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Experimental and modelling results of Permalloy thin films in the undulated magnetic state

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High performance novel magnetic materials require the study and tuning of induced anisotropy and reversal fields in order to develop new functionalities in extended magnetic media. To this purpose we have explored a semi-transparent, soft magnetic thin film (Permalloy) of nano-undulated morphology. This media is grown on the ripple surface of flexible, polymeric foil of polyethylene terephthalate (PET) that was previously patterned by a versatile pulsed-laser irradiation technique achieving a linear array with periodicity 220 – 250 nm and large amplitudes around 45 nm [1].

Vectorial Kerr (reflection) as well as Voight (transmission) magneto-optical effects confirm a complete uniaxial anisotropy induced with easy axis along the ripple pattern for Py films of thickness ranging from 10 to 30 nm. Analysis of magnetization loops and critical fields in comparison with existing models and novel micromagnetic simulations of a quasi-infinite ripple film model (with the same dimensions as the media) indicate and undulated magnetization state with the anisotropy driven by volume-like anisotropy at the ripple crests/valleys. The choice of large pattern dimensions has made possible to realize the undulated magnetic state where the anisotropy strength simply increases with film thickness, without any evidence of surface contributions [2].

References

[1] E. Rebollar *et al.*, *Eur. Polym. J.*, **73** 162-174 (2015).
[2] E. H. Sánchez *et al.*, *J. Magn. Magn. Mater.*, **514** 167149 (2020).

Figure 1. (A) 5 5 μm^2 AFM topographic image of the surface pattern of 20 nm thick Py film grown on a nano-undulated PET substrate. (B) Normalized longitudinal (black symbols) and transversal (red symbols) magnetization loops obtained from the longitudinal MOKE of the 15 nm thick Py film for the field applied along the easy-magnetic axis (upper panel) and hard-magnetic axis (lower panel). Black and red solid lines are calculated loops for such direction with Stoner-Wohlfarth model. (C) 10 nm thick ripple Py film modelled by micromagnetic simulations. The arrows show the direction of the magnetic moments and the colored regions indicate the normalized z-component (m_z/m_S) of the magnetization at field higher than the anisotropy field ($\mu_0 H > \mu_0 H_K$). (D) Simulated loops of (C) with the field applied across the ripple pattern ($\alpha_H = 89.9º$).