CHyN | in cooperation with Universität Hamburg DER FORSCHUNG | DER LEHRE | DER BILDUNG

PROSEMINAR UHH-66-518 BIO/NANO-ELECTRONICS – BLICK GROUP

Mechanical Detection of Tiny Magnetic Forces

Dr. Alexander Schwarz, INF, AG Wiesendanger

[CHyN, Rm.-301, 09. April 2024, 13.15h,
hybrid: Zoom-999-4554-8884, 894-335-73]

In this presentation, I introduce two different approaches to detect small magnetic forces by mechanical means using resonating freestanding structures. In particular, I will discuss the similarities and differences of both approaches as well as future perspectives.
The first method is based on a well-established scanning probe method, i.e., atomic force microscopy (AFM). Employing a pyramidal tip at the free end of the cantilever tip-sample interaction forces that reflect the surface topography can be sensed by detecting the mechanical response of the cantilever. The spatial resolution is limited by the sharpness of the tip apex, the tip-sample distance and the sensitivity of the detection scheme. If the tip apex is atomically sharp, the position of individual atoms can be imaged, as demonstrated in Fig. 1a in NiO(001). Standard silicon cantilevers with integrated tips can be made magnetically sensitive by coating them with a magnetic material. Such cantilevers can be used to resolve the magnetic domain structure of ferromagnetic samples (magnetic force microscopy; MFM) [1]. With atomically sharp magnetic tips it is also possible to map the atomic scale spin structure (magnetic exchange force microscopy; MExFM) [1,2].Figure 1b shows the same NiO(100) surface as in Fig. 1a, but now the antiferromagnetic order of neighboring Ni rows is resolved.
The second method is a hybrid magnetometer device sketched in Fig. 1c, which we developed and patented within OXiNEMS, a H2020 EU project, with the aim to detect biomagnetic fields in the fT regime [3]. It includes a field-to-gradient converter (FGC) made of a superconducting pick-up loop with a constriction and a magnetically sensitive resonator placed above the constriction. Conceptually, it resembles a magnetic force microscopy set-up, but it neither uses a sharp tip nor does it scan. Instead, it detects the Oersted field above the constriction generated by the supercurrent induced into the pick-up loop by an external magnetic field. The Oersted field is greatly enhanced above the constriction, because the reduced cross section increases the current density dramatically. I will show first proof-of-concept results, describe the scalability of this device and discuss the expected sensitivity.

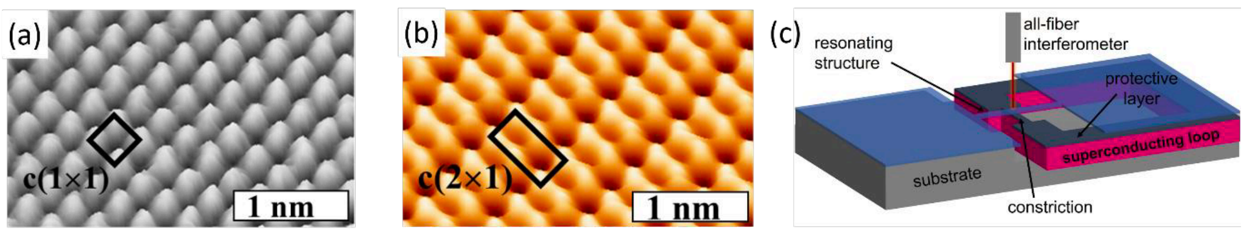

Fig. 1: (a) Atomically resolved structure of NiO(001) using AFM. Protrusion are the oxygen sites. **(b)** Antiferromagnetic order of the spins located at the Ni sites, i.e., the depressions, on NiO(001) using MExFM. **(c)** Sketch of the OXiNEMS hybrid magnetometer device.

[1] A Schwarz and R Wiesendanger, Nano Today **3** , 28 (2008).
[2] U Kaiser, A Schwarz and R Wiesendanger, Nature **446**, 522 (2007).
[3] www.OXiNEMS.eu; EU-Horizon 2020 programme: Grant Agreement 828784