Internship/PhD topic:
"Artificial synapses using relaxor ferroelectrics"

Lab: Structures, Properties and Modelling of Solids (SPMS)

Keywords: artificial synapses and neurons

Topics: ferroelectrics and relaxor ferroelectrics

Supervision: B. Dkhil

Quick summary of the internship/thesis project:

Besides the von Neumann architecture that is highly inefficient in terms of energy consumption and cost, the ever-increasing presence of Artificial Intelligence calls for a new paradigm, inspired by brain architecture where the memory, stored analogically in synapses, evolves according to signals (in the form of electrical pulses) received by adjacent neurons. By interconnecting neurons and synapses, this neuromorphic architecture allows efficient and parallel computing, and learning and adaptability functions. Recently, different solutions have been identified to mimic the behavior of artificial synapses, and particularly at SPMS we are working on memristors and memcapacitors using ferroelectrics [1-3] and relaxors which physics at the nanoscale is currently under investigation. These memory resistor and capacitor are new components allowing to access several resistance/capacitance values, depending on the number, duration, polarity, and amplitude of applied electrical pulses, and to maintain these states when electric excitation is withdrawn. These analogic (multistates) and nonvolatile characteristics are essential for mimicking synaptic plasticity (i.e., the processes of learning and forgetting as in the human brain).

During this PhD, the candidate will:

- Join a dynamic and internationally recognized team
- Participate to the synthesis of the materials and fully characterize and study them using a broad set of techniques available at SPMS and at many partners in France (CNRS-Thales, univ. Tours, univ. Picardie Jules Verne....) and also in the world (USA, China, Slovenia...). Some stays at partners will be planned.
- Use modelling techniques in the framework of a joint laboratory between SPMS and Physics depar^{t} of Arkansas, USA, to better understand the synaptic/neuronic behavior.
- Contribute and participate to the work dissemination by writting papers and participating to international conferences and workshops

Main experimental techniques/simulation tools/methods:
Both experimental and modelling techniques will be used, and depending on the skills and wishes of the student, either the main focus will be made on the experimental part using in situ XRD, Raman spectroscopy, STEM, EELS/EDX, piezoforce microscopy, I-V, C-V measurements with nanosecond electric field pulses.... or the modelling using computational first- and second-principles calculations tools (DFT, Monte Carlo, Molecular dynamics).

Bibliography:

[1] G. Feng et al., Nature Commu. **16**, 3027 (2025)
[2] D. Wang et al., Fundamental Research **4**, 1272 (2024)
[3] B. Tian et al., Exploration 3, 20220126 (2023)

If you are interested, please quickly contact brahim.dkhil@centralesupelec.fr