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TITLE:

On the origin of multi-peak and asymmetric behaviour of microstructured thin-film Permalloy GMI devices in the high frequency regime

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ABSTRACT BODY:

Digest Body:

We report a complex phenomenology and present a comprehensive investigation of the link between domain structures and the giant magnetoimpedance transport behavior of differently stacked multilayer microstructures using Permalloy as the magnetic sensing layer. For this we have fabricated microstructured GMI thin-film multilayers (400-200µm length, 40-10µm width) integrated into coplanar waveguides by a multi-level ebeam and optical lithography process. The multilayers are dc magnetron-sputtered in a transveral field of 250 Oe to induce a transveral anisotropy and consist of a Cu core layer (250nm thickness) surrounded by magnetic single (Py100nm) and multilayers ($[Py100nm/Ti5nm]_x$). Dipolar coupling becomes non-negligible in such multilayers and strongly influences the GMI curve shape and sensitivity. This questions the applicability of larger ”film-like” highly sensitive thin-film GMI mulitlayer devices so far reported in the literature at such a scales [1,2]. Our analysis demonstrates the limits of finite-element simulation of the GMI effect for finding highly sensitive multilayer systems. Such approaches often assume the simplified Stoner-Wolfahrth model with coherent magnetization rotation and no domains. In contrast we explain by widefield MOKE microscopy and MFM analysis how the mechanism of magnetization reversal determines via dipolar coupling, incoherent magnetization rotation, domain wall movement and nucleation the slope, multi-peak and asymmetry of the GMI curve for the different multilayer systems. From the Kerr-contrast change only the hysteresis curves of the top layer of the microstructures can be deduced. Therefore we also fabricate arrays of such microstructures to overcome the sensitivity limit in our VSM and to reveal the hysteresis curve of the complete multilayer and the dipolar interaction between all layers showing significant differences for odd and even overall layer number and strongly determining the slope of the GMI curve and the field sensitivity. Micromagnetic simulations employing the MUMAX framework qualitatively match MOKE-microscopy and VSM results well. Multi-peak GMI curves are showing up in low-aspect-ratio single layer microstructures within the skin-effect regime while at high aspect ratio and in the FMR regime, independently of aspect ratios, a double-peak behavior is present. Microstructural TEM analysis of FIB slices of the interfaces shows that Ti spacers prevent an intermixing/interdiffusion of Permalloy and Cu at the interfaces. Such and intermixing/interdiffusion can lead to complex domain structures and an asymmetric magnetization reversal mainly governed by magnetization rotation or domain-wall nucleation and movement in different branches of the hysteresis curves. Fig. 1 shows some steps of this reversal. Our results pose the question on possible downscaling limits of Permalloy-based GMI thin-film sensors to retain high field sensitivity but emphasize a wider use of micromagnetic simulations and domain-imaging methods at such length scales in order to further speed up the optimization of GMI sensors.

References:

[1] Fernández, E. et al., (2015). High-Frequency Magnetoimpedance Response of Thin-Film, *51*(1), 2–5.

[2] Bohn, F. et al., (2014). Magnetoimpedance effect at the high frequency range for the thin film geometry: Numerical calculation and experiment. *JAP*, *116*(24), 243904.

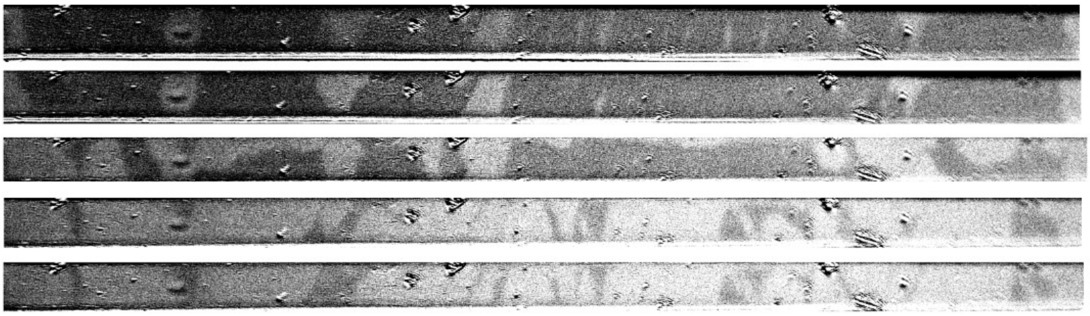

Figure 1: Longitudinal Kerr-microscopy image sequence for a multilayer system showing an asymmetric GMI curve. The external field was swept from left/negative to right/positive. Field values from top to bottom are, -4.3 Oe, 0 Oe, 2.4 Oe, 3.3 Oe, 4.3 Oe. For negative field mainly magnetization rotation determines the reversal, while for positive field up to saturation domain nucleation and movement dominate the reversal.

IMAGE CAPTION:
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