Experimental Research Internship Master 2

Academic Year 2025/2026

Laboratory : Institut de Physique et Chimie des Matériaux de Strasbourg (IPCMS)
Team: Molecular Quantum Spintronics Team, DMONS
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Antiferroelectric–Ferroelectric Transitions in Molecular Nanostructures and dielectric proximity effect

Antiferroelectric materials can store energy, making them attractive for the development of new types of electrostatic capacitor devices. In this context, the small molecule squaric acid (SQA) is of particular interest. Recent studies on SQA crystals have demonstrated their antiferroelectric behaviour and suggest that they could allow high energy density storage [1]. Lead-free compounds, such as organic antiferroelectric materials, are promising candidates for developing green energy storage technologies.

When exposed to an external electric field, such antiferroelectric systems change their polarization from an antiferroelectric (AntiFerro) to a ferroelectric (Ferro) configuration. This transition is at the origin of the charge storage capability of such material. Electrostatic energy can be stored in the resulting ferroelectric state.

This Master 2 project proposes to investigate SQA model nanostructures, focusing on their growth under ultra-high vacuum conditions, their structural characteristics, and their fundamental local polarization properties. A key challenge of this internship will be to measure and understand the piezoelectric response and relate it to the induced charges during the antiferro-ferroelectric (AFE-FE) transition in SQA nanostructures. This will be done by exploring the dielectric proximity effect induced by the molecular layer in interaction with a 2D graphene sheet. The antiferroelectric properties, including electronic polarization, hysteresis loops, and local current-voltage characteristics, will be studied using standard local probing technics. During the internship, these polarization properties will be explored in detail [2].

The experimental results of this Master's 2 research project will serve as a milestone for a PhD project aimed at advancing knowledge about this promising yet little-studied class of antiferroelectric materials. This research track offers solid training for academic/industrial career opportunities: *in situ* local probe skills into electrical charge transport/storage.

Bibliography

[1] S. Horiuchi et al., (2018) Strong Polarization Switching with Low-Energy Loss in Hydrogen-Bonded Organic Antiferroelectrics. *Chem. Sci. 9* (2), 425–432.
[2] S. Mohapatra, et al., Accessing nanoscopic polarization reversal processes in an organic ferroelectric thin film. *Nanoscale* (2021) https://doi.org/10.1039/D1NR05957B