Magnetic domain imaging using spin-filtered PhotoEmission Electron Microscopy (PEEM)

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The Objective: This workshop aims to familiarize participants with spin-resolved PEEM techniques using the NanoESCA Spin Filter Tool and to understand the extraction of spin textures in materials. Spin-PEEM is a powerful tool for imaging materials below the diffraction limit while resolving the spin degree of freedom at the nanoscale. The activity will focus on understanding how spin-resolved PEEM data is acquired by studying a polycrystalline Fe sample and developing custom codes to identify and classify magnetic domains.

The System: In spin-resolved PEEM, electrons are emitted from a material's surface by an UV photon and imaged based on their trajectories and spin states. Using a spin filter, the system allows for simultaneous imaging of electronic and spin structures, giving insight into materials' magnetization patterns and spin textures. The challenge lies in analyzing the complex datasets obtained from these experiments. This activity will focus on two tasks commonly used in spin-resolved PEEM data analysis.

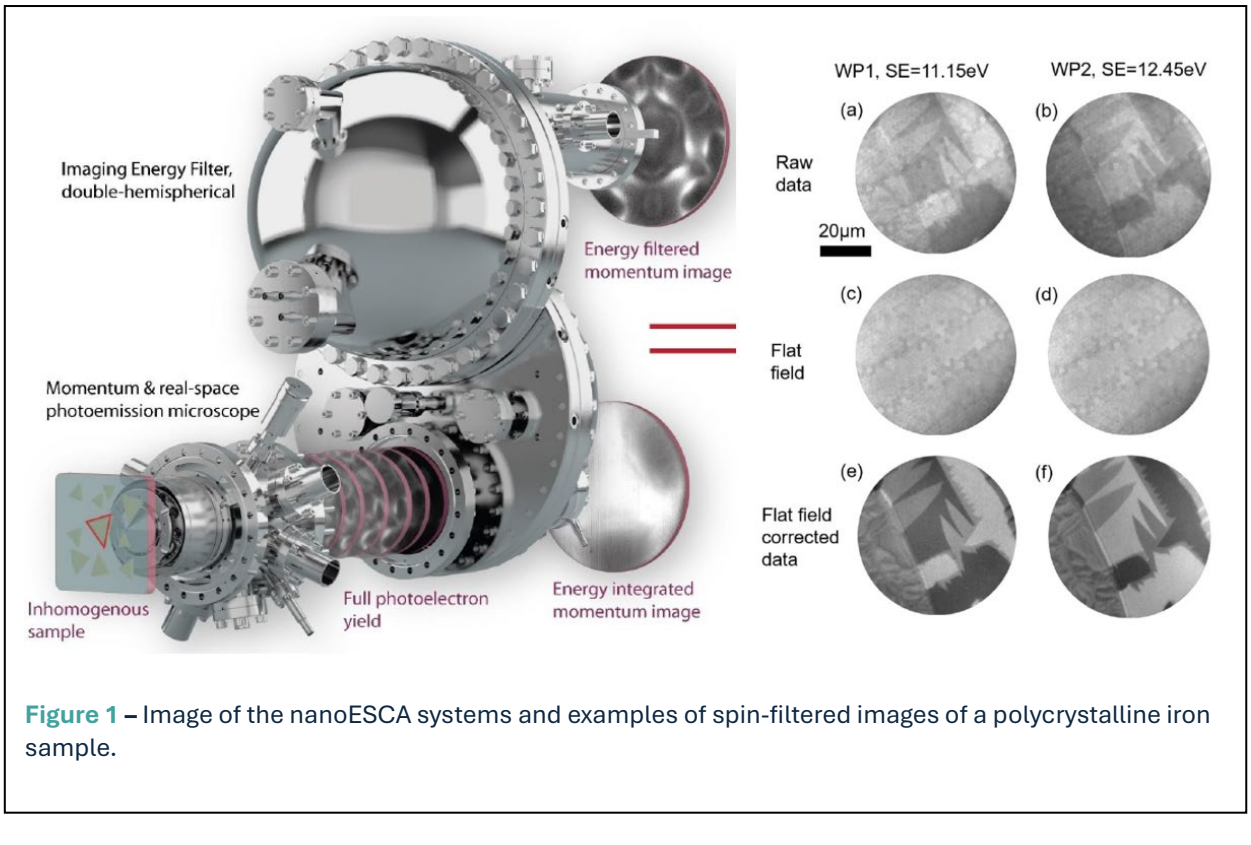

Figure 1 – Image of the nanoESCA systems and examples of spin-filtered images of a polycrystalline iron sample.

The Experiments:

1. **Measuring magnetism:** Predicting the magnitude of spin polarization in different regions of a material's surface. Within this task, we will measure spin polarization using the spin-filtered PEEM images. To this end, we:
    1. Measure spin-resolved PEEM images from polycrystalline Fe at the two working points of the spectrometer.
    2. Load the spin-resolved PEEM images from a dataset using the NanoESCA Spin Filter.
    3. Calculate the dichroism and average datasets.
    4. Extract the average spin polarization for a given region using the Sherman function.

    Question: What is the maximum spin polarization one can expect? What spin polarization can you extract from the data (Efficiency)? What is the origin of this discrepancy?

2. **Analyzing data:** Classification and identification of magnetic domains based on spin-resolved images. The second part of this activity focuses on identifying and extracting domains between regions with opposite polarization on the data measured in part 1. This will allow you to put your creativity on display and attempt different algorithms including machine learning models.

    Questions: What is the domain well thickness? What is physically happening in this region?

Further Thinking: Spin-resolved PEEM offers unique insight into the spin structures of materials, which is vital for developing spintronic devices. The ability to extract and analyze spin textures using machine learning models opens up new avenues for rapid material screening and in-depth understanding of spin-related phenomena.

Further Reading:

1. NanoESCA Spin Filter Tool
2. PEEM and Spin-Resolved Techniques