Reduction of HfZrO2 capacitor wake-up effect

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Reduction of $HfZrO_2$ capacitor wake-up effect

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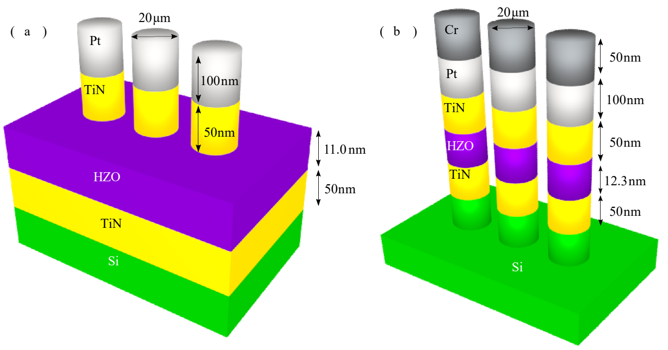
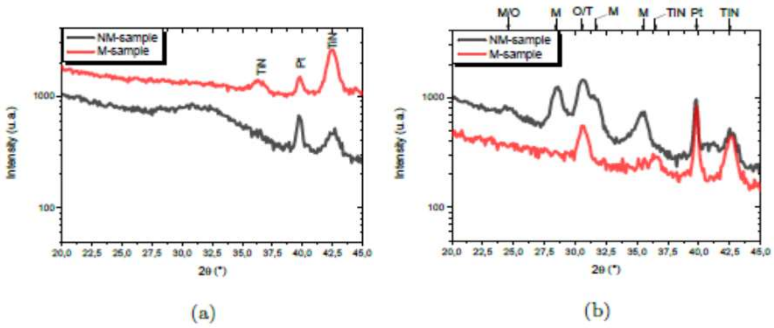
Wake-up effect is a major issue for ferroelectric HfO_2-based memory devices. Here, two TiN/$Hf_{0.5}Zr_{0.5}O_2$/TiN structures deposited by magnetron sputtering on silicon are compared. The maximum remanant polarization is higher than 21µC/cm² for both samples, a strong difference is observed in the electrical behavior. For the mesa sample, the difference between maximal and initial Pr is only 3µC/cm² whereas it is around 14µC/cm² in the non-mesa case. We discuss the root causes of these behaviors in light of structural results. Various applications have been suggested for fluorite-structure ferroelectrics due to their advantages over the conventional perovskite-structure ferroelectrics. In this presentation we will focus on $(Hf,Zr)O_2$ (HZO) thin films deposition for the capacitor of Ferroelectric Random Access Memories (FRAM) in the 1Transitor-1Capacitor (1T-1C) model. $(Hf,Zr)O_2$ thin films are studied to either fully understand the stabilization of the ferroelectric phase (f-phase) or to fit with industrial requirements. Samples are stacks of Si/TiN/$Hf_{0.5}Zr_{0.5}O$/TiN/Pt. All materials are grown by sputtering at room temperature following by a rapid thermal annealing at 450°C during 30 seconds under N_2 atmosphere. The samples are called NM, and M. NM and M refers to two different architectures, respectively non-mesa and mesa structures.

Samples structures



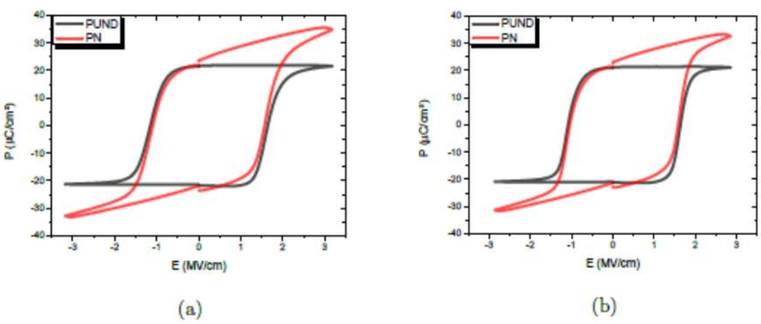
Schemes of (a) NM-sample and (b) M-sample

Grazing Incident X-Ray Diffraction

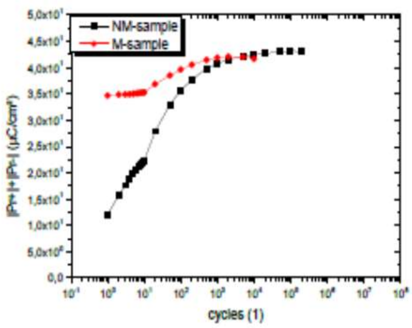


GIXRD measurements comparing NM-sample (black curve) and M-sample (red curve) (a) before RTA (b) after RTA. M stands for monoclinic, O for orthorhombic and T for tetragonal phases

Electrical characterizations PUND, PN, cycling



Polarization versus applied electrical field for (a) NM-sample at 10^5 cycles (b) M-sample at 2.10^3 cycles under the stress conditions: 2 5 kHz and 3.5 V



Change of $|P_{r+}| + |P_{r-}|$ versus the number of cycles with the stress conditions 2.5 kHz and 3.5 V for NM-sample (black curve) and M-sample (red curve)

We report the fabrication of two samples deposited by magnetron sputtering with excellent performances, quite similar to samples deposited by Atomic Layer Deposition. P_r values are among the highest for samples deposited by sputtering. Although the N-sample and NM-samples show very close P_r values, the two samples show completely different electrical behaviors. During cycling, the increase of P_r value for the NM-sample is more than an order of magnitude higher than the M-sample. It is accompanied by a decrease of the endurance which is two order of magnitude higher for the NM-sample than for the M-sample. As electrical behaviors are not the same, for low stress conditions M-sample has a higher P_r value during cycling whereas for high stress conditions NM-sample has a higher P_r value during cycling. As a matter of fact, it has been proven that maximum P_r values are more sensitive to stress conditions than the structures themselves. The origins of the different electrical behaviors come from the micro-crystalline structures of the two samples, according to GIXRD results. The crystallization takes place during the annealing step. During annealing, M-sample is built with a TiN TE fully covering the HZO layer whereas the TiN covers only partially the HZO layer in case of the NM-sample. It induces different stress states which lead to two different micro-crystalline patterning. The M-sample shows no monoclinic peak, whereas the NM-sample shows many monoclinic orientations. It can explain the huge reduction of the wake-up effect.

This work was realized on the NanoLyon technology platform and has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°780302.