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HIGH RESOLUTION MAGNETIC IMAGING BASED ON SCANNING PROBE TECHNIQUES

Scanning tunneling microscopy (STM) which was invented in 1981, stimulated the development of various scanning probe methods which became important analytical tools in many branches of solid state research. In the meantime, some of the STM offsprings, especially atomic force microscopy (AFM), even became relevant for industrial applications, e.g., for routine sub-µm quality control measurements. Systematic applications of the new techniques in the analysis of magnetic materials started in 1987 with the invention of magnetic force microscopy (MFM). Subsequently spin-polarized scanning tunneling microscopy (SPSTM) and scanning near-field optical microscopy (SNOM) were shown to be at least potentially ultrahigh-resolution magnetic imaging techniques. In the following, a review is given on the state of the art in magnetic imaging by scanning probe microscopies. Special emphasis is put on the capabilities, on still remaining problems and on present trends in the development of further related techniques.

Proc. EMMA 95, Vienna, Austria, 1995; J. Magn. Magn. Mat. ***157/158****, 545 (1996)*

F. Mielke, U. Memmert, A.A. Golubov and U. Hartmann
SCANNING TUNNELING SPECTROSCOPY ON LOW AND HIGH Tc SUPERCONDUCTORS

Using some sophisticated modes of scanning tunneling spectroscopy the local density of states on two superconducting compounds in the superconductive state at 4.2 K were analyzed. On NbSe2 which is a type-II low-Tc material, the Abrikosov flux line lattice was imaged for various external magnetic fields up to BC2. The field-induced decrease of the vortex core radius for increasing magnetic field, which was recently predicted by a microscopic theory, could be clearly verified. On sputtered YBa2Cu3O7 – films the measurements yielded some distinct types of the surface density of states involving gaps, being in accordance to the Bardeen–Cooper–Schrieffer theory, unexpectedly large gaps, Coulomb staircases, and zero-bias peaks.

Proc. STM 95 Conf., Snowmanss, USA, 1995; J. Vac. Sci. Technol. B ***14****, 1224 (1996)*

U. Memmert, U. Hodel, and U. Hartmann
COMBINED ULTRAHIGH VACUUM SCANNING TUNNELING MICROSCOPE SCANNING ELECTRON MICROSCOPE SYSTEM

We describe a combined ultrahigh vacuum scanning tunneling microscope (STM)–scanning electron microscope (SEM) system, which allows to position the STM tip with respect to the sample within an area of 5mm × 5mm under SEM control. While the SEM resolution is sufficient to clearly resolve sub-μm structures on the samples, the STM features atomic resolution on semiconductor surfaces. The combination of SEM and STM allows high-resolution studies on inhomogeneous samples in materials research as well as the use for micro- and nanoelectronic device characterization or device modification. The STM performance was checked by atomically resolved imaging of Si(111) (7×7) surfaces. The STM/SEM combination and its application in device characterization is demonstrated by the investigation of vertically grown resonant tunneling diodes on an AlAs/GaAs basis. Due to its performance the system has a high potential for high-resolution imaging in materials research, for novel device characterization and nanoscale structuring or modification of very small devices.

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THEORY OF NON-CONTACT FORCE MICROSCOPY
in: ***Scanning Tunneling Microscopy III: Theory Of STM And Related Techniques****, Eds. H.-J. Güntherodt and R. Wiesendanger, Springer Series in Surface Sciences* ***29****, 294 (2nd ed., 1996)*

U. Hodel, U.Memmert, and U. Hartmann
LOCAL MODIFICATION OF Ag THIN FILMS ON Si(100) BY SCANNING TUNNELING MICROSCOPY

20-nm-thick Ag films, deposited on UHV-cleaned Si(100) surfaces, can be substantially modified with a scanning tunneling microscope used in an oscillatory mode with junction voltages above +3 V-+4 V and currents between 0.1 and 30 nA. During modification, the tip-surface junction is quite unstable, with repeated instabilities leading to vertical tip motions of up to 150 nm in amplitude. Material is drawn toward the tip, leaving on the surface about 100-nm-high cones with a base diameter of approximately 150-300 nm that are surrounded by 50-100-nm-wide areas, where the bare substrate is exposed. Upon moving the tip across the surface, arbitrary lines can be written into the film. The width of the created surface structures increases linearly with increasing junction voltage from 4-9 V, and logarithmically when increasing the current from 30 pA to 30 nA. The experimental data suggest that the modification process is caused by an electronic field emission out of the tip, leading to heating and melting of the Ag film locally underneath the tip. At voltages of 4-8 V an unstable switching between field emission and tip-sample contact with a formation of a liquid-metal neck in the junction results in large-amplitude tip oscillations.

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