Revealing atomic structure and ferroelectric properties in 2D materials

Context: The properties of 2D materials are highly sensitive to atomic scale structural configurations, which enables electronic property modulation by tailoring their atomic structures. 2D van der Waals ferroelectric (2D vdW FE) systems have recently been attracting particular attention due to their novel polarization mechanisms and potentials for efficient devices with reduced dimensionality. Ferroelectrics are materials with ordered spontaneous polarization that can be reversed by external electric fields. Such polarization is induced, generally in atomically thin 2D materials, by local charge redistribution due to in-plane atom displacement [1] or out-of plane “sliding” lattices [2]. The ability to survey structural configuration and their properties at atomic scale in 2D materials is thus essential to understand such low-dimensional complex polarization mechanisms and further to explore new functionalities for future 2D devices.

Project: This PhD aims to develop STEM based analytical techniques enabling to access information on both atomic structure and polarization in two-dimensional van der Waals (2D vdW) ferroelectric materials. Scanning transmission electron microscopy (STEM) has become an invaluable tool for the study of 2D materials. Aberration correctors allow low voltage operation to avoid damage and provide precise atomic positions in atomically thin layers, and EELS can provide chemical composition at the individual atom level. The MEM laboratory is specialized in such STEM techniques dedicated to the various 2D materials study. In recent years, the MEM develops a new STEM acquisition method so-called four-dimensional (4D) STEM. Analyzing huge data series consisting of the local electron diffraction patterns we can today determine the local electric fields and charges generated in atomically thin 2D materials with sub-angstrom accuracy [3]. The PhD project will develop 4D-STEM techniques, based on the current expertise in MEM, for accessing information on local polarization in innovative 2D vdW ferroelectric materials developed in Spintec and study the complex physics behind the correlation between structure and polarization in strong collaboration between the two laboratories.

Required skills: Background in solid-state physics and materials science, interest in both experimental works and numerical simulations.

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Related publications:

[1] K. Chang et al., Science 353 (2016) p274.
[2] P. Meng et al., Nature Communication 13 (2022) p7696.
[3] D. Dosenovic et al., ACS Nano 18 (2024) p23354.