**YドープGeO₂界面層のY濃度に依存した界面酸化膜形成**

**Influence of Yttrium concentration on the oxidation barrier effect of Y-doped GeO₂ interfacial layer**

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[Introduction] The formation of high-quality Ge/GeO₂ interface is expected to be one of the best solutions for realizing high-performance Ge CMOS [1-3]. Many attempts have been made to control the growth rate of GeO₂ to achieve EOT scaling in the gate stacks [4, 5]. In this work, we examine the oxidation of Ge/Y₂O₃ stack for the purpose of controlling GeO₂ interfacial layer (IL) growth. The influence of yttrium incorporation on the GeO₂ IL growth is discussed.

[Experiment] Various thickness of Y₂O₃ (1.5 to 5 nm) was deposited on HF-last pGe substrate by rf-sputtering. Thermal oxidation of Ge/Y₂O₃ stacks was carried out at different temperatures (500 and 550 °C) and in different PO₂ (1 and 70 atm), as schematically shown in Fig. 1. The thicknesses and chemical states of GeO₂ IL were estimated by Ge 3d core level spectroscopy and XPS measurements. To characterize the electrical properties, Au and Al were deposited by vacuum evaporation for the gate electrode and substrate contact of the MOSCAPs, respectively.

[Results and discussion] Fig. 2(a) shows GeO₂ IL thickness as a function of oxidation time. The GeO₂ IL growth is relatively fast at the initial stage (noted as region A) and becomes much slower as oxidation time increases, indicating that self-limited GeO₂ IL is grown (noted as region B). Interestingly, the thickness of GeO₂ IL is dominated by oxidation temperature, while no major influence on GeO₂ IL thickness is observed from different Y₂O₃ thicknesses (1.5 to 5 nm) and PO₂ (1 and 70 atm). These results suggest that there is a different GeO₂ growth mechanism at Ge/Y₂O₃ stack from thermal oxidation [4]. In order to understand the oxidation mechanism in Ge/Y₂O₃ stack, we investigated the chemical states of GeO₂ IL formed at Ge/Y₂O₃ stack as a function of oxidation time, as shown in Fig. 2(b). The oxidation was carried out at 500°C in 1 and 70 atm PO₂, respectively. Lower chemical shift than pure GeO₂ was observed for the IL of both stacks, indicating the doping of Y into the GeO₂ IL. At the initial stage of the oxidation, larger percentage of Y is observed in the GeO₂ IL according to the relatively lower chemical shift. With longer oxidation time, the chemical shift becomes higher, indicating the decrease of the Y concentration in the IL by the further growth of GeO₂. The change of Y concentration greatly influences the growth rate of GeO₂ IL during oxidation. With higher Y concentration, the GeO₂ IL grows fast (corresponding to region A in Fig. 2(a)). On the other hand, relatively lower Y concentration in GeO₂ forms a strong oxidation barrier (data not shown), which limits the further growth of IL (corresponding to region B in Fig. 2(a)). This strong oxidation barrier effect might be attributed to a stable configuration of GeO₂ IL with a low oxygen potential achieved by the small percentage of Y doping.

[Conclusion] A strong oxidation barrier effect is found by doping a low concentration of Y into GeO₂, which limits the growth of the IL at Ge/Y₂O₃ stack during oxidation.


![Fig. 1](image1.png) Schematic of oxidation applied to Ge/Y₂O₃ stack. There is ultrathin GeO₂ IL formation during oxidation.

![Fig. 2](image2.png) (a) The IL thickness estimated by XPS as a function of oxidation time. Note that the Y₂O₃ thickness is varying from 1.5 to 5 nm, while its influence on the IL thickness is negligible (included in the error bar). (b) Chemical shifts of IL in Ge 3d spectra as a function of oxidation time.