Current-induced motion of antiferromagnetic domain wall in antiferromagnet/heavy metal bilayers

Se-Hyeok Oh[1*], Takayuki Shiino[2], Byong-Guk Park[2], Kyung-Jin Lee[1,3]
[1]Department of Nano Semiconductor Engineering, Korea University, Seoul 136-701, Korea
[2]Department of Materials Science and Engineering, KAIST, Daejeon 305-701, Korea
[3]Department of Material Science and Engineering, Korea University, Seoul 136-701, Korea

1. Introduction

Antiferromagnetic spintronics is attracting considerable interest nowadays as the antiferromagnet is immune to external magnetic fields [1] and compatible with metal or semiconductor electronic structure [2]. To be used as functional devices, one has to find an efficient driving force to manipulate antiferromagnet spins. The effect of spin transfer torque (STT) on antiferromagnetic spins has been identified [3]. Recently, Hals et al. [4] reported a theory of STT-induced dynamics of antiferromagnetic domain wall (AF-DW) and found that the DW velocity is proportional to the ratio between the dissipative torque and the damping, as for ferromagnet (FM) DWs.

2. Experiment

In this talk, we report theoretical and numerical results of current-induced AF-DW motion in antiferromagnet/heavy metal bilayers where the injection of in-plane current generates spin-orbit torque (SOT) as well as conventional STT (i.e. adiabatic and nonadiabatic STTs). Based on the nonlinear sigma model for the Néel vector [5], we derive analytical solution of steady-state domain wall velocity. We also perform numerical computation based on atomistic spin model [6].

3. Result and discussion

Figure 1 shows the DW velocity v_{DW} as a function of current density for $\beta/\alpha = 1$ where α is the Gilbert damping and β is the non-adiabaticity of spin current. When only STT is present (i.e., the effective spin Hall angle, $\theta_{SH} = 0$), v_{DW} is linearly proportional to the current density. On the other hand, when both STT and SOT are present, v_{DW} deviates largely from the linear relation. For a specific sign of θ_{SH} (or current direction equivalently), v_{DW} increases rapidly with current magnitude. This rapid increase of v_{DW} (i.e., $\theta_{SH} = -0.2$ in Fig. 1) assisted by SOT is similar to the case of FM-DW [7]. However, we observe an important difference between FM-DW and AF-DW; a current range for very high v_{DW} is quite narrow for FM-DW due to the Walker breakdown [7], whereas such a very high v_{DW} is obtained for the current above a certain threshold for AF-DW because the Walker breakdown of AF-DW occurs at a much higher current density (> 10^9 A/cm^2). We also observe a large deviation between analytic solution and modeling results at high current regime, caused by the breakdown of continuum approximation used for the nonlinear sigma model. In the talk, we will discuss spin wave generation from AF-DW at high current regime in detail.

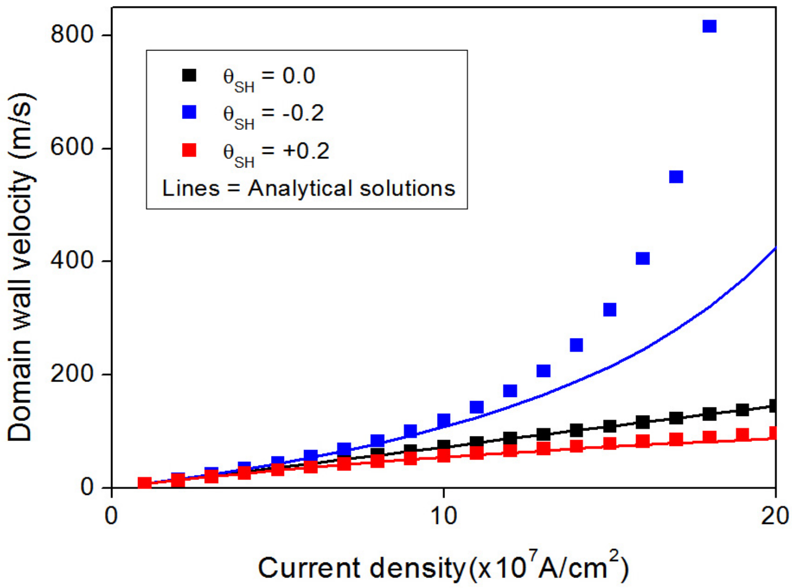

Fig. 1. Steady-state velocity of antiferromagnetic domain wall by STT and SOT. Symbols are numerical results.

4. References

[1] X. Martí, I. Fina, and T. Jungwirth, IEEE Trans. Magn. **51**, 1 (2015).

[2] T. Jungwirth et al., Phys. Rev. B **81**, 212409 (2008); P. Wadley et al., Nat. Commun.**10**, 347 (2011).

[3] A. S. Núñez, R. A. Duine, P. Haney, and A. H. Mac Donald, Phys. Rev. B **73**, 214426 (2006); Z. Wei et al., Phys. Rev. Lett. **98**, 116603 (2007); S. Urazhdin and N. Anthony, Phys. Rev. Lett.**99**, 046602 (2007); P. M. Haney and A. H. Mac Donald, Phys. Rev. Lett.**100**, 196801 (2008).

[4] K. M. D. Hals, Y. Tserkovnyak, and A. Brataas, Phys. Rev. Lett. **106**, 107206 (2011).

[5] A. C. Swaving and R. A. Duine, Phys. Rev. B **83**, 054428 (2011).

[6] R. F. L. Evans et al., J. Phys.: Condens. Matter **26**, 103202 (2014).

[7] S.-M. Seo, K.-W. Kim, J. Ryu, H.-W. Lee, and K.-J. Lee, Appl. Phys. Lett. **101**, 022405 (2012).