Importance of chiral phenomena for domain wall shift registers

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PhD may follow: Yes

Summary :

Magnetic shift registers have been proposed as a better alternative for hard-disk technology. They would be two orders of magnitude denser and faster than hard-disk technology1. Their realization relies on the possibility to shift the magnetic domain walls (transition areas that separate the uniformly magnetized domains) by the application of an electric current. We study in detail the interactions governing the physical process of current induced DW motion. For experiments we rely on the magneto-optical imaging techniques as well as electric magneto-transport detection. In order to understand our observations, we model our findings using macro-spin and micro-magnetic simulations.

Full description :

Full description of the subject (~36 lines)

The racetrack memory is an original memory concept where the information is coded by the relative positioning of magnetic domain walls (DWs) in a magnetic nano-wire1. The working principle of this device relies on the possibility to shift all DWs in the same direction without modifying the distance separating them. While this is not possible by magnetic field (pushes any two adjacent DWs in opposite directions thus modifying the distance) the current induced DW motion exhibits this special feature.

We observed that current induced DW motion is extremely efficient in materials composed of a very thin ferromagnet sandwiched between a heavy metal and an oxide2. The initial explanation of this phenomenon, in terms of spin transfer torque, has proven inadequate, and it has been shown that this remarkable feature is entirely linked to the spin orbit interaction.

Namely the simultaneous occurrence of large spin orbit interaction and the structural inversion asymmetry (SIA) of these materials leads to a conspiracy of phenomena that can explain the extraordinary efficiency of the current induced DW motion. On one hand in the presence of the SIA, the electric current produces large spin orbit torques3 and on the other hand, the SIA produces a chiral energy that forces the DWs to adopt a fixed chirality, making them extremely susceptible to be displaced by SOT4.

Besides these two phenomena playing a dominant role for the DW motion, we have discovered a third component that affects their motion: the dissipative counterpart of the chiral energy. The observation of chiral damping5 makes the picture even more complex. Disentangling the roles of these components is very difficult and challenging. However, the full understanding is necessary to control and improve the efficiency of this process to the extent required for memory applications. For this purpose, we study the current and field induced DW motion using magneto-optical microscopy.

The ideal candidate should have a taste for the deep understanding of complex physical phenomena and also be interested by the potential applications of their discoveries.

1. S.S.P. Parkin, M. Hayashi, and L. Thomas. "Magnetic domain-wall racetrack memory." Science 320.5873 (2008): 190-194.

2. I.M. Miron et al. "Fast current-induced domain-wall motion controlled by the Rashba effect." Nature materials 10.6 (2011): 419.

3. I.M. Miron et al. "Perpendicular switching of a single ferromagnetic layer induced by in-plane current injection." Nature 476.7359 (2011): 189.

4 K.-S. Ryu et al. "Chiral spin torque at magnetic domain walls." Nature nanotechnology 8.7 (2013): 527.

5. E. JuÃ© et al. "Chiral damping of magnetic domain walls." Nature materials 15.3 (2016): 272.

Requested skills :

general physics; team spirit; sense of humor;