Key Words: germanium, thermal oxidation, gate stack.

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.


This work was partly supported by JSPS-Kakenhi-Kiban(A).

![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.](image-url)