Occurrence and control of domain-wall resonance in thin-film giant magneto-impedance sensors

Gregor Buettel[1], Uwe Hartmann[1]

[1]Institute of Experimental Physics, University Saarland, Germany

Thin-film microstructured Permalloy-based giant magneto-impedance (GMI) sensors of different aspect ratios and multilayer structures were fabricated. Transport and magneto-optical characterization show a rich phenomenology of magnetic domains and varying magnetization reversals in such devices. The effective transversal anisotropy depend on the aspect ratio and dipolar coupling. The latter depends on whether there is an odd or even number of magnetic layers and on the interacting stray field. Depending on anisotropy and dipolar coupling the domain-wall resonance (DWR) becomes differently pronounced in the low-field regime being relevant for magnetic field detection. Additional peaks in the GMI curve appear due to such resonances and limit the field sensitivity in the MHz frequency regime as shown in Fig. 1. On the other hand, a change of the impedance in small GMI sensors with a high domain-wall density due to a change of the permeability induced by DWR might allow operation of such sensors at a smaller frequency than given by the ferromagnetic resonance condition. Additionally, the skin effect becomes rather small at a width of a few micrometers in the low-frequency regime. The observed DWR is strongly dependent on the flux closure between individual magnetic layers within the multilayer system, which could be utilized for the detection of magnetic nanoparticles altering this flux closure during approach to the sensor.

Methods to force and bypass the occurrence of DWR in Permalloy-based GMI sensors are discussed. While the first task can be accomplished by deposition of a multilayer system exhibiting vortex domain walls, the latter task can be achieved by annealing, operation of the sensor at appropriate frequencies or ac current magnitude, or by a layer design favoring magnetization rotation over domain transformation during the magnetization reversal. Tensile/compressive stress applied to the GMI elements upon integrating them onto Si cantilevers lead to a broadening/attenuation of the DWR in the impedance curve. The results imply different ways how planar GMI sensors at the microscale could be optimized for field, stress and magnetic particle detection.

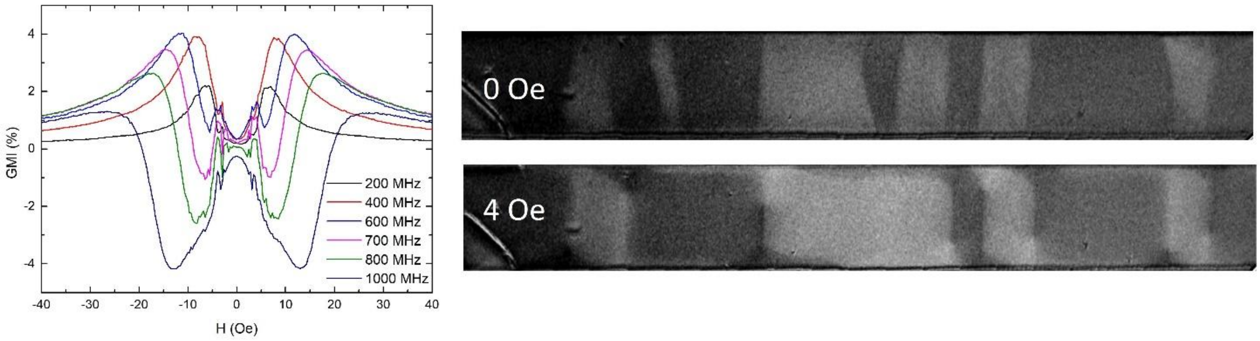

Figure 1. Left: Measurement of the GMI ratio by a vector network analyzer showing DWR emerging between 600-800 MHz. Right: Magneto-optical microscopy of the same GMI element (400x30µm² lateral dimensions, NiFe(100nm)/Cu(250nm)NiFe(100nm) layer structure) reveals vortex/anti-vortex domain walls in the field regime of DWR