SUB-NANOSECOND MAGNETORESISTANCE MEASUREMENTS OF SWITCHING TRANSIENTS

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Introduction

To complement optical studies of magnetic reversal, high speed magnetoresistance (MR) measurements are a quick method to study the dynamics of the magnetization switching behavior of small size ferromagnetic elements [1-2], a topic with considerable significance for fields such as high speed sensor systems and MRAM. We decouple parasitic capacitive effects and aim to provide a systematic study of the parameters that affect the switching transients.

Results

Our test structure consists of coplanar waveguide write and read lines contacting an exchange biased spin valve. Fast risetime (350 ps) reversal pulses are sent through the 50 Ohm terminated 20 μm wide write line. A bias tee is used to send a DC current of 10 mA through the read line and the MR response of the spin valve is measured by probing the voltage change during the reversal with a sampling oscilloscope.

For a $5 \times 20 \mu\text{m}^2$ element the MR response versus write pulse amplitude is shown in figure 1. At low amplitude pulsing one can clearly see a stochastic and slow switching process. At higher amplitudes the switching is deterministic at all times and the inverse rise time is linearly dependent on the switching field amplitude. For even higher fields, the pinned layer starts to switch before the full MR signal is reached.

Influence of scaling is studied by comparison of switching curves for different sizes of spin valves (see figure 2). For these sizes no clear influence of scaling can be seen. This can be understood from the micromagnetic argument that the demagnetizing field scales with the element and also suggests switching is not occurring via domain wall motion. A challenge is to measure accurate transients on small size devices down to $0.5 \times 2 \mu\text{m}^2$ and various aspect ratios as our data have shown significant scatter at present.

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² R. H. Koch et al, Phys. Rev. Lett. **81**, 4512-4515 (1998).

Figure 1: High speed MR Response of a spin valve for different write pulse amplitudes.

Figure 2: Comparison of the rise time of the free layer reversal for different sized spin valve elements.

HIGH RESOLUTION MAGNETIC FORCE MICROSCOPY USING FOCUSED ION BEAM MODIFIED TIPS.

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Magnetic force microscopy (MFM) is well established for imaging surface magnetic stray fields. With commercial microscopes and magnetic tips, images with 50nm resolution are quite routine; however, obtaining higher resolutions is more demanding experimentally [1]. Higher resolution is required for imaging patterned magnetic elements and the latest magnetic media where bit lengths are less than 40 nm [2].

Sub-30 nm resolution images have been obtained using Nanosensors Pointprobe Si tips coated with Co and modified by focused ion beam (FIB) milling. Imaging was performed at room temperature, in air, with a Digital Instruments D3100 MFM in tapping/lift mode.

Fig. 1 shows tips modified with an FEI200 FIB workstation equipped with a 30kV Ga⁺ ion beam. The Co elements at the apex of the tips possess end radii $\leq 25\text{nm}$. Tip (a) tapers from a width of 278nm and has an aspect ratio (AR)=30:1 while tip (b) is of constant width (50nm) and AR=20:1. Unlike previous FIB modified tips, used for quantifying fields and imaging in-plane media [3], these tips approximate the ideal MFM tip shape: a thin bar with small cross-sectional area (for maximum resolution) and high AR (for stable magnetisation) [4].

Fig. 2 shows MFM images obtained with a minimum tip-sample distance of 15nm. The images are of domains located at the periphery of a bit written in a reference sample [5] consisting of a 20 bilayer (5.5Å Co₅₀Ni₅₀/12Å Pt) MO thin film possessing perpendicular magnetic anisotropy. Fig. 3 shows scan lines through the arrows in Fig. 2, indicating features with a FWHM $\leq 30 \text{ nm}$. Line A was obtained with tip (a) and lines B and C with tip (b).

The calculated spatial response of these tips will be compared with experimental data, and the observation of features with a FWHM as small as 14nm will be discussed.

Fig. 1. Tips.

Fig. 2. MFM Images.

Fig. 3. Line scans.

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