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Thermally Oxidized Yttrium and Scandium Gate Dielectrics on Germanium with High Interfacial and Film Qualities

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Abstract

We fabricated Ge MOS capacitors by metal Y or Sc deposition and its thermal oxidation. The MOS capacitors with enough oxidation time show excellent electrical characteristics which suggest thermally oxidized Y and Sc on Ge has a potential for gate dielectric and passivation layer.

1. Introduction

Ge has been received much interest due to its attractive material characteristics such as high carrier mobilities[1,2], long spin diffusion length[3], narrow bandgap corresponding near infrared (NIR) wavelength[4], and low crystallization temperature[5]. Therefore, many application ways have been suggested such as CMOS channel, spin MOSFET channel, NIR optical devices, TFT channel on glass or plastic substrate. One of the necessity technologies for all Ge application is fabrication of a dielectric layer on Ge with high interfacial and film qualities for a gate stack and a passivation layer.

It has been reported the sputter deposited rare-earth (group 3) metal oxide (yttrium oxide (Y_2O_3)) on Ge shows superior electrical properties of small frequency dispersion and hysteresis in capacitance-voltage (*C-V*) characteristics[6]. It is also reported Y or scandium (Sc) contained Ge oxide formed by sputtering also shows excellent electrical characteristics on Ge[7]. These structure also shows good thermal and chemical stability. However, the electrical properties of Y and Sc oxide gate dielectrics strongly depends on their formation method[8].

As one of the fabrication methods of a gate dielectric, metal deposition on Si and its thermal oxidation was considered in 1980s [9, 10]. Although this method has not been applied in an actual device fabrication for a high-*k* gate dielectric on Si, similar approach for Ge has not been studied so much[11]. In this study, for a gate and a passivation dielectric on Ge with high interfacial and film qualities, we fabricated and characterize Ge MOS capacitors by using rare-earth metal deposition and its thermal oxidation.

2. Experimental

In this study, we used moderately doped (100) oriented p- and n-Ge substrate. After dilute HF cleaning, 5 nm-Y or -Sc film was deposited by magnetron sputtering. We used 3N pure metal sputtering targets. The samples were immediately transferred to a conventional quartz furnace and thermally oxidized by dry oxygen at 500 °C for 15 or 60 minutes. As a gate electrode, Au was deposited by using thermal evaporation through a metal mask. As electrical characterization, *C-V* and leakage characteristics were measured. The process is illustrated in Fig. 1.

3. Result and Discussion

Figure 2 shows multi frequency *C-V* characteristics of the Y-oxidized Ge MOS capacitors with different oxidation times of (a) 15 minutes and (b) 60 minutes. Bias sweep direction is from inversion to accumulation. The sample with 15 minutes oxidation shows large frequency dispersion for both n- and p-MOS capacitors. On the other hand, the samples with 60 minutes oxidation suppress frequency dispersion. In addition, longer oxidation time leads thicker capacitance equivalent thickness (CET). Figure 3 shows leakage current characteristics for the Y-oxidized MOS capacitors with different oxidation time. The samples with 60 minutes oxidation show lower leakage current density at low gate voltage and higher breakdown voltage. According to these results, it is supposed Y oxidation is not completed in 15 minutes oxidation. Similar tendencies were observed for the Sc-oxidized samples, as shown in Figs. 4 and 5.

Figures 6(a) and (b) show high frequency (1 MHz) *C-V* characteristics for the Y-oxidized and Sc-oxidized MOS capacitors with 60 minutes oxidation, respectively. In table I, CET, flatband voltage (V_{FB}), and hysteresis (*HT*) are summarized. All samples show small hysteresis for Ge MOS capacitor. Particularly, the Sc-oxidized p-MOS shows very small hysteresis of ~ 10 mV. Hysteresis direction of the p-MOSs is counter clockwise and the n-MOSs is clockwise. This means the dominant origin of hysteresis is injection type trap in the gate dielectric and the amount of the trap is very low considering Ge MOS capacitor. Detail characterization results about interface trap density will be present in the conference.

3. Conclusions

We fabricated and characterized the Ge MOS capacitors which has thermally oxidized Y or Sc dielectrics. For better electrical characteristics, longer oxidation is necessary and it is supposed that short oxidation time cannot oxidize metal Y or Sc completely. The samples oxidized 60 minutes at 500 °C show superior electrical characteristics such as small frequency dispersion and hysteresis for Ge MOS capacitor. These results show the thermally oxidized Y and Sc on Ge has superior interfacial and film qualities.

Acknowledgements

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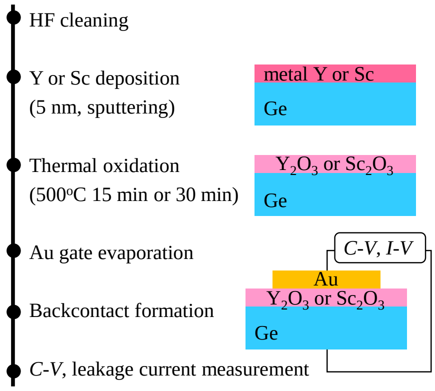

Fig. 1 Fabrication procedure for Ge MOS capacitors in this study.

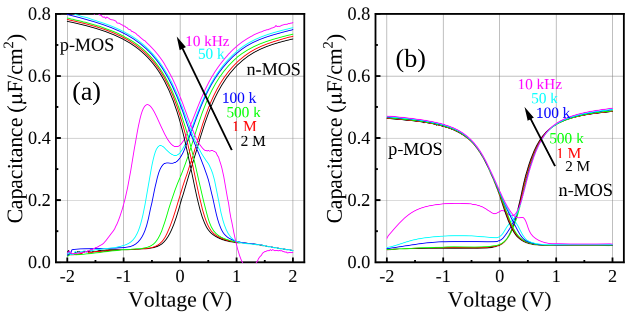

Fig. 2 *C-V* frequency dependence of the Au/**Y_2O_3**/Ge MOS capacitors. (a) 15 min oxidation and (b) 60 min oxidation.

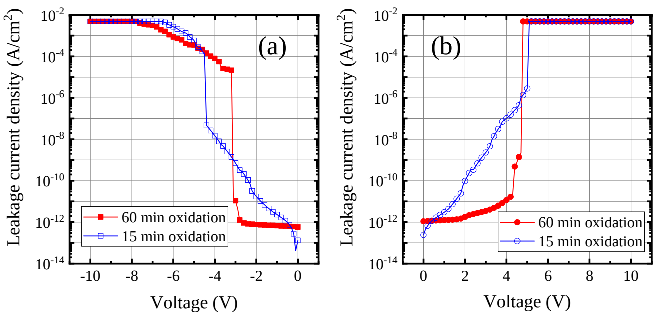

Fig. 3 Leakage current characteristics of the Au/**Y_2O_3**/Ge MOS capacitors. (a) p-type and (b) n-type.

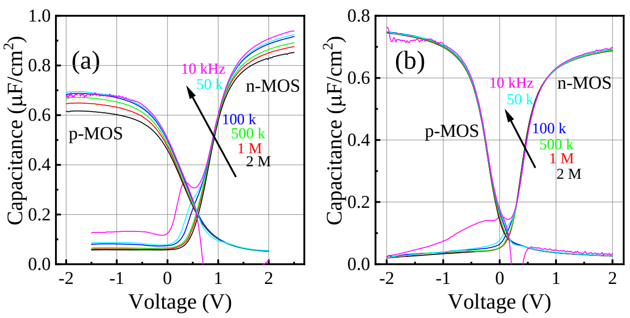

Fig. 4 *C-V* frequency dependence of the Au/**Sc_2O_3**/Ge MOS capacitors. (a) 15 min oxidation and (b) 60 min oxidation.

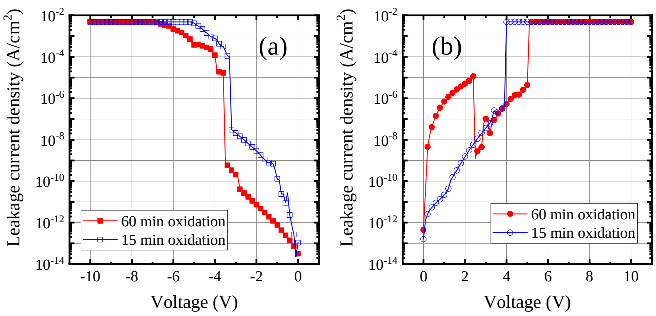

Fig. 5 Leakage current characteristics of the Au/**Sc_2O_3**/Ge MOS capacitors. (a) p-type and (b) n-type.

Table I Summary of CET, V_{FB} and *HT* for the MOS capacitors in this study.

			Oxidation time	
			15 min	60 min
n-type	Y	CET (nm)	4.6	7.2
		V_{FB} (V)	+0.36	+0.39
		HT (mV)	---	200
	Sc	CET (nm)	4.1	4.81
		V_{FB} (V)	+0.35	+0.38
		HT (mV)	---	121
p-type	Y	CET (nm)	4.5	7.2
		V_{FB} (V)	0	-0.12
		HT (mV)	---	39
	Sc	CET (nm)	4.7	4.9
		V_{FB} (V)	+0.48	-0.13
		HT (mV)	---	9.9

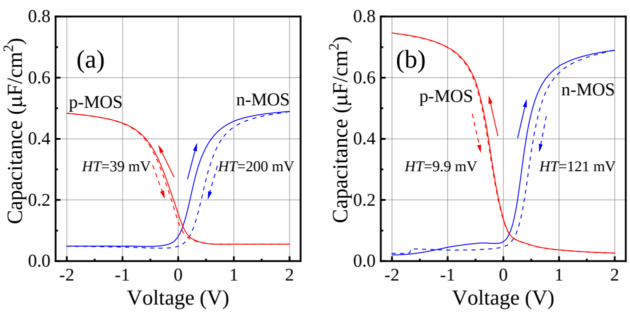

Fig. 6 Bi-directional high frequency (1 MHz) *C-V* characteristics of the (a) Au/**Y_2O_3**/Ge and (b) Au/**Sc_2O_3**/Ge MOS capacitors with 60 min oxidation.