A New Technique Based on Current Measurement for Nanoscale Ferroelectricity Assessment : Nano-Positive Up Negative Down

S. Martin[1], D. Albertini[1], N. Baboux[1], B. Gautier[1*]
[1]Institut des Nanotechnologies de Lyon, Institut National des Sciences Appliquées de Lyon, Université de Lyon, UMR CNRS 5270
7, Avenue Capelle, VILLEURBANNE Cedex, FRANCE, F-69621
*Brice Gautier: brice.gautier@insa-lyon.fr

Piezoresponse Force Microscopy (PFM) remains one of the most used technique to assess ferroelectricity at the nanoscale. However, in numerous cases, the signal provided by PFM is at best ambiguous [1]. The need for a more objective technique of characterization has become mandatory, especially in the case where characterization by PFM is hampered by parasitic sources of signal like oxygen vacancies or charge trapping, leading to nearly perfect PFM images and loops on samples which are obviously not ferroelectric [2]. The problem becomes even more acute in the case of layers of a material which is supposed to be ferroelectric, because its crystalline structure allows ferroelectricity, and/or calculations lead to a non null remanent polarization [3], but where no non ambiguous experimental proof of ferroelectricity can be provided. In such cases, the assessment of ferroelectricity by PFM may seem easy but turns to be sometimes tricky [4]. As a consequence, the need for the development of new characterization techniques which would allow to provide an artefact-free signal has become urgent.

We propose a new procedure which aims at measuring the polarization switching current at the nanoscale on ferroelectric thin films with the atomic force microscope tip used as a top electrode. Our technique derives from the so-called Positive Up Negative Down (PUND) method commonly operated on large electrodes, and is based on current measurement during the application of voltage pulses. The main obstacle that must be overcome to implement such measurement is the enhancement of the signal to noise ratio, in a context where the stray capacitance of the sample / tip / lever / lever holder system generates a dielectric displacement current several orders of magnitude higher than the current to be measured. This problem is solved by the subtraction of the displacement current through a reference capacitance. For the first time, we show an example of nano-PUND measurement of the polarization charge on a $PbZrTiO_3$ thin film. A ~4 fC polarization charge is detected on PZT. This value is compared to the value measured on para-electric samples to deduce the noise level of the method. From the comparison with PUND measurement on large electrodes of known area, we deduce the effective surface of contact between the tip and the sample.

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