CHARGING EFFECTS ON FERROELECTRIC SBT THIN FILMS IMAGED BY NONCONTACT ELECTROSTATIC FORCE MICROSCOPY

Norbert Junghans and B. O. Kolbesen
Institute of Inorganic Chemistry / Analytical Chemistry,
Johann Wolfgang Goethe-University Frankfurt,
Marie-Curie-Strasse 11, D-60439 Frankfurt am Main, Germany

The research on SBT (SrBi₂Ta₂O₉) thin films is focused on their integration into non-volatile Ferroelectric Random Access Memories (FeRAMs). The functionality of SBT in memories of this category is mainly based on its polarization properties. Noncontact Electrostatic Force Microscopy (nc-EFM) is a technique based on Atomic Force Microscopy and a tool to study these polarization properties on the nano and micrometer scale. In AFM experiments the FeRAM capacitor is imitated by replacing the top electrode with an AFM-tip. Scanning in contact over the surface with a voltage shift between tip and bottom electrode polarizes the SBT in the scanned area. A second step is applied to image the polarization with nc-EFM by detection of the phase shift of an oscillating tip. As a result the total electrostatic field of the polarized area is imaged by this method. However, the electrostatic field after the polarization step has different origins. One is charge which is representative of permanent polarization and reflects the polarization properties of SBT. Another is overcharge due to the polarization step with the AFM tip. Overcharging can easily be mistaken for permanent polarization and distort the polarization characteristics of SBT layers.

To characterize these charging effects, polarized SBT films were exposed to different conditions and the resulting electrostatic fields were imaged by nc-EFM: SBT films with different remanent polarization were polarized in a (1.5 µm)² field. The resulting electrostatic field of the film with high remanent polarization is fixed due to the strong attractive force between permanent polarization and surface charge. In contrast the electrostatic field on the film with low remanent polarization spreads around the (1.5 µm)² field. It cannot be representative of permanent polarization, it is a kind of overcharge effect (Fig. 1). In a further experiment the electrostatic field of a polarized SBT-film could be reduced drastically by contact scanning with a grounded tip (Fig. 2). A polarization loss due to grounding is not probable. Most of the detected electrostatic field before grounding is assumed to show a more stable behaviour on SBT films (Fig. 3). After immersion in isopropanol a decrease of the electrostatic field on polarized SBT surfaces was observed, in some SBT films no electrostatic filed was detectable after the isopropanol dip.

All experiments showed the important role of charging effects on SBT films for nc-EM investigations. Overcharging seems to be imaged mainly by this AFM mode because charging which represents permanent polarization is assumed to show a more stable behaviour on SBT films under the conditions described above. The ability of fixing surface charge on polarized SBT thin films can be used for assessment of their polarization properties. It has to be taken into account that the nc-EMF method only images a mixture of charging, of which one is due to overcharging and one is representative of permanent polarization.

Fig. 1. Electrostatic field of two polarized SBT films with high remanent polarization (left) and with low remanent polarization (right), respectively. $U_{pol} = 4\text{ V}$

Fig. 2. EFM image of a polarized SBT film after grounding with an AFM tip. Electrostatic field after 2 (left) and 10 grounding scans (right), respectively.

Fig. 3. Decrease of electrostatic fields. EFM reference image (left), EFM image after annealing at 140 °C (right) of a 167 nm thick polarized MOCVD SBT film.