ゲルマニウムの熱酸化機構のモデル化

Kinetic Model for Thermal Oxidation of Germanium

東大院工　王 旭、 西村 知紀、 矢嶋 赳彬、 鳥海 明

Univ. of Tokyo, Xu Wang, Tomonori Nishimura, Takeaki Yajima, and Akira Toriumi

E-mail: xuwang@adam.t.u-tokyo.ac.jp

1. Introduction

The oxidation is one of the most important processes in semiconductor device fabrication. Silicon (Si) has been described by the Deal-Grove model [1]. Germanium (Ge) has similar characteristics as Si in various aspects [2]. However, oxidation kinetics of Ge has been proved quite different from that of Si experimentally [3]. Therefore, a kinetic model is needed to better understand the mechanism of Ge oxidation.

In this work, we propose a possible kinetic model for Ge oxidation by considering two oxidant diffusion processes and two reactions.

2. Experiment

Both SiO_2/Ge and GeO_2/SiO_2/Ge stacks as shown in **Fig. 1(a)** were prepared. All oxide layers were deposited by radio-frequency (rf) sputtering followed by post-deposition annealing (PDA) in N_2 at 550ºC. Then these stacks were thermally treated in 1-atm O_2 ambient at 550ºC, and GeO_2 layer generated at Ge/SiO_2 interface was estimated after removing the top GeO_2 layer by the grazing incidence X-ray reflectivity (GIXR) measurement.

3. Results and discussions

Fig. 1 (b) shows the thickness change of the GeO_2 layer generated at SiO_2/Ge interface with different GeO_2 top layer thicknesses. The SiO_2/Ge stack (50 nm SiO_2) yields the highest interfacial GeO_2 growing rate, implying a fast O_2 diffusion through the SiO_2 cap layer, while the interfacial GeO_2 growing rate on Ge is sharply reduced with the increase of top-GeO_2 cap layer thickness. It suggests that O_2 diffusion in the top-GeO_2 layer is significantly suppressed comparing with that in SiO_2.

It was already reported that oxygen vacancy (V_O) was formed through the GeO_2/Ge interfacial reaction [4]. This fact can be regarded as the oxidation of Ge by GeO_2. In **Fig. 2**, we propose a possible kinetic model for the Ge oxidation by considering two oxidant diffusion processes: One is the O_2 diffusion from oxide surface, and the other is V_O diffusion from the interface on Ge substrate. A hypothetical boundary at which O_2 molecule may react with V_O (O_2 molecule decomposes into O) is located at ξ in **Fig. 2**. An analytical model for the Ge oxidation rate will be shown in this work. For limiting cases (thin and thick oxide cases), Ge oxidation follows approximately the linear-parabolic law, but the reaction kinetics is quite different from the Deal-Grove model for Si.

4. Conclusions

We have proposed a new kinetic model for thermal oxidation of Ge, based on two kinds of oxidant diffusions and two reactions. It is totally different from the Deal-Grove model. It can help to deeply understand the thermal oxidation kinetics of Ge, as well as achieving well-controlled gate stacks on Ge.

This work was supported by JSPS Grant-in-Aid for Scientific Research (A).

Reference

[1] B. E. Deal and A. S. Grove, J. Appl. Phys., 36, 3770 (1965). [2] B. Fischer, etc., Phys. Rev. B15, 3193 (1977). [3] X. Wang, etc., Appl. Phys. Lett., 111, 052101 (2017). [4] S. K. Wang, etc., J. Appl. Phys., 108, 054104 (2010).

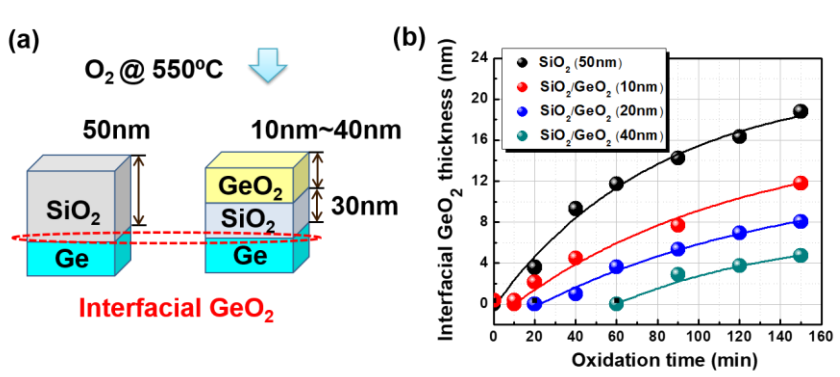

Fig. 1 (a) Schematic of SiO_2/Ge and GeO_2/SiO_2/Ge stacks structure. **(b)** Thickness change of the interfacial GeO_2 at Ge/SiO_2 interface in these stacks.

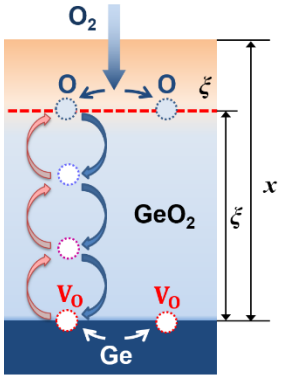

Fig. 2 schematic illustration of Ge oxidation model.