ADVANCED MAGNETOMETRY

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Introduction:

I will elucidate why the measurement of the magnetization of particles with (sub-) nm-scale dimensions is scientifically interesting and experimentally demanding. In short, the scientific interest is due to often novel magnetic properties of particles of reduced dimensions. For example, both magnetization and magnetic anisotropy are expected to deviate sharply from the respective bulk quantities. The ever increasing influence of strain, interfaces, adsorbate coverage, and atomic coordination on the magnetic anisotropy has been clearly demonstrated experimentally and theoretically [1,2], corresponding experimental data on the magnetization of nanoparticles are rare. The limited experimental activity on quantitative magnetometry on of nanoparticles is surprising at first sight, as the determination of the saturation magnetization and of the magnetization vs. applied magnetic field, i.e. the hysteresis curve of nanoparticles, are of fundamental interest. The lack of abundant experimental data on magnetization can be partially ascribed to significant experimental challenges connected with the strive for accurate quantitative results. The basic requirements regarding sensitivity and accuracy of magnetometry on the nanoscale will be reviewed. A short refresher on the units of magnetism (magnetic field strength, magnetic moment, and magnetization) will be given [3].

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Experimental techniques

Several techniques have been established for the magnetometry of bulk samples [4]. I will review those techniques which have been adjusted to meet the requirements for magnetometry of nanoscale particles. Vibrating sample magnetometry [5], SQUID magnetometry [6], alternating gradient magnetometry [7], and torque magnetometry [8] will be briefly reviewed. I will discuss how these venerable techniques have been adjusted to meet the requirements for magnetometry on the nanoscale. Special emphasis will be given to torsion oscillation magnetometry [9] and to recent advancements regarding cantilever magnetometry [10], micromechanical torque magnetometry [11], and SQUID magnetometry [12]. Micro SQUID and Hall microprobe have been discussed in a previous summer school, and the audience is referred to the respective reference for further details [12].

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Selected results

Selected results will be discussed which demonstrate the capabilities and limits of different magnetometers. The application of torque magnetometry for the determination of magnetic anisotropy will be discussed [13]. The determination of the magnetization of ferromagnetic monolayers by cantilever magnetometry will be presented [10]. SQUID magnetometry of Co monolayers indicates a possible enhancement of the saturation magnetization with decreasing film thickness in the monolayer range [12]. These results are discussed in view of theoretical predictions [14, 15]. In an outlook the potential for single spin detection using micromechanical sensor is discussed [11].

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