Direct measurement of ferroelectric remanent polarisation with an atomic force microscope

Simon Martin,[a], Nicolas Baboux[b], David Albertini[b], Brice Gautier[b*]

a. Commissariat à l'énergie atomique (CEA-LETI) de Grenoble, Laboratoire de Caractérisation et Test Electriques, 17 rue des martyrs, 38054 GRENOBLE Cedex.

b. Institut des Nanotrchnologies de Lyon (INL), Institut National des Sciences Appliquées de Lyon (INSA), Université de Lyon, UMR-CNRS 5270, 7 Avenue Capelle 69621 VILLEURBANNE Cedex

∗ brice.gautier@insa-lyon.fr ≫

Measuring the electrical properties of ferroelectrics at the nanoscale is a crucial step in the development of electronic devices based on such materials. Since more than two decades, Piezoresponse Force Microscopy (PFM), based on Atomic Force Microscopy (AFM) has been used to assess ferroelectricity at the nanoscale by means of direct domains writing with the AFM tip and obtention of local hysteresis loops.

Yet, PFM has also proved to suffer from severe artefacts in certain cases e.g. when the concentration of oxygen vacancies is high in the layer under study, or when electrostatic contributions are unavoidable. In these cases, relatively stable PFM images and hysteresis loops can be obtained on obviously non ferroelectric samples [1].These artefacts prevent PFM from being able to assess ferrolectricity in the most critical cases. This is why alternative methods must be developed.

This communication presents a method called nano-PUND [2] which aims at measuring remanent ferroelectric polarisation at the nanoscale with an atomic force microscope. It is based on current measurement and detection of the polarisation switching displacement current. This is an adaptation at the nanoscale of the PUND method used on several hundreds of micrometers large electrodes [3]. Classical PUND method can not be used at the nanoscale due to the lack of signal to noise ratio inherent to the relative amplitudes of the expected current contributions. This is why the capacitive dielectric displacement current and (when applicable) the leakage current must be removed. We show that polarisation switching current can, under certain assumptions, be extracted from the noise thanks to a real-time correction procedure.

Examples of nano-PUND measurements will be shown. In particular, with $\mathrm{PbZrTiO_3}$ samples, a 4.2 fC remanent polarisation charge has been measured [2]. Non ferroelectric (dielectric) samples, which lead to misleading PFM images, are also tested and allow to define the noise level of the nano-PUND method, which shows that it may be more reliable than PFM in certain cases.

[1] A. S. Borowiak et al. J. Appl. Phys. 105(1), 012906 (2014)

[2] S. Martin et al. Rev. Sci. Instr. 88, 023901 (2017)

[3] J.F. Scott et al., J. Appl. Phys, 64(2):787-792 (1988)