UNIVERSITÉ DE LYON

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CONIFER

PhD thesis project

Institut des Nanotechnologies de Lyon UMR 5270

Institut de Nanotechnologies de Lyon
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Director: Catherine Bru-Chevallier

Title: nanoscale CONduction phenomena In new photoFERroelectrics systems: from synthesis to devices

Scientific description

The present PhD project aims to explore ferroelectric oxides as promising candidates with exciting photo(ferro)conductive properties in new nanoelectronic devices. Commonly described as wide bandgap semiconductors, ferroelectrics possess a remnant internal electric dipole called polarization. Recently, ferroelectric oxides were found to have larger than bandgap open circuit photovoltages. Further, the recent discoveries of other various photoconduction effects *e.g.* photostriction or photocatalysis and in different ferroelectrics have triggered an intense global effort in a disruptive materials paradigm, where multifunctional applications combine light with charge for their operation. This has led to these materials cast in entirely new "light", termed as photoferroelectrics.

In this framework, this project aims at searching new materials and ways to combine them to control the band gap while retrieving the ferroelectric state. Investigations on the nanoconductive phenomena in classical ferroelectrics, still not fully understood, under equivalent conditions, will be needed to understand the conductive phenomena in these new materials, under different external stimuli, including light, to end up proposing new device concepts based in these photo(ferro)electric systems.

The student will work on the synthesis of large large scale deposition techniques, *i.e.* solgel derived route and radio-frequency sputtering, of thin films of reference ferroelectric compounds from the PbZrxTi1-xO3 (PZT) family, and from BaSn1-xTixO3 (BSnT) solid solution, on single crystalline substrates, firstly in structurally compatible oxide crystals and later on on silicon and/or transparent substrates.

In the material synthesis topic, whereas PZT compositions are currently mature, the development of synthesis routes to obtain solution-derived BSnT thin films will be needed within the PhD project. The interest in such BSnT composition is related to the expected effect that Ti-site substitution with Sn can lead to the increase of the electron mobility due to Sn 5s5p empty states in the conduction band are expected, together with the tuning of the ferroelectric state and the creation of near to band edge optical transitions that may favor photoinduced responses. For the synthesis part, the PhD student will synthesize the end members of the BSnT solid solution, BaTiO3 and BaSnO3, and an intermediate composition where it is expected the simultaneous stabilization of ferroelectric polarization and highly mobile photoinduced charges, *i.e.* BaSn0.1Ti0.9O3.

Using the appropriate compositions and tuning the processing conditions for PZT and BSnT, it will be possible to explore the effect of the as-grown or induced ferroelectric polarization, point defects, piezoelectric coefficients, in the nanoscale (photo)ferroconduction. It will be required to study in the synthesized ferroelectric-based thin film systems from the crystalline phase and epitaxial growth window, to the interface phenomena, to probe the chemical and electronic states at the surface and within the thin film, using different experimental techniques available at the laboratory or through stabilised collaborations: at the macro/micro scale, using X-ray diffraction and reflectometry tools, X-ray photoelectron spectroscopy or Raman spectroscopy, and at the nanoscale, using atomic force microscopy, mastered at the laboratory, and scanning transmission electron microscopy tools. Technological steps towards devices will be granted by the NanoLyon clean room facilities, to pattern and design different demonstrator, from top-bottom or in-plane microcapacitors to more complex nanodevices, based on the ferroelectric thin films. On these systems, the ferroelectric/conductive properties will be further investigated using environmental micrometric probe stations and devoted electronics to understand the role played by different parameters, intrinsically related to the thin film processing – thickness, electrode nature, growth conditions – to environmental and time dependent conditions – sample temperature, electrical cycling, and finally studied under controlled external stimuli, including micro-spot illumination.

In summary, the objectives of the PhD project are to (1) master the ferroelectric thin films synthesis and interface using techniques compatible with semiconductor and transparent electronics technologies, (2) understand the ferroelectric properties at the nanoscale, in particular using atomic scale techniques as atomic force microscopy, and exploit the versatility of this tool to work under different external stimuli, and (3) design and produce innovative demonstrators based on ferroelectrics where the conductivity can be driven by light, electric field or mechanic load.

Keywords

ferroelectrics, thin films technology, nanoscale electrical properties

Applicant skills

robust material science training (preferable in chemistry, or physics); skills for thin film characterization, technology and processing; scientific curiosity and easiness to work in team; large capabilities to read/write and communicate in English

Scientific partners

INL partners: Ingrid Cañero Infante (co-advisor, structural characterisation, Electronic Devices team); Bertrand Vilquin (ferroelectric thin film technology, Materials team); Virginie Monnier (soft chemistry, Surface Chemistry team); Nicolas Baboux (microscale dielectric and ferroelectric properties, Electronic Devices team)

External partners: Jules Galipaud (LTDS lab, UMR 5513, on X-ray photoelectron spectroscopy and Raman spectroscopy), Matthieu Budget (MATEIS lab, UMR 5510, on transmission electron microscopy tools)

PhD supervisor

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PhD location

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