Force Microscopy Experiments with Ultrasensitive Cantilevers

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Force microscopy experiments are performed with atto-Newton-sensitivity. Cantilevers with sub-mN-spring constants are annealed under ultrahigh vacuum conditions. It is found that annealing with temperatures below 500°C can improve the quality factor by an order of magnitude. A second important pre-requisite for ultra-sensitive force measurements is to detect frequency shifts as accurate as possible. A novel digital phase locked loop has been developed, where micro-Hz frequency shifts can be detected. Variable temperature experiments will be presented, where the mechanical properties of elastic modulus and Q-factor are described by continuum models [1]. The Debye temperature of the cantilever is determined from frequency shift measurements. Some insights into internal friction will be given. The transition of a superconducting sample mounted on a cantilever is measured by the detection of frequency shifts. An increase of dissipation is observed below the critical temperature.

The dissipation between the probing tip and the sample is another important ingredient for ultrasensitive force measurements. It is found that dissipation increases at separations of 100nm. The origins of this type of dissipation are poorly understood. However, it is predicted theoretically that adsorbates can increase this dissipation channel [2]. First experiments are performed under ultrahigh vacuum to reduce this type of dissipation.

Variable temperatures with ultrasensitive cantilevers are performed on quantum dots, which exhibit Coulomb blockade. Magnetic resonance force microscopy (MRFM) with the novel OSCAR-scheme [3] are performed, where small numbers of electron spins can be observed and manipulated.

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[3] D. Rugar et al., *Nature* **43**, 329 (2005).

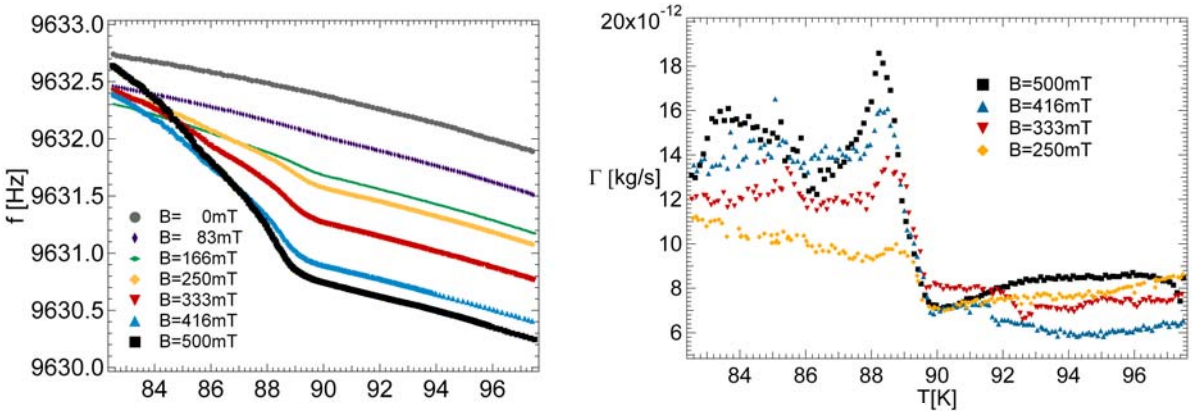

Fig.1 : Observation of the phase transition of a superconductor mounted on a cantilever by the detection of frequency shifts and