4H-SiC 表面構造に対するイオン注入と熱酸化の影響の類似性と機構の違い

Similarity and Difference of the Impact of Ion Implantation and Thermal Oxidation on the Lattice Structure of 4H-SiC Surfaces

Dept. of Materials Engineering, The Univ. of Tokyo, °Adhi Dwi Hatmanto and Koji Kita

E-mail: hatmanto@scio.t.u-tokyo.ac.jp

[Introduction] Recently, we reported thermal-oxidation-induced lattice distortion locally at the surface region of 4H-SiC caused by the formation of SiO_2/4H-SiC interface [1], however, the origin of such anomalous distortion has not been clarified yet. In this report, we investigated the impact of O and Ar implantation on the lattice structure of 4H-SiC (0001) surfaces to compare with that of thermal oxidation, directly from the changes of the interspacing of lattice planes perpendicular to the wafer surfaces by in-plane X-ray diffractometry (XRD) analysis. Since the damaged 4H-SiC structure due to O and Ar implantation have also been reported [2, 3], we may expect a similar effect on the lattice structure on the surface region as that of thermal oxidation if we assume the interstitial atom is the origin of such anomalous distortion of the lattice.

[Experimental] 4° off-axis 4H-SiC (0001) wafers with 5 μm-thick n-type doped (~1×10^{16} cm^{-3}) epitaxial layers were used as substrates in this work. For the sample with thermal oxidation, the dry oxidation in 1 atm oxygen (O_2) gas at 1300 °C for 18 min was performed, followed by annealing in O_2 at 800 °C for 30 min. For the samples with ion implantations, O and Ar ion implantation were performed at the dose of 10^{15} atoms/cm^2 at 15 and 35 keV, respectively. Around 10 nm-thick SiO_2 was deposited on 4H-SiC samples before implantation. For the implanted samples, Ar annealing at 1300 ºC for 10 min was performed after oxide removal. All samples were then characterized by using in-plane XRD. The shallow incident angles from 0.23 to 1.25 degree were employed to limit the X-ray penetration depth from around 5 nm to 1.5 μm.

[Results and discussions] Lattice distortion at the surface region of 4H-SiC was observed as the increase of $(1\bar{1}00)$ interplanar spacing, $d_{(1\bar{1}00)}$ [1]. Penetration depth dependence of $d_{(1\bar{1}00)}$ of O-implanted 4H-SiC at the dose of 10^{14} atoms/cm^2 and 10^{15} atoms/cm^2 and thermally-oxidized 4H-SiC sample with around 29-nm thick SiO_2 were shown in **Fig. 1(a)**. For the O-implantation samples, the higher dose induces more significant lattice distortion. Furthermore, the distortion is almost as large as the one induced by thermal oxidation. The significant lattice distortion induced by O implantation could be caused by two possible factors, O-effect itself or high dose implantation effect. Penetration depth dependence of $d_{(1\bar{1}00)}$ of Ar-implanted 4H-SiC was shown in **Fig. 1(b)**, while the comparison between the impact of O and Ar implantation and thermal oxidation was summarized in **Fig. 2**. Both O and Ar implantation induces significant lattice distortion, almost as large as induced by thermal oxidation. High dose implantation, irrespective of ion species, causes lattice expansion in implanted layers due to the formation of excess interstitials and vacancies, while heavier ions tend to cause larger effects [4]. Higher amount of interstitials and vacancies is expected to be induced by Ar than O implantation, however, **Fig. 2** shows that the impact of O is much more significant. Besides the interstitials and vacancies, O possibly causes additional distortion by forms a chemical bond with Si and C atoms to induces a bond rearrangement, which might be a more dominant factor. Our results revealed that both ion implantation and thermal oxidation induces significant lattice distortion at 4H-SiC surface, while the existence of oxygen inside 4H-SiC might be a dominant factor to induce the lattice distortion.

Acknowledgments. This work was partly supported by CSTI, Cross-ministerial Strategic Innovation Promotion Program, "Next-generation power electronics" (funding agency: NEDO), and by JSPS KAKENHI.

References. [1] A. D. Hatmanto and K. Kita, APEX **11**, 011201 (2018). [2] M. Liu et al., J. Mater. Sci. **54**,1147 (2014). [3] C. Jiang et al., Nucl. Instr. Meth. B **374**, 71 (2016). [4] S. Sasaki et al., J. Appl. Phys. **111**, 103715 (2012).

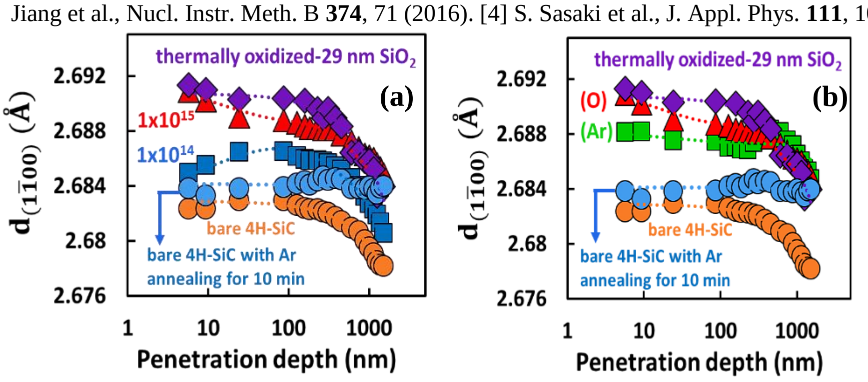

Fig. 1. Penetration depth dependence of $d_{(1\bar{1}00)}$ of thermally-oxidized 4H-SiC and **(a)** O-implanted 4H-SiC at different dose and **(b)** Ar-implanted 4H-SiC at the dose of 10^{15} atoms/cm^2.

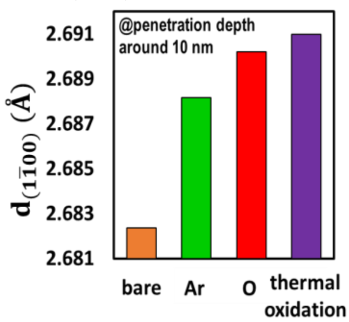

Fig. 2 Comparison between the impact of O and Ar implantation and thermal oxidation on the lattice structure of 4H-SiC surface.