In-situ crystallization of ferroelectric $Hf_{0.5}Zr_{0.5}O_2$ thin films with record-high $2P_r$ ($56 \mu C/cm^2$) at low thermal budget (300°C) towards full BEOL-compatibility

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In barely over a decade, HfO_2-based ferroelectric thin film went from the early research stage to possibly being integrated into backend- of-line (BEOL) and even industrialized. Acting as the dielectric layer in the 1T1C unit for ferroelectric random-access memory (FRAM) or Dynamic random-access memory (DRAM), HfO_2-based ferroelectric thin film should be compatible with the thermal budget (<400°C) of BEOL process, especially in advanced nodes. However, a high rapid thermal annealing (RTA) temperature beyond 400°C seems indispensable for HfO_2-based ferroelectric thin film. Nowadays, seeking a lower thermal budget (<400°C) has been a hot topic in the area of HfO_2-based ferroelectric materials. A real sense of a low thermal budget for ferroelectric HfO_2-based materials with both high P_r and endurance remains a great challenge.

In this work, we present a process solution in thermal ALD for fabricating ferroelectric $Hf_{0.5}Zr_{0.5}O_2$ (HZO) capacitors annealed at 300°C with high remanent polarization (P_r) and good endurance for full compatibility with BEOL. Record-high $2P_r$ values in 300°C-annealed ($56 \mu C/cm^2$) $Hf_{0.5}Zr_{0.5}O_2$ (HZO)-based metal-ferroelectric- metal (MFM) devices are demonstrated by using an in-situ crystallization process in atomic layer deposition, i.e., using TDMA-based precursors and interfacial O_3 engineering at a slightly higher temperature of 320°C. This work is believed to leading a trend in fabricating the fully BEOL-compatible HZO ferroelectric devices, especially for advanced nodes requiring a much lower thermal budget.

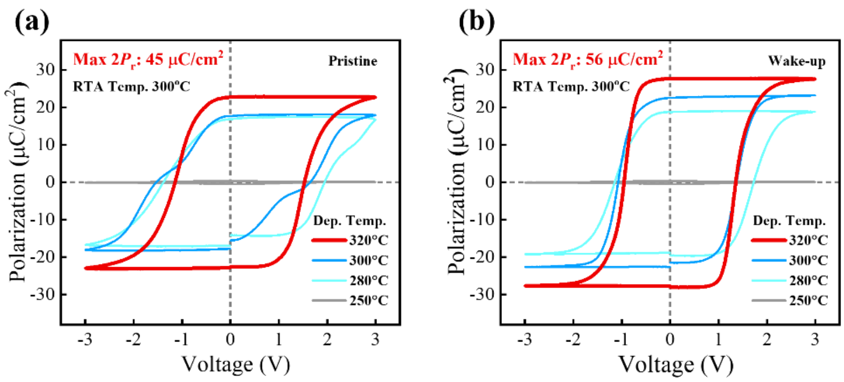

Fig.1. Basic electric characterizations of 11-nm thick TiN/HZO/TiN stacks annealed at a rather low temperature of 300°C. (a) initial and (b) wake-up P-V hysteresis curves measured by positive-up-negative-down (PUND) measurement.

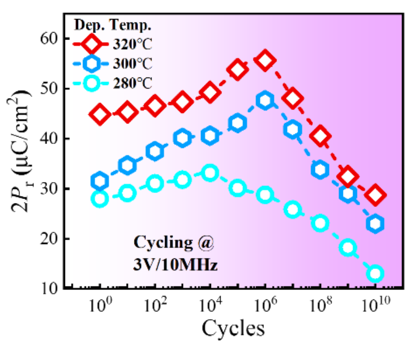

Fig.2. Typical $2P_r$ cycling behaviors of HZO MFM stacks deposited at different temperatures.

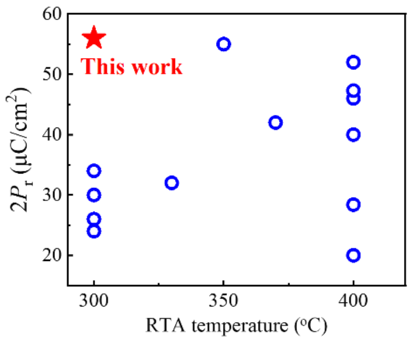

Fig.3. Benchmark of low-thermal-budget HZO capacitors results.