Exchange bias coupling between Co and TbCo alloy layers with controlled concentration gradient

Ł. Frąckowiak,[1] F. Stobiecki,[1] G. Chaves-O'Flynn,[1] M. Urbaniak,[1] and P. Kuświk[1]

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

The ability to tune the switching fields (H^S) of ferromagnetic layers (F) exhibiting perpendicular magnetic anisotropy (PMA) in a wide range is important for many spintronics applications. This is usually realized by exchange bias coupling in AF/F (AF-antiferromagnetic layer) bilayers. We have recently[1] shown that replacing the AF layer with a ferrimagnetic (FI) layer allows to tune the H^S of the F layer from minus to plus several kOe. This work investigates the exchange bias coupling between the F and FI layers, where the FI layer is an alloy. Here, we study F(Co)/FI(Tb-Co) and F(Co)/S(Au-tAu)/FI(Tb-Co) layered systems, where t_{Au} is the thickness of a Au wedge. For comparison with our previous studies, Tb-Co alloy layers with a well-defined c_{Tb} gradient parallel to the substrate's edge (x) were deposited. This was obtained by co-sputtering from Co and Tb targets, where the desired c_{Tb}(x) gradient was first calculated and then experimentally verified using energy-dispersive X-ray spectroscopy and polar magneto-optical Kerr effect measurements. In this work, we focus on a (Au-1nm/Co-0.8nm)$_3$/Au-t_{Au}/(Tb-Co-c_{Tb}) structure, in which changes of the c_{Tb} and t_{Au} occur along mutually perpendicular directions. This morphology allows us to determine the magnetization reversal as a function of c_{Tb} and t_{Au} values in a single sample. We found that the strongest interaction between F and FI occurs for c_{Tb} near the compensation point (c_{comp}) of the Co and Tb sublattices. For t_{Au}=0, c_{comp} is around the c_{Tb}=29at.% and it does not change up to t_{Au}=0.8nm. As t_{Au} increases above 0.8nm, c_{comp} starts to decrease and approaches constant (c_{Tb} = 22at.%) for $t_{Au}\geq$1nm. For t_{Au}<0.8nm, the top Co layer interacts more strongly with the Tb-Co alloy than with two other Co layers in the (Au/Co)$_3$ multilayers and undergoes magnetization reversal together with Tb-Co alloy. This means that the top Co layer is coupled to the FI layer and this causes an increase of the amount of Tb needed to compensate the Co sublattice. In the case when the top Co and Tb-Co layers are separated by a thick Au layer, the interactions between them are much weaker and the magnetization reversal of the top Co layer of (Au/Co)$_3$ takes place together with the other two Co layers. As a result, the compensation occurs at c_{Tb} = 22at.%, which is in good agreement with recent reports for Tb-Co film[2].

References:

[1] Frąckowiak Ł., et al. Sci. Rep. 8, (2018)
[2] Tang M. H., et al. Sci. Rep. 5, (2015)

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