Measureing Interfacial Dzyaloshinsky-Moriya Interaction in Pt/Co/Pt Structures Dusted by Gd via Domain Wall Expansion

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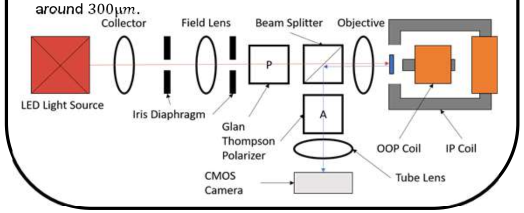
I. Motivation

Efficient manipulation of topological spin textures in multilayer systems might be achieved by breaking spatial inversion symmetry at the interfaces. Such an approach could be important for spintronic applications. Symmetry breaking at interfaces increases chiral phenomena, which could yield new material properties. In ferromagnetic (FM) thin films, the chiral exchange interaction is known as interfacial Dzyaloshinsky–Moriya interaction (iDMI). So, manipulating the iDMI could provide a general route to tailor chirality in magnetic materials through interface engineering. In this study, the influence of a Gd dusting layer on perpendicular magnetic anisotropy (PMA) and iDMI was measured via asymmetric domain-wall expansion by Kerr microscopy in a Pt/Co/Pt base structure. The measurements show that the existence of the Gd dusting layer enhanced the iDMI, while the strong PMA of the system is preserved. We expect that this study could inspire future investigation about the influence of rare-earth-element dusting on magnetic properties and might open new approaches for Skyrmion stabilization in metallic FM systems.

II. Experimental

$Ta/Pt/Co/Gd(x)/Pt$ samples were prepared on thermally oxidized silicon substrates at room temperature by DC Magnetron sputtering in an Ar atmosphere in a high vacuum chamber maintained at a base pressure of less than $1 \cdot 10^{-7} mbar$. For the series a Gd dusting of varying thickness between 0Å and 4.9Å was deposited between the Co and the lower Pt layer. For the asymmetric bubble domain expansion (ABE) [1] measurements a Köhler type widefield polarization microscope was upgraded with a coil pair in perpendicular orientation to each other. The yoke core coil generates a static magnetic field of up to $200mT$ parallel to the sample surface, while the second coil is used for out of plane field pulses with a duration of 1 to $2s$ to drive the domain wall motion (DWM). The microscope achieves a resolution of $1.2\mu m$ at tenfold magnification. The measurements were conducted at a wavelength of $650nm$ and a field of view of around $300\mu m$.



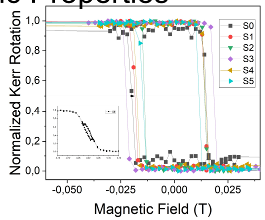
III. Results

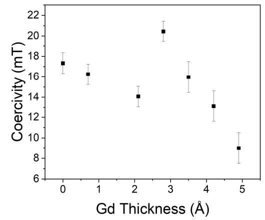
Sample Structure

Sample	Structure
S0	Ta(3nm)/Pt(3nm)/Co(0.52nm)/Pt(2nm)
S1	Ta/Pt/Gd(0.07nm)/Co/Pt
S2	Ta/Pt/Gd(0.21nm)/Co/Pt
S3	Ta/Pt/Gd(0.28nm)/Co/Pt
S4	Ta/Pt/Gd(0.35nm)/Co/Pt
S5	Ta/Pt/Gd(0.42nm)/Co/Pt
S6	Ta/Pt/Gd(0.49nm)/Co/Pt

All samples were deposited via DC magnetron sputtering in an Ar atmosphere. Next, a hysteresis loop was measured via MOKE in a maximum field of $\pm 1T$ to determine the coercivities and easy axis. After this, the samples were inserted into the MOKE microscope to measure H_{DMI} via ABE.

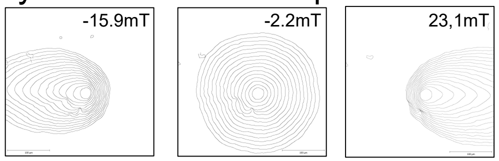
Magnetic Properties





PMA was confirmed via MOKE measurements for all samples except S6 which show in-plane magnetized easy axis. As ABE measurements are only possible for PMA samples [3], sample S6 was not further investigated. From the MOKE loops, we observed that the coercivity decreases as the Gd dusting layer increases, which gives indication of a decreasing of PMA.

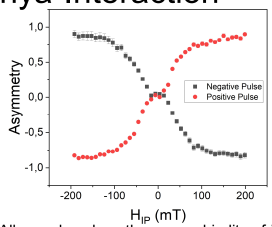
Asymmetric Bubble Expansion

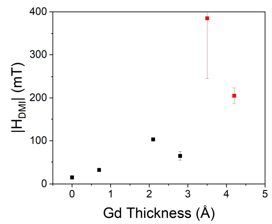


To determine the iDMI field, the asymmetry of bubble domain walls driven by an out of plane field (OOP) in a simultaneously applied in plane field (IP) was measured. For these trains of field pulses were applied to measure the expansion in the slow and fast direction simultaneously. The domain wall position was extracted from the collected images via Canny edge detection before all images of each pulse train were combined. The resulting images were evaluated using Gwyddion. The asymmetry was calculated as $(v_l - v_r)/(v_l + v_r)$, were v_l and v_r are the domain wall velocities parallel to the applied IP field [2]. Samples S4 and especially S5 exhibited an emergent dentritic DWM for high IP fields.

Dzyaloshinsky-Moriya Interaction

Exemplarily, the asymmetry graph of S2 is shown. To preclude magnetization or field direction dependent artifacts the asymmetry was determined for up and down magnetization. From these graphs, the linear dependence of the low IP field region and saturation asymmetry of the high IP field region were extracted. H_{DMI} was determined for all four branches as the intersect of these two. The asymptotic behavior confirms the applicability of the ABE method [2]. Samples S2, S4 and S5 exhibit a field independence of the asymmetry for IP fields up to a few $10mT$.





All samples show the same chirality of iDMI, its magnitude increasing with the thickness of the Gd dusting layer. Values in red were calculated with an estimated saturation asymmetry and do not constitute a fully reliable measurement.

IV. Conclusion

The iDMI field of a $Pt/Co/Gd(x)/Pt$ series was determined via ABE. A well defined IP field dependence could be observed in the asymmetry of the domain expansion for samples below 3.5Å Gd thickness. For samples with higher thickness, no saturation of the asymmetry as well as dentritic DWM at high IP fields in case of S5 was observed. In the samples S2, S4, and S5 a symmetric expansion was observed in an interval of a few $10mT$ around zero field. This behavior was not reproduced in samples S0, S1, and S3, which exhibit either a far lower iDMI field or a higher coercivity. This suggests the stabilization of fully chiral Néel walls in the interval. This assumption will be confirmed via a measurement of the anisotropy field as these fields are competing in the stabilization of chiral DW [1]. If this assumption proves to be right, Gd dusting might open the way to ferrimagnetic systems with chiral spin structures such as Skyrmions and Néel walls.

References

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