# DataCube PFM for understanding ferroic materials electrical and mechanical properties

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Ferroic materials, such as ferromagnets, ferroelectrics, and ferroelastics, are usually defined as exhibiting a phase transition from a high-symmetry phase, known as the paraphase, to a low symmetry phase that exhibits a new quantity, characteristic of the symmetry change, called the order parameter (magnetic moment, spontaneous polarisation, spontaneous strain, respectively). For example, ferroelastics have several ferroelastic domain states, that differ in their spontaneous strain but are identical or enantiomorphous in their crystal structure. Similarly, ferroelectrics have several ferroelectric domain states, which differ in the spontaneous polarisation. Since ferroelastic and ferroelectric domain states have the same point group, they are energetically degenerated and occur with the same probability leading to the spontaneous formation of domain structures.

Techniques based on atomic force microscopy (AFM) allow to probe the domain structure of ferroic materials at the nanoscale. Change in topography can be used to determine the local spontaneous strain associated with ferroelasticity and while the mechanical vibration triggered by an applied electric field (PiezoForce Microscopy, PFM) can be used to develop a 3D map of the polarisation direction in different domains in ferroelectrics.

This presentation will discuss the spatial variation of mechanical and electrical properties across domain structures in different ferroic materials.

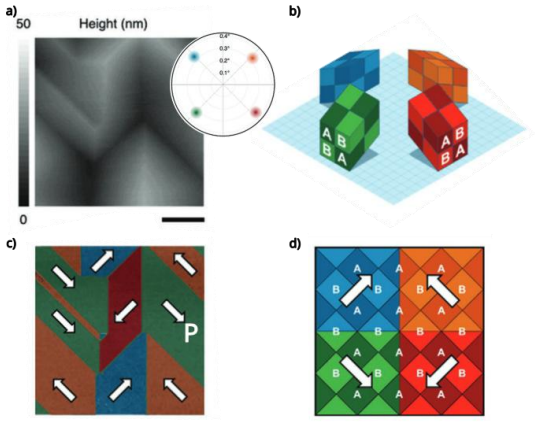


Fig.1. a) Local topography using AFM with the associated spontaneous shear strain. c) PFM maps of the same area. b/d) Schematic explaining the ferroelastic and ferroelectric domains distributions. The scale bar measures 5 µm. Adapted from [1]

[1] J. Guy, C. Cochard, P. Aguado-Puente, *et. al*, Advanced Materials **33**, 16, 2008068 (2021).