Magnetic Sensitive Force Microscopy

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Magnetism is an intriguing and, from a technological perspective, an extremely important phenomenon. Its existence is long known to mankind and nowadays still essential for data storage and sensing in, e.g., automobiles or consumer electronic products. Miniaturization asks for tools to investigate magnetic structures with high resolution and high sensitivity. Force microscopy provides two tools to study magnetism on the nanometer down to the atomic scale: magnetic force microscopy (MFM) [1], introduced already 1987 just one year after atomic force microscopy has been invented, and magnetic exchange force microscopy (MExFM), which could be realized in 2007 [2].

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 as well as spectroscopic modes, etc. Thereafter, some examples will be presented to demonstrate the capabilities of both techniques: imaging ferromagnetic domains, visualization of flux line lattice in superconductors, mapping antiferromagnetic spin structures with atomic resolution, determining magnitude and distance dependence of the magnetic exchange interaction. Finally, the issue of thorough data analysis will be discussed, as this is very important to avoid false interpretation of contrast patterns.

[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).