the lattice distortion recovery. It indicates that Ar annealing could partially reduce the lattice distortion, while the longer annealing time resulted in the larger recovery. We speculated this Ar annealing process should cause the migration and removal of accumulated defects that cause the lattice distortion at the surface of 4H-SiC.

Furthermore, we examined the lattice distortion at the surface of NO-annealed sample and found that the impact of NO annealing on the lattice distortion recovery was almost the same as Ar annealing, as shown in Fig. 2. In conclusion, the thermal-oxidation-induced lattice distortion at surface of 4H-SiC (0001) was clearly observed by in-plane XRD measurements. It could be partially recovered by post-oxidation Ar annealing, while the recovery was larger for longer annealing time. Our results revealed that oxidation and annealing processes should have a significant impact on the quality of the 4H-SiC surface.

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Fig. 1. (a) Penetration depth dependence of d_{(1\bar{1}0\bar{0})} of SiO2/4H-SiC with different SiO2 thicknesses, and (b) the effect of Ar annealing time on the lattice distortion recovery.

Fig. 2 Comparison between the impact of Ar and NO annealing on the lattice distortion recovery.