Magnetic properties of Pt/Co/Pt trilayers with W insert layer

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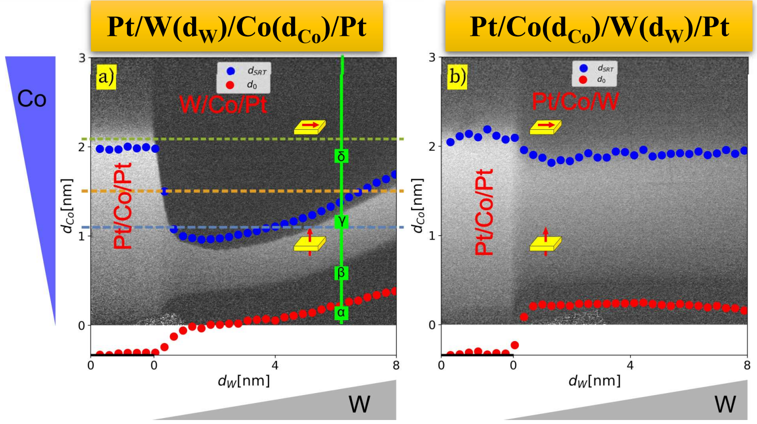
Sample description

Ultra-thin ferromagnetic layers located between two different heavy metals are of great interest due to their potential application as a new material for magnetic memory or spin devices [1, 2]. The double wedge geometry samples Pt/W(d_W)/Co(d_{Co})/Pt and Pt/Co(d_{Co})/W(d_W)/Pt, where d_W and d_{Co} are the thicknesses of W and Co layers, were epitaxially grown on sapphire substrate.



Methodology The influences of d_{Co} and d_W on magnetization parameters were studied using polar magnetooptical Kerr effect (**PMOKE**) and Brillouin light scattering (**BLS**) methods. The dependence of PMOKE magnetization on applied in-plane field was used to determine uniaxial anisotropy field H_{A1}; $H_{A1}>0$, $H_{A1}<0$ defining perpendicular and in-plane magnetization configurations, respectively. $H_{A1}(d_{Co}, d_W)=0$ corresponds to spin reorientation transition (**SRT**) Co layer thicknesses. The dead layer thickness d_0 was determined from the dependency of maximal PMOKE rotation $\theta_{max}(d_{Co})$ as interception of its linear approximation with horizontal axis (Fig 3) [3]. The strength of interfacial Dzyaloshinskii-Moriya interaction (**iDMI**) and spin wave (**SW**) damping for selected d_{Co} thicknesses as a function of d_W were determined from the dynamic characteristics measured by **BLS** in Damon-Eshbach mode. The inclination of the dependency of frequency shift between magnon Stokes and anti-Stokes peaks Δf on magnon wavevector q allows us to determine iDMI constant D_S as:

$$D_S = \frac{\pi M_S}{2\gamma}\frac{\Delta f}{q}d_{Co}$$ where: M_s is magnetization saturation, and γ - gyromagnetic ratio.

Fig.1. *PMOKE remanence images of: a) sapphire/Pt/W/Co/Pt and b) sapphire/Pt/Co/W/Pt samples. Colour intensity is proportional to θ_{REM}, defined in the Fig.2 inset. The regions with perpendicular magnetic anisotropy (PMA) are visible as light grey areas while the black regions illustrate either in-plane magnetization (thick d_{Co}) or nonmagnetic or superparamagnetic states (very thin d_{Co}). The blue and red dotted lines describe SRT positions of d_{SRT} and the thickness of dead layer d_0 as a function of d_W. The anisotropy fields in Fig. 5 were determined along dashed horizontal lines (Fig.1a).*

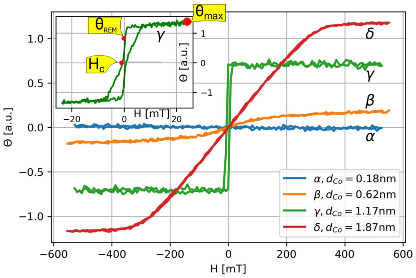


Fig.2. Exemplary PMOKE hysteresis loops recorded in the Pt/W/Co/Pt sample at the points α, β, γ and δ along the green vertical line (d_W=6.1nm, Fig. 1a). PMOKE rotation angle θ is proportional to the local out-of-plane magnetization. α) d_{Co}=0.18 nm - non-magnetic area; β) d_{Co}=0.62 nm – non-hysteresis (super)paramagnetic area; γ) d_{Co}=1.17 nm - "rectangular" shape loop typical for the PMA;
δ) d_{Co}=1.87 nm - non-hysteresis loop typical for magnetization in-plane. The definitions of θ_{max}, θ_{REM}, and H_C values, used in further calculations, are indicated by the red dots in the inset.

Results & Discussions

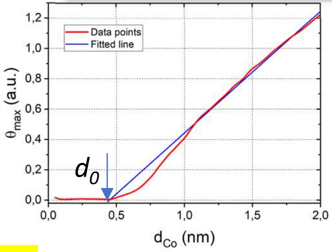


Fig.3. An exemplary dependence of $\theta_{max}(d_{Co})$ for d_W=7.9 nm (sample Pt/W/Co/Pt). The intersection of linear approximation (blue line) with θ_{max}=0 corresponds to the magnetic dead layer thickness d_0.

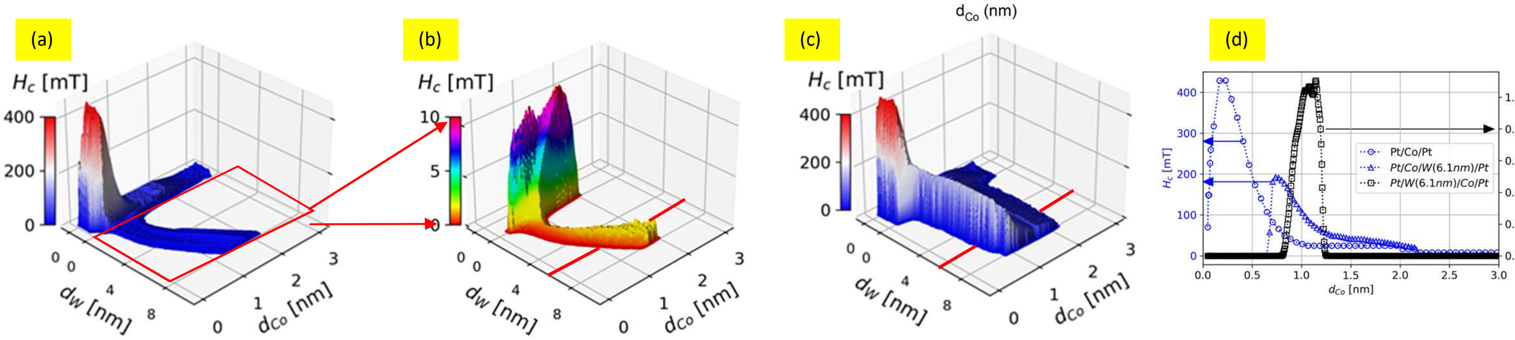


Fig.4 3D maps of coercive fields $H_C(d_W, d_{Co})$ in PMA regions. Figs (a) and (c) show the full ranges of H_c in Pt/W/Co/Pt and Pt/Co/W/Pt samples, respectively. High coercivity regions (red capped) are recorded in the reference Pt/Co/Pt regions. Fig (b) presents magnified part of (a). Fig (d) shows H_c a profile in the reference region and for a W buffer/cover layer thickness of d_W=6.1 nm.

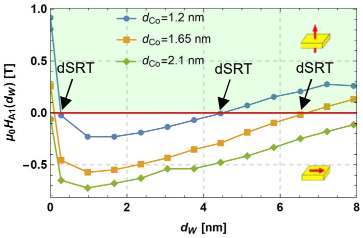
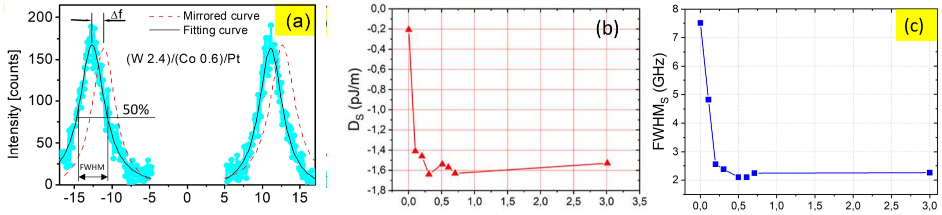


Fig.5. The dependences of anisotropy field H_{A1} (d_W) for d_{Co}=1.2, 1.65 and 2.1 nm (according to the profile lines shown in Fig.1A with appropriate colors).

Fig.6 (a) BLS spectrum (Stokes f_S (left) and anti-Stokes f_{aS} (right) peaks) from the sample Pt/W(2.4)/Co(0.6)/Pt (thicknesses in nm) measured at the incidence angle of $\theta = 40^0$ ($q = 15.2\ \mu m^{-1}$) and in-plane magnetic field $\mu_0 H_{||}$=0.47 T (light blue points). Sample Pt/W(d_W)/Co(2.1)/Pt: (b) The dependence of D_S on d_W. (c) Full width at half maximum of Stokes peak ($FWHM_S$) as function of d_W.



Conclusions:

Abrupt changes (induced by sub-/few W atomic monolayer) of :

- magnetic anisotropy field H_{A1}
- coercivity field H_C (two orders or two time decrease in the case of W buffer and overlayer, respectively)
- decrease in iDMI constant Ds and width of Stokes peaks ($FWHM_S$)

The difference in the W buffer and overlayer influence on magnetic properties can be explained by modifications of both Co interfaces and crystallographic structure.

W layer-tuned properties are important for designing more complicated nanostructures (synthetic ferromagnets and antiferromagnets with iDMI) which could be perspective for further applications, e.g. magnonic structures.

Acknowledgements:

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References :

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