THERMAL OXIDATION KINETICS OF GERMANIUM

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We have studied Ge gate stacks for many years, and demonstrated very interesting properties in Ge [1]. Recently we have published a review paper on Ge from viewpoints of device and process for CMOS applications. Through this study, we have noticed that GeO_2/Ge is so different from SiO_2/Si. It means that the oxidation kinetics of Ge should be studied carefully and understood correctly, though that of Si is almost understood.

We carried out the oxygen isotope (^{18}O) tracing experiments in Ge oxidation process. Figure 1 shows a comparison between Si oxidation and Ge one, inspected by the SIMS. First, we prepared SiO_2/Si and GeO_2/Ge oxidized in $^{16}O_2$, then both were reoxidized in $^{18}O_2$. SIMS results clearly exhibit a significant difference of ^{18}O profile in the oxides. The result in SiO_2/Si system is as expected by the Deal-Grove type kinetics, while that in GeO_2/Ge shows rather flat profile of ^{18}O in GeO_2 and not ^{18}O accumulation at GeO_2/Ge interface. The results demonstrate a significant difference of oxidation kinetics between Si and Ge.

Results suggest that Ge oxidation should be described by kinetics completely different from the Deal-Grove model. Thus, we propose for the first time a new kinetic model of thermal oxidation of Ge, considering both O-vacancy and atomic O diffusion as a function of O_2 pressure. The model can reasonably explain anomalous O_2 pressure dependence in Ge oxidation as well. Furthermore, experimental results in the oxidation of SiO_2/GeO_2/Ge, GeO_2/SiO_2/Si and GeO_2/SiO_2/Ge stacks are also. They also strongly support the new kinetic model of Ge oxidation. This is critically important for achieving high quality Ge gate stacks, as the Deal-Grove model have played a significant role in Si technology.

[1] A. Toriumi. presented at ULSIC-TFT (Lake Tahoe, 2015), and (Vienna, 2017).
[2] A. Toriumi and T. Nishimura, Jpn. J. Appl. Phys. Vol.57(1), 010101 (2018).

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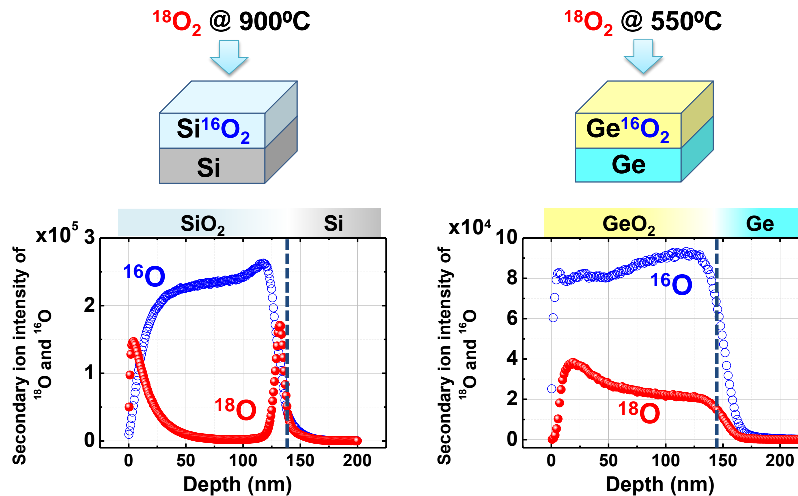

Figure 1 ^{18}O isotope tracing experiment in Si and Ge with SIMS. In Si, it is clearly reproduced that ^{18}O atoms are accumulated at the interface and that only a slight amount of ^{18}O exists in the film. While in Ge, ^{18}O has a rather flat profile inside GeO_2 film.