Computational Study of Domain-Wall-Induced Switching of Co/Pt Multilayer

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Introduction: Clocking Magnetic Field-Coupled Devices by Domain Wall

Nanomagnetic logic (NML) emerges as a new field of spintronics [1-2]. For NML operation, strong external magnetic clocking field pulses are required. The power-efficient generation of such fields is a challenge for magnetic computing. The idea of clocking Co/Pt nanomagnets with stray field from the domain wall of a Permalloy stripe was proposed in [3]. Here, we present a micromagnetic study of Co/Pt multilayer films that strongly interact with the stray field of a Permalloy domain-wall conductor. The simulated domain patterns agree well with experimental results.

Interaction Between Permalloy Domain Wall And Co/Pt Film

Figure 1 schematically shows the idea of applying the stray field from a domain wall of a Permalloy stripe to clock the out-of-plane magnetization of Co/Pt nanomagnets. To realize this blueprint, we first investigate the magnetic interaction between the Permalloy domain wall and the Co/Pt films. Fig. 2 (a) shows the fabricated structure from our experiment, and we verified that the field of domain wall can reverse the magnetization of the Co/Pt stripe on top. However, not the whole Co/Pt stripe switches and the stripe splits into multiple domains (see the MFM image in Fig. 2 (b)).

Simulation Results

Using the OOMMF simulation packages, we numerically investigated the domain-wall-induced reversal behaviour of the Co/Pt stripe [4]. We implemented the three-dimensional mode with point-wise varying material parameters. The material parameters were calibrated by fitting with experimental data. The modelling structure of our simulation is shown in Fig. 3. The simulation results verified that the reversal of the Co/Pt stripe is dependent upon the type of domain wall (head-to-head or tail-to-tail) and how this domain wall propagates through Permalloy stripe. The stray field direction of a head-to-head domain wall is to the opposite to that of a tail-to-tail domain wall, as shown in Fig. 4. In some cases, vortex-type domain walls exist, which makes the reversal behaviour more complex. Our simulation results prove that Co/Pt stripes with a stripe width larger than 100 nm are most likely to split into multiple-domains. Our simulations also suggest that the coupling from Co/Pt material beside the Permalloy is another reason leading to split.

Conclusion

We developed a computational model to explore the interaction between domain walls in a Permalloy wire underneath a Co/Pt multi-layer film. With this model we verified that such a Permalloy domain wall can reverse the magnetization of Co/Pt film and the reversal behaviour is dependent upon the type of domain wall. Our simulations also suggest the proper width of the Co/Pt stripe in order to avoid splitting into multiple-domains.

Acknowledgment

This project is financially supported by Deutsche Forschungsgemeinschaft (DFG) through Grant SCHM 1478/9-1 and Grant CS 62/2-1, and by the Defense Advanced Research Project Agency (DARPA).

References

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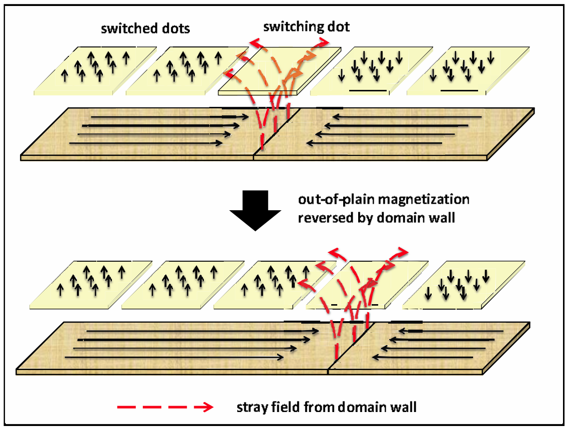

Fig. 1. Domain wall clocking: using the out-of-plane stray field from Permalloy domain wall to switch the logic state of single domain Co/Pt nanomagnets and drive the system to computational ground state.

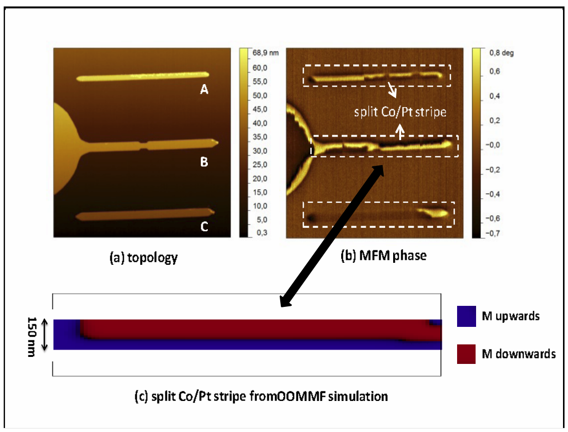

Fig. 2. (a) MFM image, showing the topography of the fabricated structure: the large pad on the left end is used to generate domain wall at low field. The width for stripe A is 140 nm; for B and C are about 240 nm. (b) MFM phase image of the structure showing the interaction of the Permalloy domain wall conductor and the Co/Pt multilayer stripe. The structure was saturated by 700 mT out-of-plane field with an additional x-component of 80 mT. The structure is relaxed by reducing the external magnetic field simultaneously to zero. (c) OOMMF simulation snapshot: split Co/Pt multilayer stripe, which is consistent with experimental result in (b).

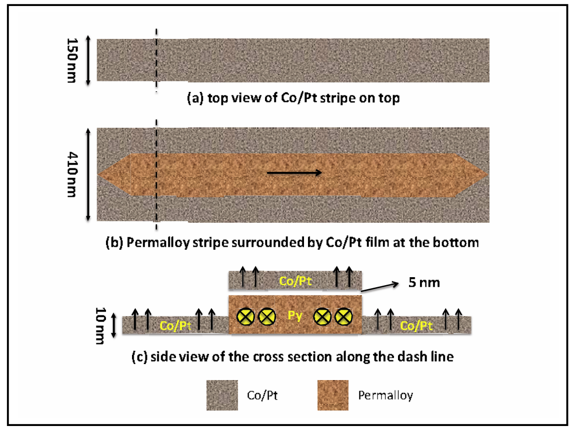

Fig. 3. The simulated three dimensional structure: he deposited Co/Pt material surrounding Permalloy was also considered.

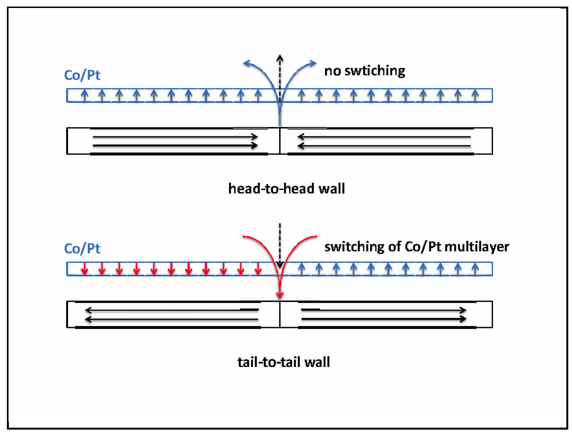

Fig. 4. The switching of the Co/Pt stripe is dependent upon the type of domain wall. The stray field direction of a head- to-head wall is opposite to that of a tail-to-tail wall.

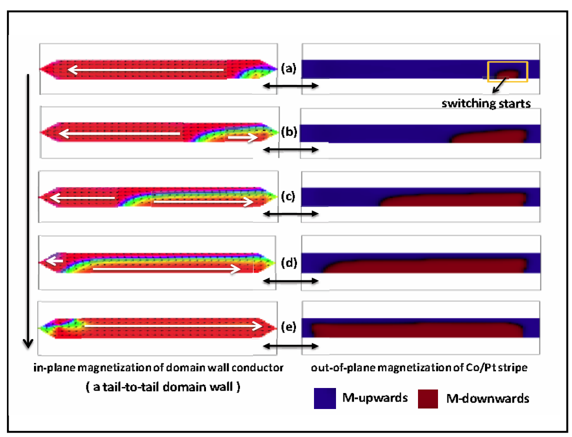

Fig. 5. (a) – (e) are five groups of snapshots from OOMMF simulation. Strong interactions between conductor and Co/Pt stripe were observed: as the domain wall propagates, the switching of Co/Pt follows the trace of domain wall.