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Ferroelectric domain state stability in La-doped $Hf_{0.5}Zr_{0.5}O_2$ thin films

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Hafnia-based thin films have been suggested for a next-generation memory and logic devices thanks to the robust ferroelectricity at the nanoscale that strongly increases storage capacity, the lower power consumption, the high performance operation, the non-destructive readout, as well as the compatibility with CMOS technologies [1, 2]. Probing the ability to “write” ferroelectric states and retain them over time and temperature is an important step before film integration into device.

Here, we present the study of ferroelectric domains “written” in a 10 nm thick $Hf_{0.5}Zr_{0.5}O_2$ film doped by 2.3%mol La (HZLO) after top electrode (TiN) lift-off. Domains were “written” at different coercive fields ranging from 1 to 4 MV/cm and probed using piezoresponse force microscopy (PFM) and low energy electron microscopy (LEEM). Two different processes have been observed during domain writing. Not only polarization state Up (P↑) or Down (P↓) can be written under the PFM tip, the potential difference together with the tip surface potential barrier can lead to charge injection. Both the Schottky barrier and the band skewing due to the internal field appear to play a role in the charge injection, which, in turn, can modulate the ferroelectric domain writing by bias applied to the PFM tip. The obtained surface potential map in LEEM and electromechanical response in PFM allowed concluding that the actual amount of charge injection depends on the quantitative conduction and valence band offsets of HZLO with respect to the bottom electrode (TiN) and the tip. We have also evidenced that injected charges in HZLO film have spread over one-two weeks, whereas residual domain state is related to a “written” ferroelectric nature. Remaining ferroelectric states were found to be permanently stable. Retention of HZLO ferroelectric state has been also studied at 85° C as for consumer electronics applications 10 years at 85°C is often specified [3]. This study was done on a matrix of P↑ and P↓ domains that was continuously annealed in UHV at 85°C and probed over weeks by PFM (Figure 1). Results are in a fairly good agreement with our studies at room temperature, were written ferroelectric states were in a steady state over six months. This study has important consequences for applications requiring high temperature operation and good retention performance such as in the automotive industry.

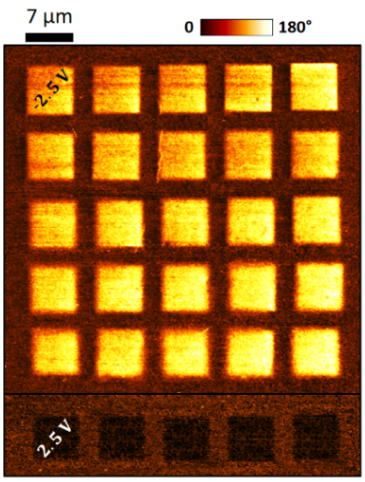

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Figure 1. PFM phase image of ferroelectric domains in HZLO used for retention measurements at 85°C.