Evaluation of border-traps in GeO_2/Ge gate stacks grown by thermal oxidation and plasma oxidation

Wei-Chen Wen[1], Taisei Sakaguchi[1], Keisuke Yamamoto[1], Dong Wang[1] and Hiroshi Nakashima[2]

[1] Interdisciplinary Graduate School of Engineering Sciences, Kyushu Univ.

[2] Global Innovation Center, Kyushu Univ.

E-mail: 3ES17010E@s.kyushu-u.ac.jp

Introduction

Ge is of great interest in ULSI technology due to its high carrier mobilities. Some research groups have studied Ge oxidation mechanisms and evaluation of border-traps (BTs) in Ge-MOS.[1,2] Recently, we developed a method for evaluating BT density (N_{bt}) using deep-level transient spectroscopy (DLTS), and reported that an Al-PMA can reduce the N_{bt} in p-MOS but not in n-MOS.[3] In this study, we focused on n-MOS and investigated the N_{bt} into GeO_2/Ge gate stacks formed by thermal oxidation and plasma oxidation using DLTS.

Experimental

An n-type (100) Ge substrate with doping concentration 9.3×10^{15} cm^{-3} was used. After wet cleaning, GeO_2 films were grown by two methods. One was the bilayer passivation (1nm-GeO_2/1-nm SiO_2) using plasma oxidation and SiO_2 deposition, followed by a post thermal oxidation (PTO) at 550°C for 15 min (total GeO_2 thickness: 6.6 nm) and 425°C for 9 h (total GeO_2 thickness: 2.6 nm) in O_2 ambient. Another was ECR plasma oxidation (GeO_2 thickness: 2.8 nm). Then, SiO_2 films were deposited up to a total thickness of 15 nm for all samples, and a post thermal oxidation (PDA) was performed at 400°C for 30 min in N_2 ambient. Finally, Al was deposited and patterned. A schematic of sample structure is shown in Fig. 1. The N_{bt} was measured by DLTS with a pulse electric field (E_{AP}) of 2 MV/cm under a frequency (f) of 10 Hz, corresponding to a BT position of 2.0 nm from the GeO_2/Ge interface. The N_{bt} distribution was measured by changing f.

Results and discussion

Figure 2 shows dependence of N_{bt} on temperature of all samples. The N_{BT} in the plasma oxidation sample by ECR showed lower than those of the PTO samples and a smaller temperature dependence. These results indicate that the GeO_2 quality formed by ECR plasma oxidation is much better, and the species of border-traps in the plasma oxidation sample would be different from those of thermal oxidation samples. Thermal oxidation of Ge involves oxygen vacancy because O_2 dose not arrive at GeO_2/Ge interface.[2] By contrast, in the case of plasma oxidation, oxygen plasma provide oxygen atoms so that the mechanism of GeO_2 formation through plasma oxidation is different from those through PTO, leading to different border-trap species. We will present the N_{bt} distribution for each sample.

References

[1] K. Tanaka *et al*., JJAP, **54**, 04DA02 (2015).
[2] X. Wang *et al*., APL, **111**, 052101 (2017).
[3] W.-C. Wen *et al*., SSDM2017, p.505 (2017).

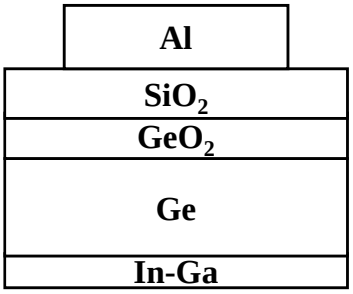

Fig. 1 sample structure.

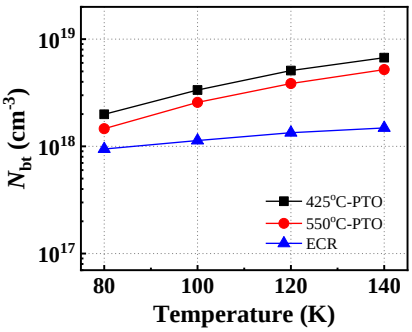

Fig. 2 Dependence of N_{bt} on temperature.