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MARIA: Magnetic reflectometer with high incident angle

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Abstract: The neutron reflectometer MARIA with polarisation analysis, which is operated by JCNS, Forschungszentrum Jülich, was designed for the investigation of thin magnetic layered structures down to the monolayer scale and lateral structures.

1 Introduction

The reflection of polarised neutrons allows to determine individually the density and the modulus and the direction of the magnetisation vector of buried layers.

MARIA is optimised for layer thicknesses between 3 – 300 Å and lateral structure sizes from nm to µm sizes. Consequently the instrument is designed for small focused beam and sample sizes of 1 cm^2 at λ = 4.5 Å (available: 4.5 Å $<\lambda<$ 40 Å) in a vertical orientation with a maximum incident angle of 180° and outgoing angle ranging from -14° to 100°. MARIA provides polarisation analysis in standard operation, where the beam is polarised by a polarising guide (z-geometry; 4.5 Å $<\lambda<$ 10 Å) and analysed by a wide angle ^{3}He-cell.

Beside the above described reflectometer mode with good resolution in the horizontal scattering plane, MARIA can be used in the GISANS mode with additional resolution in the vertical direction. The latter mode allows for measuring lateral structures down to the nm scale.

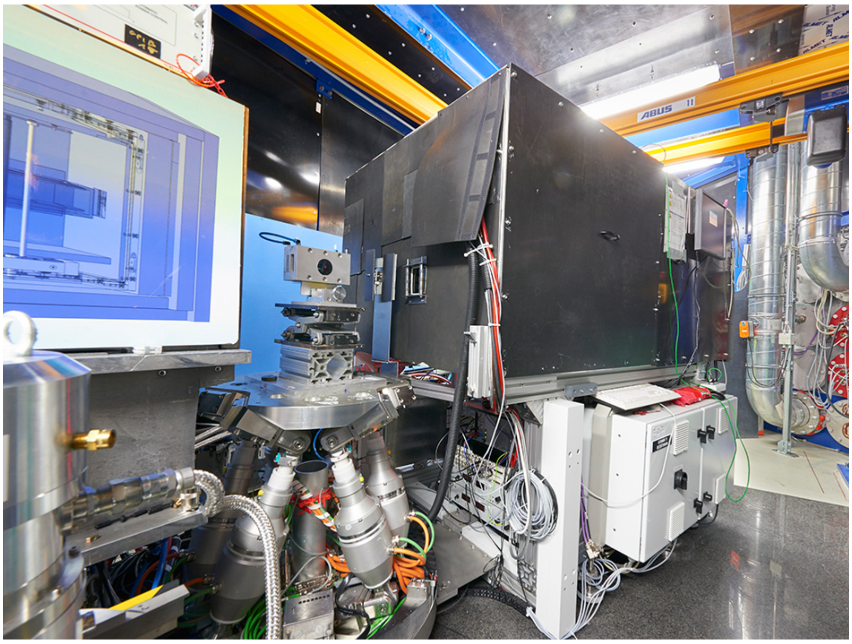

Figure 1: Sample position of the instrument MARIA. On the left with the end of the 4 m collimation base with the vertical focusing neutron guide. In the centre the versatile Hexapod combined with a 360° rotation stage below, as sample table. The black box on the right is the detector arm carrying the analyzer system using a in-situ pumped ^{3}He spin filter (SEOP) and the 2D-detector (Copyright by W. Schürmann, TUM).

At the sample position, a Hexapod with an additional turntable (360°) is installed, which can take a load up to 500 kg. In the standard configuration magnetic fields are provided up to 1.3 T (Bruker electromagnet) and cryogenic temperatures down to 4 K (He closed cycle cryostat). Beside this standard setup the complete sample environment of the JCNS can be adopted to MARIA so that magnetic fields up to 5 T and temperatures from 50 mK to 500 K are available.

All parts of MARIA are controlled by a computer system according to the "Jülich-Munich" standard based on a Linux workstation. This allows a flexible remote control with automatic scan programs, including the control of sample environment as cryostat and electromagnet.

2 Typical Applications

With scattering under grazing incidence we investigate depth-resolved the laterally-averaged magnetisations and the correlations between their lateral fluctuations. With an additionally polarised neutron beam we derive a vector information on the laterally-averaged magnetisation (reflectivity) and on the correlations between their lateral fluctuations (off-specular scattering – µm length scale, GISANS – nm length scale).

In general, MARIA can be used for measurements of magnetic roughness, the formation of magnetic domains in thin layered structures, lateral structures, etc. (polarised mode) and density profiles, structures of solid polymer layers, etc. (unpolarised mode with higher intensity).

Furthermore possible without the need for multilayers investigation of:

- Diluted semiconductors
- Influence of the substrate
- Interfaces between oxide materials

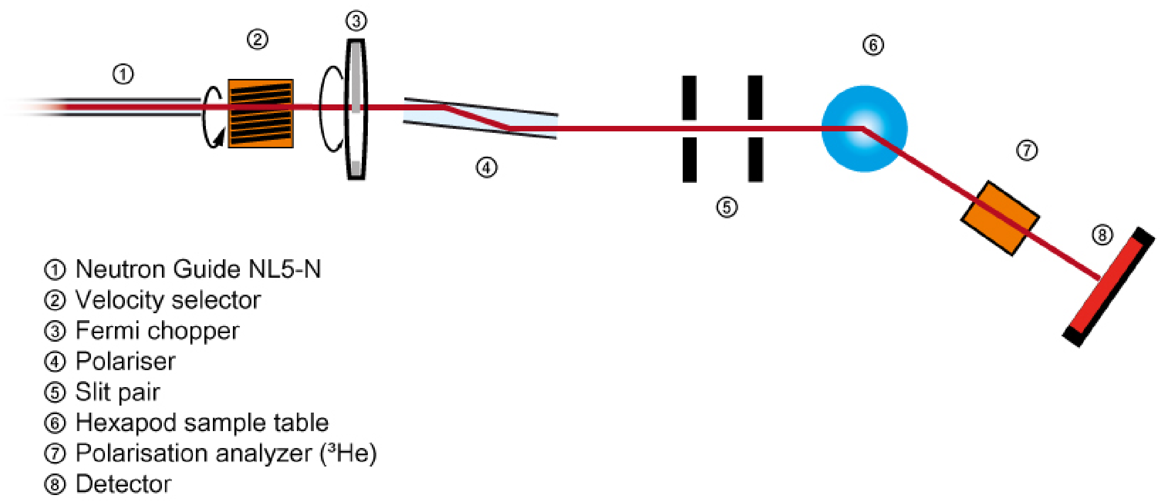

Figure 2: Schematic drawing of MARIA.

Additionally the instrument in non-polarised beam mode can be used for reflectometry and GISANS studies of "soft" layers at the solid/ liquid interface by the use of appropriate liquid cells that are available at the beamline. Candidate systems for such investigations include polymer brushes, polyelectrolyte multilayers, biomimetic supported membranes, adsorbed proteins etc. For typical applications involving deuterated solvents the dynamic range that can be expected covers 7 order of magnitude.

3 Sample Environment

The optimal sample size for MARIA is 10 x 10 mm^2 with the following parameters:

- Thin magnetic layers down to sub mono layers
- Polarisation analysis as standard
- Layer thickness of 1 – 300 Å optimised, but – 1000 Å (multi layers) should be feasible
- Lateral structures of nm to µm
- Temperature controlled liquid cells for soft matter, accomodating various substrates

Besides the described cryogenic temperatures and magnetic fields MARIA can provide users with a fully equipped Oxid-MBE (Molecular Beam Epitaxy).The typical sample sizes are 10 × 10 mm^2 and as targets we can provide Al, Cr, Pr, Fe, La, Nb, Ag, Nd, Tb, Sr, Mn, Ti and Co.

4 Technical Data

4.1 Primary beam

- Neutron guide NL5-N: vertically focussing elliptic guide
- Monochromator: Velocity selector
- Wavelength:
  - 4.5 Å – 10 Å (polarised)
  - 4.5 Å – 40 Å (unpolarised)
- Resolution:
  - 10 % velocity selector
  - 1 %, 3 % Fermi chopper
- Double reflection polariser
- Horizontal scattering plane

4.2 Flux at sample

- Polarized flux: $5 \cdot 10^7$ n cm^{-2} s^{-1} for 3 mrad collimation

4.3 Distances and angles

- 4100 mm distance S1 – S2 (collimation)
- 400 mm distance S2 – sample
- 50 mm x 40 mm (w x h) max. opening S2
- 1910 mm distance sample – detector
- 120° maximum detector angle
- GISANS option: 4 m collimation length

4.4 Accessible Q-range

- Reflectometry:
  Qz- range 0.002 $Å^{-1}$ – 3.2 $Å^{-1}$
  Qx- range $6 \cdot 10^{-5}$ $Å^{-1}$ – 0.001 $Å^{-1}$
  α_f -14° – 100°
- GISANS option:
  Q_y- range 0.002 $Å^{-1}$ – 0.2 $Å^{-1}$

4.5 Polarisation analysis

- ^{3}He-cell