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

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Hafnia-based thin films have recently attracted strong interest for integration into fast, cheap non-volatile memories and logic devices thanks to their robust ferroelectricity in the orthorhombic polar phase that can be observed in 8-15 nm thick films [1, 2]. Understanding the ferroelectric state stability over time and temperature is an important step before film integration into device.

Here, we present the study of ferroelectric domain stability in a 10 nm thick $Hf_{0.5}Zr_{0.5}O_2$ film doped by 2.3%mol La (HZLO) as a function of time and temperature. Microscopic domains have been "written" at different coercive fields ranging from 1-3 MV/cm (Fig. 1a) using piezoresponse force microscopy (PFM) and imaged by low energy electron microscopy (LEEM). The ferroelectric nature of the film was confirmed and the polarization of "written" domains is stable over several days. The kinetic energy of the transition from reflected (mirror electron microscopy, MEM) to backscattered electrons allows to probe electrostatic potential of the film which is strongly dependent on the polarization and the screening of the surface polarization charge [3]. Thus, we were able to probe out-of-plane polarization direction [4] of "written" ferroelectric domains and deduce corresponding values of surface potential (Fig. 1b).

Surface charging due to electron beam exposure has been observed during LEEM measurements. The charge injection reaches a steady-state value after the first hour of exposure. Simultaneous annealing up to 100°C led to polarization back-switching to the original state whereas domains not exposed to the electron beam backswitch at 200°C. Charge injection therefore destabilizes the written polarization state. In both cases, the orthombic structural phase appears to be conserved as it was possible to write fresh domain in the HZLO film for annealing temperatures up to 600°C.

This study has important consequences for applications requiring high temperature operation and good retention performance such as in the automotive industry.

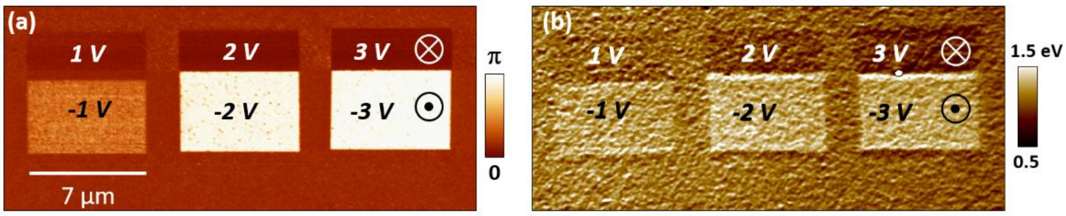

Figure 1. HZLO thin film. (a) PFM phase image of ferroelectric domains for different "writing" voltages and (b) the corresponding LEEM surface potential map.

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