Development of *In Situ* Thin Film Growth Capabilities for Polarized Neutron Reflectometry

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Abstract:

Magnetic layers and heterostructures thereof are the fundamental building blocks of many commercial magneto-electronic devices, such as the read heads of hard disk drives or novel magnetic storage media like magnetic random-access memory (MRAM) or prototype racetrack memory structures.

The ultimate quality and performance of such devices crucially depends on the magnetic properties of the individual layers, their interfaces and the coupling between them. These properties are correlated with each other, and can be influenced by the specific processes during the thin film layer growth. For an optimization of the magnetic properties of thin films for scientific and technological applications, it is therefore essential to investigate the development of magnetism in layers and heterostructures *in situ* during growth and to correlate the evolving magnetism with the respectively evolving microstructures.

Such an *in situ* characterization of thin films by electron- and photon-based probes as well as by scanning probe techniques is common practice. However, growing thin films *in situ* directly in the neutron beam and investigating them at different deposition steps by (polarized) neutron reflectometry ((P)NR), is a technologically challenging task [1].

Here, the development work, carried out over one decade as a collaboration of TUM, University Augsburg and MPI Stuttgart, to realize and utilize a mobile sputtering facility [1,2,3] sample environment for the growth and *in situ* monitoring of magnetic multilayers by PNR at suitable neutron beamlines will be presented: as starting point, the early setup [2] and unpolarized & polarized proof of principle neutron reflectivity measurements on Ni/Cr and Fe thin films at the ToF reflectometer REFSANS at the FRM II neutron source will be shown. This will be followed by all the major development steps [2,3,4] and experimental milestones that ultimately allowed very fast *in situ* PNR measurements at the AMOR beamline at PSI to be performed. It is also a prime example of how an advanced sample environment for novel experiments needs the power of advanced neutron optics to fully unfold its capabilities.

The experiments [5,6] demonstrate that *in situ* PNR offers unique opportunities for answering a wide range of scientific questions at hand [1] and to potentially also advance the data analysis [7]. An overview over the latest developments and planned future modifications as well as the completion work carried out to allow the setup to be applied for even broader scientific research will conclude the talk.

As of 2023/2024, the setup has been transferred to and is permanently located at (and operated by) PSI, where it currently undergoes modifications to re-adapt it to the newly upgraded Amor beamline.

References:

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