CHARACTERIZATION OF MAGNETIC FORCE MICROSCOPE PROBES FOR QUANTITATIVE MAGNETIC FIELD MAPPING AT MICRON LENGTH SCALES

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Abstract

Magnetic Force Microscopy is used to image magnetic features at micron length scales in many situations. For the image contrast to be quantitative the tip of the scanning probe needs to be characterised. Methods for achieving this are being developed and will be presented.

Introduction

With recent advances in thin film fabrication and lithography, new magnetic properties have been observed and these have many applications in industries as diverse as space exploration and high-density information storage. An example is provided by the Giant MagnetoResistance (GMR) exhibited by magnetic multilayers and spin valves [1]. The application of this and many other novel properties requires detailed knowledge of the micromagnetic mechanisms controlling the behaviour. Since many applications use patterned magnetic films these properties are required on a local scale over distances of a few microns or less. Magnetic Force Microscopy (MFM) is a popular choice due to relatively low cost and ease of use [2]. Methods for determining quantitative information using MFM will be discussed.

Magnetic Force Microscopes

Magnetic imaging using Magnetic Force Microscopes is a special mode of atomic force imaging. The principle involves coating the tip of the probe with a suitable magnetic material. The actual material selected depends on the type of surface being imaged since the stray magnetic fields from the magnetic tip can magnetise the surface and vice versa. Two cases are usually considered in which the tip material is either magnetically soft or hard and either reverses during scanning or remains fixed respectively. Such ideal behaviour cannot be achieved and so it is necessary to determine the reversal and contrast characteristics of the magnetic force probe at regular intervals during their use. With this information quantitative analyses of the image can be considered.

Reference surfaces to establish the behaviour of the magnetic force probe are being developed and will be reported during the conference. One approach will be to use a surface network of fabricated current carrying wires with suitable width and spacing. For the geometry of these wires and the applied current density the magnetic field profile can be calculated. By scanning a magnetic force tip over such a surface at different lift off heights the reversal and contrast properties of the tip will be determined. This is shown schematically in Figure 1.

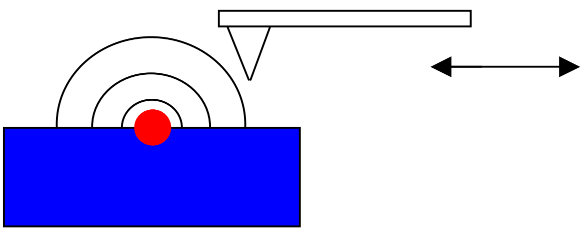

Figure 1. Magnetic field distribution generated by current carrying conductor and imaged by the scanning tip.

During imaging, the magnetic material of the MFM probe that is involved in the imaging process is located on the tip of the probe. Referring to Figure 1, the magnetic signal originates from material on the surface of the triangle and principally the material near the apex. The magnetic material that coats the cantilever of the probe and possibly also the substrate are not significantly involved in the imaging process. Because of the shape of the MFM tip, the anisotropy contribution this makes alters the magnetic behaviour of the magnetic material on the tip compared to that of a bulk specimen of the same material. Any method for characterising the magnetic behaviour of MFM tips therefore needs to be sensitive to the magnetic material of the MFM tip.

Theoretical work [3] has shown that the calibration of an MFM tip will involve the determination of parameters that are related to the quantity and distribution of the magnetic material involved in the imaging. Three quantities; magnetic monopole moment, magnetic dipole moment and their imaginary location within the real physical thin film have been identified and these need to be determined in a way that is independent of the topology of the reference surface used. Early work has shown that the value of these three quantities depends on the spatial distribution of the magnetic profile being imaged. In particular, it is the decay length of the magnetic field that is important. It is therefore necessary to establish a reference surface that allows the calibration of the MFM tip to be made for similar decay characteristics.

Details will be presented on the design of a current network that can achieve this as well as a novel approach to eliminating contributions to the image from the surface topography. Since the magnetic field gradients necessary to produce an image are generated near the edges of a conductor where the wall can be steep, this significantly improves the confidence with which the reference surface can be used for MFM tip calibration since the sensitivity to the speed of the scan is considerably reduced.

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