Micromagnetic investigation of domain walls in Spin-valves for enhanced spin-torque processes

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Displacing a magnetic domain wall by a simple electric current is a growing demand as it could offer an incomparable low-energy consuming and easy to built devices for the future of magnetic recording [1] or a future magnetic logic [2]. Nevertheless, very few success of such spin-torque processes have been demonstrated as the Joule heating is by far the most important driving parameter when an electric current is injected into a ferromagnetic metallic stripe. Moreover an extended zoology of the different domain walls found in such stripes have been established and it comes out that only specific domain walls can be considered as interesting objects to be displace efficiently by an electric current. To overcome the main problems presented above, spin-valves structures have been demonstrated as a reliable counterpart to the traditional and uniform Cobalt (Co) or Permalloy (Py) stripes. Stacking including a Co and Py layer separated by a copper spacer have been demonstrated to enhance the DW velocity (> 100 $m.s^{-1}$) as compare into traditional Py or Co stripes. Moreover, critical currents (i.e. the necessary current to move a domain wall) where found to be lower than previously reported for pure Co or Py stripes [3]. If domain walls configuration and displacement are well known within simple layer there is a lack of extensive description of domain walls in Spin valves. It is the aim of the present work to deepen the knowledge of such structures in order to be able to use them in the vicinity of on-board devices.

Two main families of domain walls co-exists in nano-stripes : vortex and transverse walls. The later is of primary interest for domain wall displacement as it offer a large area of magnetization transverse to the stripe direction which can be used to form a torque with the help of a field or a current to easily move it. A well known phase diagram was drawn (Fig 1) to highlight the predominance of one or the other family of domain wall. Constructing various micromagnetic states via simulation is possible and demonstrates clearly that transverse walls can only be found in the regime of low thickness and low width. Comparison of the results obtains for a Py stripe alone and a Py stripe on the top of a spin-valve structure showed an enhancement of the stability of transverse walls towards higher thicknesses. Moreover, micromagnetic simulations also showed that, due to stray field considerations, such transverse walls where always asymmetric.

This presentation will be dedicated to the analysis of the the micromagnetic structure of such walls by means of magnetic imaging. Here the complementary informations given by Magnetic Force Microscopy, XMCD Photomemission Electron Microscopy and Lorentz Transmission Microscopy will be used to reveal the inner structure of such walls. We will show that new kind of domain walls are taking place in such stacking that can not be addressed, notably regarding wall motion, with the common used definition found in the literature. A discussion will be made regarding the possibility of carrying spin-torque processes on spin valves, especially with the help of in-situ observation including applied field and currents.

References

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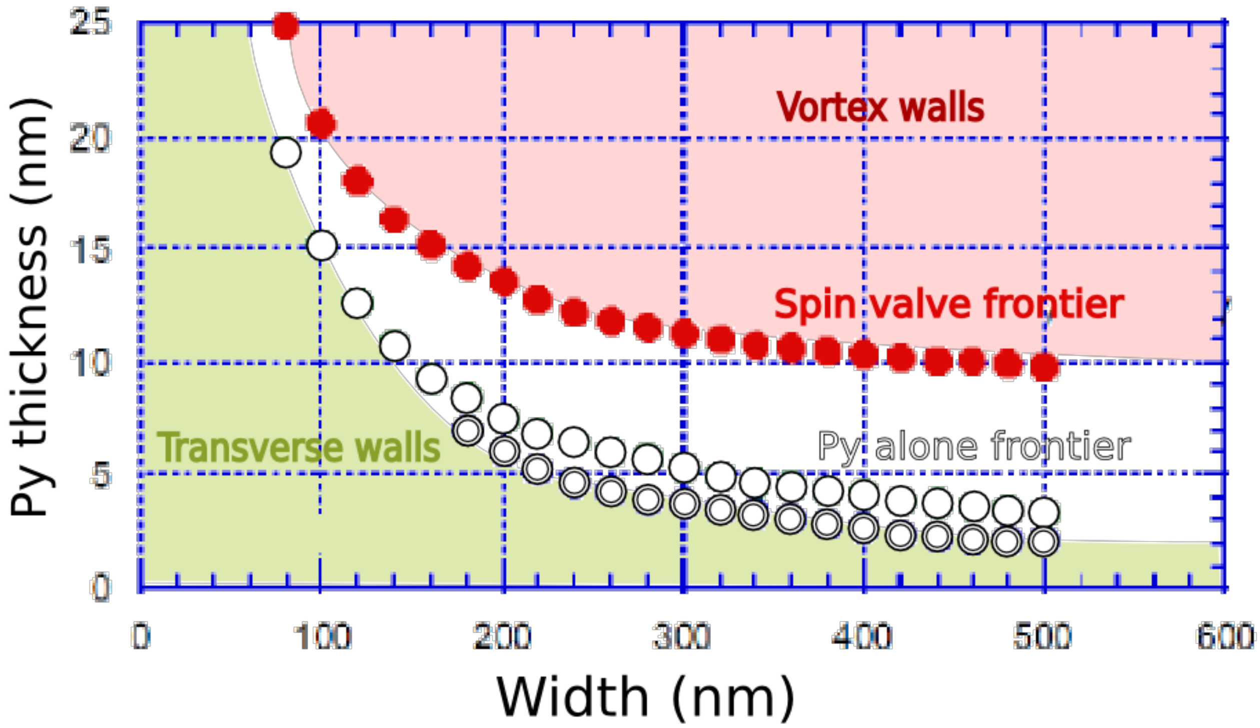

Figure 1. *Phase diagram of the coexistence of vortex and transverse domain walls inside a Py stripe and a Spin Valve stripe (thickness vs. width of the Py stripe). The open circle described the frontier between the presence of transverse and vortex walls (the double open circles mark the frontier in the case of an asymmetric transverse wall). The filled circles corresponds to the frontier in the case of a spin valve stacking.*

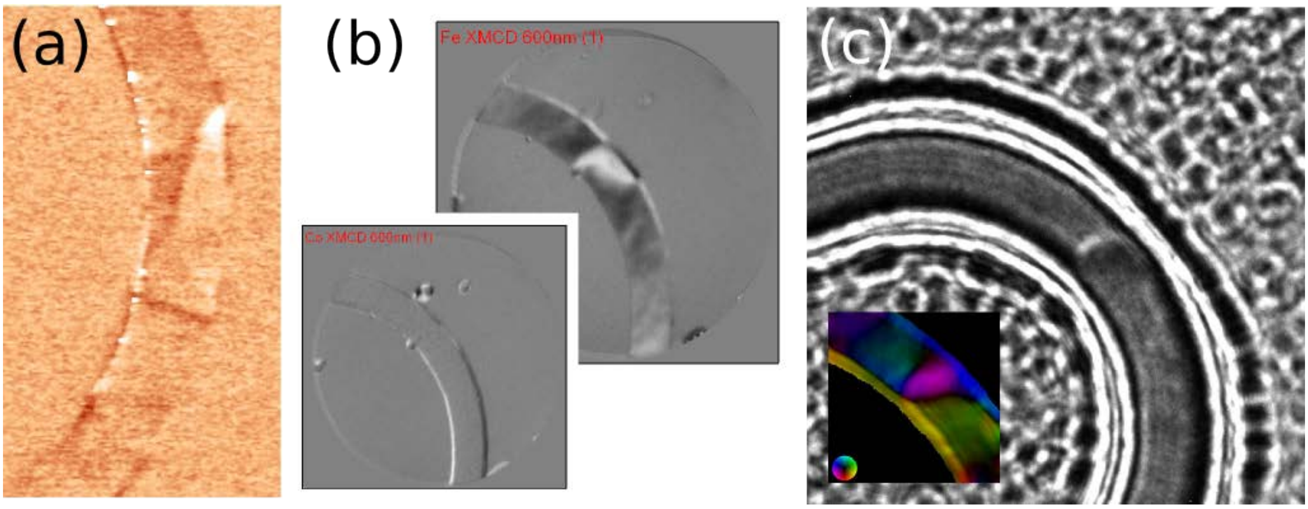

Figure 2. *MFM (a), XMCD-PEEM (b) and Lorentz microscopy (c) showing a transverse wall in a spin-valve structure. (a) MFM image shows that the transverse wall is asymmetric. (b) XMCD PEEM confirm the shape of the wall but highlight the presence of a wall inside the cobalt layer (bottom image @ Co edge, only a shadow contrast can be seen on the border of the stripe). (c) LTEM which integrates the signal from both Co and Py layer exhibits an overall transverse wall shape with a relative asymmetricity but contrast is melted within the DW contrast.*