Nonreciprocal spin wave dynamics in uniformly and nonuniformly magnetized symmetric Pt/Co/Pt multilayers

A. Dhiman,[1] R. Gieniusz,[1] P. Mazalski,[1] J. Kisielewski,[1] Z. Kurant,[1] M. Matczak,[2] F. Stobiecki,[2] N. Lesniewski,[3] P. Gruszecki,[3] M. Krawczyk,[3] and A. Maziewski[1]

[1] *Department of Physics of Magnetism, Faculty of Physics, University of Bialystok, Bialystok, Poland*

[2] *Institute of Molecular Physics, Polish Academy of Sciences, Poznan, Poland*

[3] *Faculty of Physics, Adam Mickiewicz University, Poznan, Poland*

In modern times, magnetic multilayers are considered as a building block of various magnetic memory applications such as magneto-resistive heads, magneto-optical recording devices [1]. Magnetic excitations of multilayers contain intriguing physics related to exchange interactions and spin configurations. A symmetric multilayer of Pt/Co/Pt was deposited, on an oxidized silicon substrate, by dc magnetron sputtering with a nominal structure of Ti(4)/Pt(29.3)/$[Pt(0.7)/Co(2.2)]_{24}$/Pt(3) (all thicknesses are given in nm). The sample was characterized by: (i) vibrating sample magnetometry, (ii) magneto-optical Kerr effect magnetometry and microscopy, and (iii) magnetic force microscopy. The following hybrid magnetization structure was deduced: (i) large with size in sub micrometer scale domains with in-plane "core magnetization", these domains are responsible for magnetization hysteresis driven by in-plane applied magnetic field H, and (ii) small – in nanometer scale "weak stripe domains" with opposite out-of-plane magnetization component, realizing demagnetized remanent state. Optical Brillouin light scattering (BLS) spectroscopy was used to observe the multimode dispersion characteristics in the in-plane magnetic saturation state as well as in the remanent state, in the presence of a stripe domain structure [2]. In both cases, some excitations were characterized by strong non-reciprocity (difference between the frequencies of the Stokes f_{St} and anti-Stokes f_{aSt} peaks, $\Delta f = f_{aSt} - f_{St}$, increased with the increase of the wave vector) in comparison to other frequency modes with $\Delta f = 0$. Magnetization dynamics have also been studied using cavity based X-band (9.5 GHz) ferromagnetic resonance (FMR) and broadband Vector Network Analyzer (VNA) VNA-FMR spectroscopies as a function of magnetic field. The hysteresis of the dynamical responses measured by both FMR is related to the switching in sign of core in-plane magnetization. Experimental investigations of multimodal spectra were also supported by micromagnetic simulations, which gave us an insight into their origin. Our findings of observed spin-wave modes in both in-plane and out-of-plane magnetization states are intriguing and provide information about the spin-wave band structure in multilayer magnonic structures.

References:

[1] J. R. Childress et al., Comptes Rendus Physique 6, 997–1012 (2005)

[2] C. Banerjee et al., Phys. Rev. B 96, 3–10 (2017)

Polish National Science Center projects: DEC-2016/23/G/ST3/04196 Beethoven, UMO-2018/28/C/ST5/00308 SONATINA and UMO-2019/35/D/ST3/03729.