MA 32: Magnetic Imaging Techniques I

Time: Wednesday 15:00–16:30 Location: HSZ 401

MA 32.1 Wed 15:00 HSZ 401

Correlating Magnetic Force Microscopy imaging with bulk Magnetometry for ferroelastic Fe7S8 inspection — •Samuel Seddon[1], Peter Milde[1], Marin Alexe[2], Charles Haines[3], Michael Carpenter[3], and Lukas Eng[1,4] — [1]TU Dresden, Institute of Applied Physics, Noethnitzer Straße 61, 01187 Dresden, Germany — [2]University of Warwick, Coventry, CV4 7AL, England — [3]Universtiy of Cambridge, Cambridge, CB3 0WA, England — [4]ct.qmat: Dresden-Wuerzburg Cluster of Excellence-EXC 2147, TU Dresden, 01062 Dresden

Pyrrhotite, Fe7S8, is a natural mineral exhibiting a strong magnetoelastic coupling - which is to say that the material's ferroelastic domains directly determine the allowed directions of its magnetic moments. This system provides an interesting environment to explore the role that a material's crystal structure has on its magnetic properties, on a unit-cellular level. Here, magnetic force microcopy (MFM) is used to directly correlate local magnetic switching behaviors with various features observed from the bulk magnetic hysteresis; a magnetic hysteresis as acquired from MFM field dependent measurements is visualized. Local magnetic domains thus can be directly correlated to the expected ferroelastic domain wall pinning, as well as to domains that are responsible for the differences observed in saturation magnetization. Preliminary results pertaining to the application of mechanical strain will also be presented.

MA 32.2 Wed 15:15 HSZ 401

Simultaneous Magnetic Field and Field Gradient Mapping of Hexagonal MnNiGa by Quantitative Magnetic Force Microscopy — Norbert H. Freitag[1], Christopher F. Reiche[2], Volker Neu[1], Parul Devi[3], Ulrich Burkhardt[3], Claudia Felser[3], Daniel Wolf[1], Axel Lubk[1], Bernd Büchner[1], and •Thomas Mühl[1] — [1]Leibniz Institute for Solid State and Materials Research IFW Dresden, 01069 Dresden, Germany — [2]Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT-84112, USA — [3]Max Planck Institute for Chemical Physics of Solids Dresden, 01187 Dresden, Germany

A quantitative, single-pass magnetic force microscopy (MFM) technique is presented that maps one magnetic stray-field component and its spatial derivative at the same time. This technique uses a special cantilever design and a special high-aspect-ratio magnetic interaction tip that approximates a monopole-like moment. Experimental details, such as the control scheme, the sensor design, which enables simultaneous force and force gradient measurements, as well as the potential and limits of the monopole description of the tip moment are discussed. To demonstrate the merit of this technique for studying complex magnetic samples it is applied to the examination of polycrystalline MnNiGa bulk samples. In these experiments, the focus lies on mapping and analyzing the stray-field distribution of individual bubble-like magnetization patterns in a centrosymmetric [001] MnNiGa phase. The results indicate that the magnetic bubbles have a significant spatial extent in depth and a buried bubble top base.

MA 32.3 Wed 15:30 HSZ 401

Quantum calibration of Magnetic Force Microscopy — •Baha Sakar[1], Yan Liu[2], Sibylle Sievers[1], Fedor Jelezko[2], and Hans W. Schumacher[1] — [1]Physikalisch Technische Bundesanstalt — [2]University of Ulm

Magnetic Force Microscopy (MFM) is a magnetic imaging technique that allows to image magnetic structures with nanometer resolution. However, per se it only delivers qualitative information since the magnetic properties of the tip are not known. The only method of obtaining quantitative information from these qualitative data is through a calibration. In this study we report the quantum calibration of a magnetic force microscope (MFM) by measuring the two-dimensional magnetic stray-field distribution of the MFM tip using a single nitrogen vacancy (NV) center in diamond. From the measured stray-field distribution and the mechanical properties of the cantilever a calibration function is derived allowing to convert MFM images to quantum calibrated stray-field maps. This approach overcomes limitations of prior MFM calibration schemes and allows quantum calibrated nanoscale stray-field measurements in a field range inaccessible to scanning NV magnetometry. Quantum calibrated measurements of a stray-field reference sample allow its use as a transfer standard, opening the road towards fast and easily accessible quantum traceable calibrations of virtually any MFM.

MA 32.4 Wed 15:45 HSZ 401

Controlled surface-modification to revive shallow NV^--centers — •Toni Hache[1,5], Jeffrey N. Neethirajan[1,2,5], Domenico Paone[1,2,5], Dinesh Pinto[1,3], Andrej Denisenko[2], Rainer Stöhr[2], Péter Udvarhelyi[4], Anton Pershin[4], Ádám Gali[4], Jörg Wrachtrup[1,2], Klaus Kern[1,3], and Aparajita Singha[1] — [1]Max Planck Institute for Solid State Research — [2]3rd Institute of Physics and Research Center SCoPE, University of Stuttgart — [3]Institute de Physique, École Polytechnique Fédérale de Lausanne — [4]Wigner Research Centre for Physics, Institute for Solid State Physics and Optics, Hungarian Academy of Sciences — [5]Equal contribution.

Nitrogen-vacancy (NV) centers in diamond have attracted an immense interest for non-invasive magnetic imaging and quantum sensing. All NV based magnetic sensing protocols rely on the negative charge state of this quantum sensor (NV^-). In this work we demonstrate dramatic charge state conversions within individual NV centers at cryogenic (4.7 K) and $2 \cdot 10^{-10}$ mbar ultra-high-vacuum (UHV) conditions. The NV centers are characterized based on autocorrelation measurements, ODMR contrast and emission spectra. Under these extreme conditions, each of these measurements indicate a significant decrease of the relative occupancy of the NV^- charge state. Furthermore, we note a slight recovery of the NV^- charge state by dosing water (H_2O) on top of the diamond surface under UHV conditions. These results indicate that controlled surface treatments are essential for implementing NV center based quantum sensing protocols at cryogenic-UHV conditions.

MA 32.5 Wed 16:00 HSZ 401

Deep learning assisted reconstruction of the magnetization from the 2D antiferromagnetic van der Waals material CrSBr — •Riccardo Silvioli, Michele Bissolo, Kartikay Tehlan, Martin Schalk, Ferdinand Menzel, Nathan P. Wilson, Andreas V. Stier, and Jonathan J. Finley — Walter Schottky Institute and TUM School of Natural Sciences, Technische Universität München

We investigate the layered antiferromagnet (AFM) CrSBr, a material with three phase transitions. Order within the layers ($T_{intra} \sim 160K$), order between the layers ($T_N \sim 135K$) and a low T phase close to 40K that is speculated to originate from the ordering of Br vacancies. We use widefield nitrogen vacancy (NV) vector magnetometry to investigate the magnetic phases of this material. We image the 3D magnetic stray field in the plane of the NV centers, located 100nm from the surface of the diamond. Retrieving information on the magnetization (M) from an NV measurement requires reconstruction of M. For out-of-plane M, this is an analytically solvable problem, whereas for in-plane M this problem is ill-posed. We employ a deep learning (DL) approach based on a convolutional neural network (CNN), in order to solve the inverse problem, and determine M from the data. We apply additional constrains to the CNN to follow Maxwells equations by incorporating micro magnetic simulations in the computation of loss during the training phase. We discuss the advantages of this physics informed CNN training approach and compare it to conventional CNN methods as well as reconstruction efforts.

MA 32.6 Wed 16:15 HSZ 401

Magnetic imaging with spin defects in hexagonal boron nitride — Pawan Kumar[1], Florentin Fabre[1], Alrik Durand[1], Tristan Clua-Provost[1], Jiahan Li[2], James H. Edgar[2], Nicolas Rougemaille[3], Johann Coraux[3], Xavier Marie[4], Pierre Renucci[4], Cédric Robert[4], Isabelle Robert-Philip[1], Bernard Gil[1], Guillaume Cassabois[1], •Aurore Finco[1], and Vincent Jacques[1] — [1]Laboratoire Charles Coulomb, Université de Montpellier, CNRS, Montpellier, France — [2]Tim Taylor Department of Chemical Engineering, Kansas State University, Manhattan, Kansas, USA — [3]Université Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, Grenoble, France — [4]Université de Toulouse, INSA-CNRS-UPS, LPCNO, Toulouse, France

Optically-active spin defects hosted in hexagonal boron nitride (hBN)

are promising candidates for the development of a two-dimensional quantum sensing unit. Here, we demonstrate quantitative magnetic imaging with hBN flakes doped with negatively-charged boron-vacancy ($V_B{}^-$) centers through neutron irradiation [1]. As a proof-of-concept, we image the magnetic field produced by $CrTe_2$, a van der Waals ferromagnet with a Curie temperature slightly above 300 K. The advantages of the hBN-based magnetic sensor described in this work are its ease of use, high flexibility and, more importantly, its ability to be placed in close proximity to a target sample and included in van der Waals heterostructures.

[1] Kumar et al, arXiv 2207.10477 (2022).