Anomalous temperature dependence of dipole layer strength at the Al_2O_3/SiO_2 interface

°Siri Nittayakasetwat, Hironobu Kamata, and Koji Kita,

Department of Materials Engineering, The University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo113-8656, Japan
E-mail: siri.n@scio.t.u-tokyo.ac.jp

Several models have been developed to explain the physical origin of the dipole layer formation at high-k/SiO_2 interfaces. One of the possible models considers the relative difference in oxygen density at high-k/SiO_2 interface as the driving force of the dipole layer formation [1]. However, none of those models reported on the effect of temperature on the interface dipole layer strength. For a wider range of application, it is crucial to comprehend its behavior with the change in temperature. In this study, we investigated the temperature dependence of dipole layer strength in $Al_2O_3/SiO_2/Si$ MOS stacks from 100K to 400K.

The capacitors were fabricated on a p-type Si wafer with a thermally grown ~10 nm SiO_2 top layer. After the RCA cleaning, a wedge-shaped Al_2O_3 was deposited using rf sputtering. The post-deposition annealing was performed at 800°C in 0.1% O_2 ambient for 5 min. Finally, Au metal was deposited by vapor evaporation. The flatband voltages (V_{fb}) were extracted from C-V curves at various temperatures with the frequency of 1MHz.

A series of V_{fb} was obtained from various Al_2O_3 thicknesses and extrapolated to the point where the Al_2O_3 thickness became zero, to determine the dipole layer strength of Al_2O_3/SiO_2 by removing the influence of fixed charges in the stacks. The series of V_{fb} as a function of capacitance equivalent thickness (CET) at different temperatures is shown in Fig. 1. The magnitude of the slope ($dV_{fb}/dCET$) corresponds to the density of fixed charges in the stack. Figure 2 shows the correlation between the dipole strength and temperature. From 100K to 300K, the dipole strength changed approximately at the rate of 2-3 mV/K, though the rate reduced at higher temperatures. This rate is surprisingly larger than what we expected from a simple consideration of volume expansion. The dipole strength can be increased by lengthening the distance between two opposite charges; however, the thermal expansion coefficient for Al_2O_3 and SiO_2 only ranges in the order of 10^{-6} K^{-1} [2], and 10^{-7} K^{-1} [3], respectively. Thus, it is clear that other anomalous factors contributed to the unexpectedly large change of dipole strength at Al_2O_3/SiO_2 interfaces with temperature. *Acknowledgement*: *This work was partly supported by JSPS KAKENHI*

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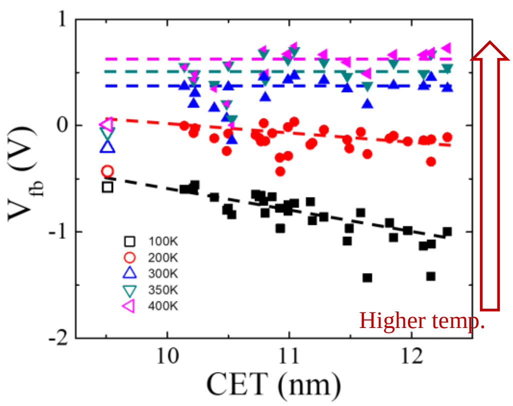

Fig. 1. V_{fb} vs CET at different temperature for $Al_2O_3/SiO_2/Si$ stack. The open and solid symbols represent V_{fb} of SiO_2/Si and $Al_2O_3/SiO_2/Si$ stacks, respectively.

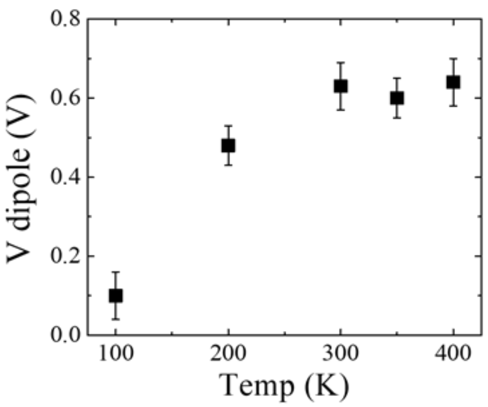

Fig. 2. Temperature dependence of the interface dipole layer strength of the Al_2O_3/SiO_2 interface.