Exploring Dipolar Skyrmion Sheets at Ferroelectric Interfaces

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Research Centre: CQMT
Suitable for: Students interested in solid state physics, materials and microstructure
Type of Project: Mainly experimental but also perhaps some modelling components
Skills required: Reasonable laboratory skills and common sense
Skills gained: Expertise in high-end microscopy techniques and data analysis

Background

Normally, ferroelectric microstructures are characterised by the formation of distinct domains, in which local electrical dipoles coalign in specific directions. However, recently, in thin films and nanostructures, much more complex dipolar arrangements have been seen [1], reminiscent of murmurations of roosting starlings [2]. These complex patterns are characterised by the existence of topological defects: distinct singularities in the dipolar "field" that have been mooted as objects that may be suitable in exotic forms of data storage and processing (skyrmion race-tracks for example [3]).

In truth, these complicated dipolar patterns have so far emerged either due to a combination of electrostatics (depolarising fields) and stress (due to epitaxial growth) [4,5], or through stress gradients [6]. In QUB, we have discovered skyrmionic lattices that are visually stunning and unlike any other electrical dipolar pattern seen to date. They form in a single unit cell layer at the interface between two lithium niobate crystals that have been thermomechanically bonded in a furnace, such that hard discontinuities in polarisation develop.

This Project

This project will build on the initial discoveries, by bonding a variety of other single crystals, in which polarisation discontinuities should be achieved. The work will initially involve crystal bonding, cutting and polishing, but will then quickly move onto the preparation of thin lamellae (using a Focused Ion Beam Microscope) which contain both cross-sections and plan-view sections of the bonded interfaces. These lamellae will then be examined using transmission electron microscopy (TEM) to see if interesting and varied dipolar patterns emerge. The physics associated with their existence will be probed and developed.

Useful references

[1] P. Tong *et al.* Nat. Phys. **21** 464 (2025); [2] JM Gregg, Nat Phys. **21** 344 (2025); [3] R. Tomasello *et al.* Sci. Rep. **4** 6784 (2014); [4] A. K. Yadav *et al.* Nature **530** 198 (2016); [5] S. Das *et al.* Nature **568** 368 (2019); [6] G. Sanchez-Santolino *et al.* Nature **626** 529 (2024).