Impact of Alkali Earth Elements Incorporation on Electrical Characteristics of La_2O_3 Gated MOS Device

T. Koyanagi, K. Okamoto, K. Kakushima*, P. Ahmet,
K. Tsutsui*, N. Sugii*, K. Natori, T. Hattori and H.I wai
Frontier Research Center,
*Interdisciplinary Graduate School of Science,
Tokyo Institute of Technology
4259, Nagatsuta, Midori-ku, Yokohama 226-8502, Japan

Abstract

The impacts of Mg, SrO or BaO capping, alkali earth oxides, into La_2O_3 MOS devices have been examined. A roll-off characteristic in flat-band voltage (V_{fb}) dependence on equivalent oxide thickness (EOT) has been weakened with Mg capping and incorporation. On the other hand, SrO and BaO incorporation have showed roll-up characteristics below an EOT of 1.2 nm. The main reason can be considered as the change in the fixed charges. Note that no change in leakage current (J_g) has been observed.

Introduction

Mobility degradation of high-k gated MOSFET caused by fixed charges has been one of the major problems for EOT scaling. La_2O_3 is expected as one of the high-k materials for next generation [1], however, it also suffers from the fixed charge-related mobility degradation at small EOT below 1.3 nm. Recently, it has been reported that the incorporation of Mg into La_2O_3 dielectrics suppresses the generation of fixed charges and corresponding mobility improvement has been observed [2]. In this paper, capping of SrO or BaO, alkali earth oxides, have been investigated and its impact on electrical characteristics are discussed.

Experiment

La_2O_3 layers ranging from 2 to 4 nm in thicknesses were deposited by e-beam evaporation on a HF-last n-Si(100) wafer with SiO_2 isolation. A Mg, SrO or BaO layer was successively evaporated onto the formed La_2O_3 layer, followed by 60-nm-thick *in situ* sputtered W layer. W was patterned by reactive ion etching (RIE) using SF_6 chemistry to form gate electrodes. Wafers were then post-metallization annealed (PMA) in a rapid thermal annealing (RTA) furnace in forming gas (FG)(N_2:H_2= 97%:3%) ambient at 500 ^oC for 30 min. Backside Al was finally deposited as a bottom electrode by thermal evaporation. The schematic illustration of the as-deposited gate stack structure is shown in fig. 1.

Results and Discussion

Figure 2 shows the dependence of V_{fb} on EOT with and without alkali earth elements capping. In the case of Mg capping, a negative V_{fb} shift (roll-off) was controlled owing to the suppression of the fixed charge generation [2]. In the case of BaO or SrO capping, a positive shift (roll-up), is observed below 1.1 nm. These results indicate the change in polarity of fixed charges in the high-k layer at EOT of 1.1 nm. Figure 3 shows the EOT dependence of J_g change with or without the alkali earth elements capping, where no distinct change in J_g is observed.

Conclusion

The impact of alkali earth elements capping onto La_2O_3 gated MOS device on electrical characteristics have been conducted. The trend of V_{fb} dependence on EOT with SrO or BaO capping is different from that of Mg capping. The main reason can be considered as the change in the fixed charges. No change in leakage current (J_g) has been observed with cappings.

References

[1] J. A. Ng, et al., IEICE Electronics Express, Vol. 3, No. 13, pp. 316 (2006).
[2] T. Koyanagi, et al., Extended Abstracts of IWDTF-08, pp. 73 (2008).

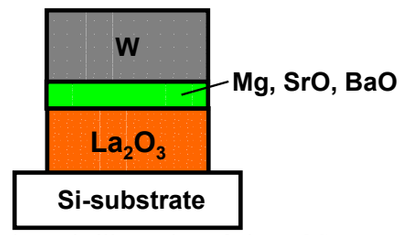

Fig.1. Schematic illustration of the MOS structure in as-deposited condition.

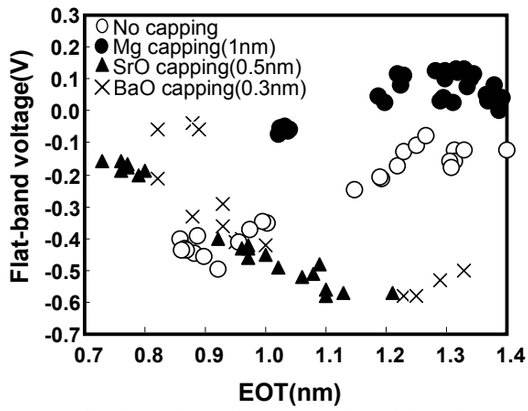

Fig. 2 V_{fb} dependence on EOT with and without alkali earth elements capping.

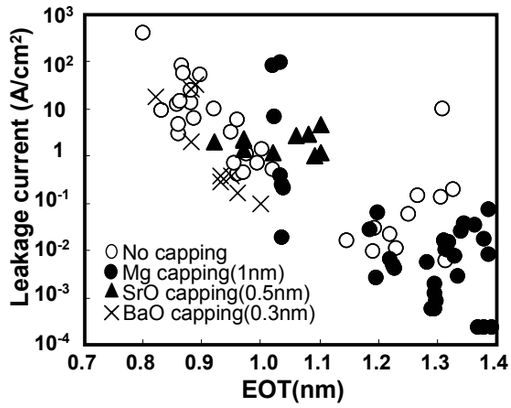

Fig.3. The dependence of leakage current on EOT with and without alkali earth elements capping.