Magnetic Sensitive Force Microscopy

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Magnetism is a scientifically very interesting and technological extremely important phenomenon. Its existence is long known to mankind and nowadays still essential to further miniaturize magnetic data storage devices or to develop novel sensor elements in, e.g., automobiles or consumer electronic products. Force microscopy actually provides two tools to investigate magnetic phenomena on the nanometer down to the atomic scale: magnetic force microscopy (MFM) [1], introduced already 1987, shortly after atomic force microscopy has been invented 1986, and magnetic exchange force microscopy (MExFM) [2], an approach proposed in 1990 [3], but which could only be realized in 2007.

After a general introduction to magnetism, its origin and the relevant energy contribution, which fundamentally determine the magnetic state of a system, both microscopy techniques will be described in detail: tip preparation, separation of magnetic forces from other forces, imaging modes, etc. Thereafter, some examples will be presented to demonstrate the capabilities of both techniques: Visualization of the Barkhausen effect, imaging the melting of a flux line lattice, mapping antiferromagnetic spin structures with atomic resolution, determining magnitude and distance dependence of the magnetic exchange interaction, etc. Finally, the issue of thorough image analysis will be discussed, as this is very important to avoid false interpretation of contrast patterns.

References

[1] *Magnetic Imaging by 'Force Microscopy' with 1000 Å Resolution*; Y. Martin and K. Wickramasinghe, Appl. Phys. Lett. **50**, 1455 (1987).

[2] *Magnetic Exchange Force Microscopy with Atomic Resolution*; U. Kaiser, A. Schwarz, and R. Wiesendanger; Nature **446**, 522 (2007).

[3] *Vacuum Tunneling of Spin-Polarized Electrons Detected by Scanning Tunneling Microscopy*; R. Wiesendanger *et al.*; J. Vac. Sci. Technol. B **9**, 519 (1990).