PhD topic 2016
Control of the domains and domain walls at the nanoscale

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Scientific Context :

Keywords : Ferroelectric domains, Domain walls, Piezoresponse Force Microscopy, Conductive AFM, Atomic Force Microscopy, transport properties, electronic devices, domain switching.

Objectives and originality of the topic

The aim of this work is the control by means of electrical or mechanical stress of ferroelectric domains and domain walls in thinned single crystals and thin films with the aim of developing innovative electronic devices based on the displacement of the walls.

The increase of the density and rapidity of electronic devices, and the need for a decrease of the energetic consumption leads to consider the capabilities of the ferroelectric materials. Indeed, the abruptness of the domain walls which are as thin a as a single atomic plane, and their electrical properties which can be tuned with small electric fields [McGilly] [Guyonnet] allow to imagine extremely dense memory devices. Coupled to an adequate architecture, those domains and domain walls can form the basis of innovative devices, especially for electronics involving more than two basic states. The switching speed of ferroelectric domains and the very small energy needed to switch are additional advantages [Blaser]. The presence or the absence of a conductive domain wall between two electrodes will be the basis of devices based on the electrical properties of such objects.

It has been shown recently that the application of a mechanical stress allows tune the electrical field needed to switch the domains [Lu]. This operating mode, which is still poorly studied, has to be worked out more systematically by applying an in-situ stress during the creation of charged domain walls.

The aim of this topic is to explore all the means that allow to control the domains and domain walls. One crucial point of this work will be the determination of the influence of the chemical state of the surface on the electrical properties of domains and domain walls. Previous work conducted at the lab has shown that the electrical properties of thin films measured by atomic force microscopy are strongly dependent on the environment [Hourani], [Gautier]. The influence of the oxygen vacancies which are natively present or added in the layer will also be addressed. To do so, a comparison between measurements operated in air, in controlled atmosphere or in ultra-high vacuum will be conducted.

Devices including domain walls between two electrodes will be fabricated and their performances assessed.

Scientific program :

- Fabrication of samples of LiTaO$_3$ and/or LiNbO$_3$ from thinned single crystals
- Study in air, controlled atmosphere and UHV of the creation, propagation and stability of ferroelectric domains.
- Study of the influence of the chemical state of the surface on the properties of domains and domain walls.
- Measurement of the figure of merits of devices based on ferroelectric domains : switching speed, velocity of domain walls, fatigue...
- Measurement and identification at the nanoscale of the transport properties of the domain walls
- Influence of the mechanical stress on the creation and displacement of ferroelectric...
domains.
• Fabrication and test of electronic devices based on the motion of charged domain walls using the capabilities of the NanoLyon technology platform.

Scientific supervision:

This work will be supervised by Pr Brice Gautier and Dr Nicolas Baboux. David Albertini (research engineer) will be in charge of the formation of the PhD student on the different AFM apparatus. Nicolas Baboux will be specifically in charge of the interpretation and evolution of the electrical measurements under UHV with the AFM. Internal collaborations will allow to deposit electrodes and grow thin films for the creation of domain walls by sol-gel and/or sputtering methods. External collaborations with CEA IRAMIS (N. Barrett) and with the « Unité mixte CNRS/Thalès » (S. Fusil) will allow to gain access to PLD grown BiFeO₃ thin films and XPEEM measurement (real time measurement of the motion of the domain walls), as well as to a specific device allowing to apply an in-situ strain on the samples to study its influence on the domains. A close collaboration with FreqNSys company (S. Ballandras) will allow to fabricate thinned single crystals.

Références bibliographiques sur le sujet de thèse


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