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U. Hartmann
MAGNETIC MICROFIELD ANALYSIS BY FORCE MICROSCOPY

The potential of magnetic force microscopy (MFM) for a nondestructive, highresolution, and quantitative imaging of magnetic microstructures is discussed. Experimental examples are provided by MFM data of Bloch walls and digital bit structures on a commercial magnetic recording medium.

Proc. EMMA'89 Conference, Rimini, Italy, 1989; J. Magn. Magn. Mat. ***83****, 545 (1990)*

U. Hartmann
MAGNETIC FORCE MICROSCOPY: A HIGH-RESOLUTION TECHNIQUE FOR MICROFIELD ANALYSIS
Proc. SMM'9 Conference, El Escorial, Spain, 1989; Anal. Fisica B ***40****, 67 (1990)*

U. Hartmann
THEORY OF MAGNETIC FORCE MICROSCOPY

A theory is presented describing the fundamentals of contrast formation in magnetic force microscopy (MFM). In particular, effects due to the finite MFM probe size are taken into account. As a result, complete MFM images can be simulated in good agreement with experimental data employing only minimum information about the actual probe configuration. As an example, the 180° Bloch wall in iron is considered.

Proc. STM'89 Conference, Oarai, Japan, 1989; J. Vac. Sci. Technol. A ***8****, 411 (1990)*

T. Göddenhenrich, H. Lemke, U. Hartmann, and C. Heiden
MICROSCOPE WITH CAPACITIVE DISPLACEMENT DETECTION

We developed a force microscope using a capacitively controlled lever displacement. Both mechanical construction and electronics are simple and lead to a very compact device. Different measurement modes of the microscope are described. In the constant-capacitance mode the observed capacitance between tip and sample is in the order of femtofarad. In the force mode, various tip-sample interactions are investigated under ambient air. The obtained force resolution is comparable to that of laser-controlled atomic force microscopy. As an application, the magnetic force signal between the tip and the local surface–microfield configuration of a bit structure in a magnetic recording medium was imaged.

Proc. STM'89 Conference, Oarai, Japan, 1989; J. Vac. Sci. Technol. A ***8****, 383 (1990)*

U. Hartmann
MANIFESTATION OF ZERO-POINT QUANTUM FLUCTUATIONS IN ATOMIC FORCE MICROSCOPY

Based on rigorous quantum-field theory, long-range probe-sample dispersion forces in atomic force microscopy are analyzed. The interactions, being attractive or repulsive, can be divided into a purely geometrical part, depending on probe geometry and working distance, and a solely material-dependent part given in terms of the dielectric permittivities involved. The calculations are consistent with published experimental data and promise new analytical possibilities opened by ``dispersion microscopy."

*Phys. Rev. B **42**, 1541 (1990)*

T. Göddenhenrich, H. Lemke, U. Hartmann, and C. Heiden
MAGNETIC FORCE MICROSCOPY OF DOMAIN-WALL STRAY FIELDS ON SINGLE CRYSTAL IRON WHISKERS

Using a capacitively controlled force microscope we have imaged typical domain wall configurations like 90° closure structures and subdivided 180° wall segments in single-crystal iron whiskers. Differences in wall contrast between 90° and 180° domain walls are clearly observed. The effect of tip-to-sample distance on lateral resolution and wall contrast in magnetic force microscopy is shown.

*Appl. Phys. Lett. **56**, 2578 (1990)*

R. Berthe, U. Hartmann, and C. Heiden
SCANNING TUNNELING MICROSCOPY OF THE ABRIKOSOV FLUX LATTICE WITH FERROMAGNETIC PROBES

Using a low-temperature scanning tunneling microscope spatial variations of the current-voltage characteristics have been investigated on $NbSe_2$ single crystals employing PtIr and ferromagnetic Ni tips. At 4.2 K a clear superconducting energy gap is visible even when tunneling through the Ni tip. After field-induced transfer of the sample into the superconducting mixed state a complete Abrikosov flux lattice is imaged for both types of probes by recording the tunneling current at a fixed voltage within the superconducting gap. Comparison of the images obtained by the two probe materials clearly shows that no distortion of the flux lattice is produced by magnetostatic interactions between the ferromagnetic tip and the individual vortices. This provides the basis for future investigations of flux distributions in superconductors by magnetic force microscopy.

*Appl. Phys. Lett. **57**, 2351 (1990)*

U. Hartmann
INTERMAG'90 CONFERENCE IN BRIGHTON - CONFERENCE REPORT

The 1990 INTERMAG Conference was held from April 17- 20 at the Metropole Hotel in Brighton, UK. The meeting was sponsored by The Magnetics Society of The Institute of Electrical and Electronics Engineers (IEEE) and was perfectly managed by Brighton Polytechnic. For more than 1200 participants an outstanding opportunity was provided to meet with colleagues and discuss new and controversal developments in all branches of magnetics and related technology. The diversity of magnetics was underlined by the about 630 contributions related to 34 different topics which were presented in 35 oral and 20 poster sessions. 21 invited and more than 600 contributed papers had to be presented in up to seven parallel sessions. Additionally, a technical exhibition of materials, services, instruments and literature was held during the conference.

Adv. Mater. ***2****, 380 (1990)*

H. Lemke, T. Göddenhenrich, H.P. Bochem, U. Hartmann, and C. Heiden
IMPROVED MICROTIPS FOR SCANNING PROBE MICROSCOPY

Improved electrochemical techniques for the reproducible fabrication of sharp metallic tips are presented. Radii of curvature down to 10 nm make the tips particularly suitable for scanning tunneling microscopy (STM) and atomic force microscopy (AFM). Additionally, simple methods are developed for preparing AFM cantilevers. A new type of spherical probe suitable for long-range scanning force microscopy has been fabricated. The probes consist of nearly perfect spheres with adjustable radii between about 50 and several 100 nm deposited at the very tip of tiny probe holders. Both probe and probe holder may consist of any metal. First experimental investigations confirm that the spherical probes are particularly suitable for van der Waals and magnetic force microscopy.

Rev. Sci. Instrum. ***61****, 2538 (1990)*

U. Hartmann
MAGNETIC FORCE MICROSCOPY

Magnetic force microscopy (MFM) is a technique related to atomic force microscopy (AFM) [l]. A ferromagnetic microprobe is attached to a highly f1exible cantilever beam, and the sample is mounted on a three-dimensional piezo translator (Fig. 1). Magnetostatic interactions of the scanning probe with the sample are detected through microscopic lever def1ections and are converted into an electrical voltage by a deflection sensor. A feedback loop then allows operation of the microscope in a constant force mode or, alternatively, in a constant-compliance mode. Various schemes for the detection of magnetostatically-induced cantilever deflections are summarized in Figure 2. The ultimately obtained force sensitivity is limited by thermal fluctuations and amounts to several pN under ambient conditions. The basic instrumentation can be considered as largely optimized.

Adv. Mater. ***2****, 550 (1990)*

T. Göddenhenrich, H. Lemke, M. Mück, U. Hartmann, and C. Heiden
PROBE CALIBRATION IN MAGNETIC FORCE MICROSCOPY

Quantitative image interpretation in magnetic force microscopy requires information about the geometric and magnetic configuration of the employed microprobe. If the magnetic microfield of a given sample is known in detail, a calibration of the probe is possible. Using the well-defined current-induced microfield of a nanolithographically structured conducting pattern, calibration measurements combined with model calculations provide an insight into the effective domain configuration of magnetic force microscopy probes.

Appl. Phys. Lett. ***57****, 2612 (1990)*

U. Hartmann
VAN DER WAALS INTERACTIONS IN FORCE MICROSCOPY

Van der Waals (VDW) interactions arise, apart from permanent polarization effects, from instantaneous moments of atoms or molecules (Fig. 1). The quantum fluctuations involved are mostly in the UV range and play an important role in optical dispersion. In scanning force microscopy VDW forces are ever-present, but are, however, frequently masked by other contributions, such as short-range repulsive contact forces or long-range surface tension, electrostatic, and magnetostatic forces.

Adv. Mater. ***2****, 594 (1990)*

U. Hartmann, T. Göddenhenrich, H. Lemke, and C. Heiden
DOMAIN-WALL IMAGING BY FORCE MICROSCOPY
Proc. Intermag'90 Conference, Brighton, U.K., 1990; IEEE Trans. Magn. ***26****, 1512 (1990)*