Aging Effects in Co/Gd Thin Films

Mateusz Kowacz,[1] Feliks Stobiecki,[1] and Piotr Kuświk[1]

[1] *Institute of Molecular Physics, Polish Academy of Sciences, Mariana Smoluchowskiego 17, 60-179 Poznań, Poland*

Thin-film rare-earth/transition-metal heterostructures are useful because their magnetic properties can be easily controlled. These systems are commonly characterized by perpendicular magnetic anisotropy (PMA) and are relevant for a magneto-ionic transport and a data storage. Recent studies have shown that ionic migration induced by a perpendicular gate voltage in Pt/Co/GdOx structures can reversibly modify magnetic anisotropy via oxygen or hydrogen incorporation under ambient or moist conditions [1,2]. This motivates the investigation of whether similar interfacial modifications can also occur without applying a voltage during environmental aging.

Here, we investigate magnetic aging at room temperature (RT) in magnetron-sputtered thin Co/Gd films. The study includes two sample films with the wedge-shaped Co layer and the Gd layer with the constant thickness (samples **A**): buffer/Co (wedge: 0–3.6 nm)/Gd-5 nm/Au-5 nm, and one sample with the wedge-shaped Gd layer and the Co layer with the uniform thickness (sample **B**): buffer/Co-1.2 nm/Gd (wedge: 0–10 nm)/Au-5 nm (buffer = Ti-4 nm/Au-60nm). The role of storage conditions was examined by storing the samples A in different environments: in air ($\mathbf{A}_{air}$) and ultra-high vacuum (UHV) conditions ($\mathbf{A}_{vac}$). The sample **B** was stored only in air. Changes in magnetic properties were measured along wedges as a function of storage time at RT using the polar magneto-optical Kerr effect.

For the sample $\mathbf{A}_{air}$, the range of PMA was initially limited to $t_{\mathrm{Co}} = 1.2$–1.3 nm. This range broadens within the first days of aging to $t_{\mathrm{Co}} = 1.1$–1.7 nm and data analysis reveals that it is correlated with a reduction of the volume anisotropy contribution and an enhancement of the interfacial contributions. This indicates a complex evolution of magnetic anisotropy parameters during aging. In contrast, sample $\mathbf{A}_{vac}$ stored under vacuum for 14 days did not develop PMA, and no PMA induction was observed over an additional two-week period, highlighting the crucial role of environmental exposure. Whereas the sample **B** exhibits an oscillatory dependence of magnetic anisotropy on Gd thickness characterized by spin-reorientation transitions (SRTs) between PMA and in-plane anisotropy. These SRTs are progressively suppressed over aging time, resulting in a wider Gd thickness range of PMA, consistent with the trends observed for sample $\mathbf{A}_{air}$.

These results demonstrate that storage conditions are critical to the evolution of magnetic anisotropy in Co/Gd films, as evidenced by the strong contrast between air and vacuum aging.

References:

[1] U. Bauer *et al.*, *Nat. Mater.* **14**, 174-181 (2015)
[2] A. J. Tan *et al.*, *Nat. Mater.* **18**, 35-40 (2019)

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