18p-E1-3

Data Retention of TaO_x ReRAM in Low Current Operation and after Cycling

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Introduction: Bipolar-type resistive random access memory (ReRAM) based on binary metal oxides shows major potential for use in non-volatile memory applications [1]. Among other oxides, tantalum oxide was confirmed to be a superior material for excellent switching endurance [2]. In this study, we discuss data retention of TaO_x based ReRAM under two conditions which would be required for actual use: one is retention properties under low current operation and the other is post-cycling data retention.

Device structure: A one transistor and one resistance test array was integrated using the 0.18 μm CMOS process for measuring retention characteristics. The resistive switching cell with an Ir/$Ta_2O_{5-\delta}$/TaO_x/TaN film stack was patterned to form 0.5×0.5 μm^2 square (Fig. 1). The conductive filament (CF), in which resistive switching takes place, is formed by breaking down the $Ta_2O_{5-\delta}$ layer. According to the hopping percolation model [3], we characterized CF properties such as oxygen vacancy concentration, $N(V_O)$, and CF size.

Results and Discussion: At first, we addressed a retention failure issue under low current operation. Using characterized CF properties, we revealed that the control of $N(V_O)$ is indispensable for ensuring data retention including tail bits (Fig. 2). To improve retention property under low set current, CF size must be scaled down while keeping the $N(V_O)$ high enough. Based on this concept, we achieved sufficient retention results exceeding 500 hours at 150 °C under 80 μA set. Then, physical expansion of a CF was investigated with the aim of improving post-cycling data retention. We found that CF size gradually grows with increasing pulse cycles (Fig. 3) due to thermal oxygen diffusion from the region surrounding each CF. To suppress CF size growth, the key is to control both an electric power and a pulse width. We minimized CF expansion by optimizing input pulse conditions and demonstrated long data retention even after 10^6 cycles.

Acknowledgment: We would like to appreciate M. Fukui, J. Fuse, and Y. Inada (Hitachi High-Tech Corporation) for EBAC measurements.

References: [1] H.-S. P. Wong *et al.*: Proc. IEEE **100** (2012) 1951. [2] J. J. Yang *et al.*: Appl. Phys. Lett. **97** (2010) 232102. [3] Y. M. Strelinker *et al.*: Phys. Rev. B **72** (2005) 016121.

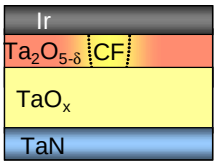

Fig. 1. Schematic of ReRAM cell with an Ir/$Ta_2O_{5-\delta}$/TaO_x/TaN film stack. A CF is formed at the $Ta_2O_{5-\delta}$ layer

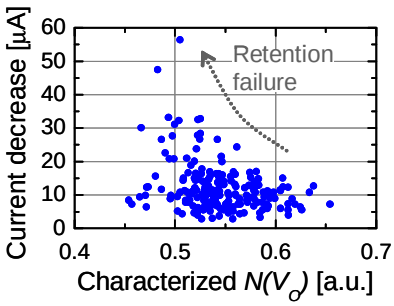

Fig. 2. Dependence of current decrease during retention at 150 °C for 100 hours on characterized $N(V_O)$. Failure bits exhibit low $N(V_O)$.

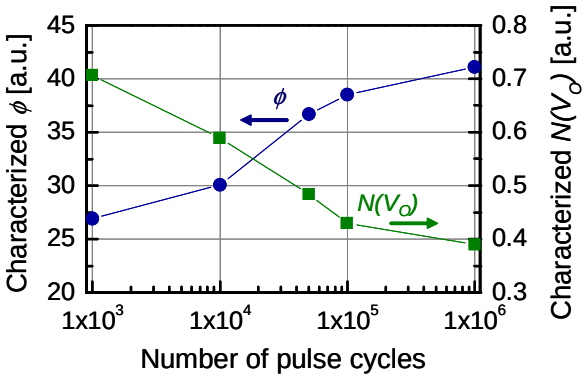

Fig. 3. Characterized CF size (ϕ) and $N(V_O)$ during 10^6 pulse cycles. Retention property degrades after cycling due to low $N(V_O)$ caused by CF size growth.