Magnetization dynamics in an antiferromagnetic layer: a micromagnetic approach.

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In the last few years, spintronics community has focused on antiferromagnets (AFM) [1-3]. The most important reason is that the typical frequencies of switching between different states of an AFM are higher than those frequencies for ferromagnetic (FM) materials, that promises high-speed devices operating in the range of terahertz (gigahertz for FM). AFMs, however, need a different theoretical approach, that takes into account several characteristics, such as the fundamental exchange interactions and the absence of macroscopic magnetization. In general, magnetization dynamics can be studied considering the magnetizations M_1 and M_2 of the two AFM sublattices. The motion of M_1 and M_2 is ruled by two coupled Landau-Lifshitz equations [3].

We have developed a micromagnetic code which performs numerical simulations of an antiferromagnetic layer by solving the equations of motion for the magnetizations M_1 and M_2 of the two sublattices. First performed simulations have focused on the relaxation dynamics of the AFM sublattices, starting from different initial states and with different parameters of the material. The AFM has dimensions 40x40x2 nm^3 and has been discretized in cells of 2x2x2 nm^3. We have also considered the following parameters: saturation magnetization M_s=350x10^3 A/m, exchange constant A=0.5x10^{11} J/m. Anisotropy has been considered in-plane (IP) and out-of-plane (OOP) in two different sets of simulations. In the latter case, the contribution of interfacial Dzyaloshinskii-Moriya interaction (DMI) has been also evaluated, in particular to highlight whether a Néel-type skyrmion can remain stable in the AFM. Other initial states include uniform IP AFM and non-AFM states, and uniform OOP AFM state. Neither external field nor charge current are applied.

If anisotropy is not considered, magnetizations go OOP, starting from both OOP AFM and IP non-AFM state. Only if the initial state is IP AFM, magnetizations do not change and remain IP. When anisotropy is IP, any initial state evolves to IP AFM state along the easy axis and the duration of the transient is shorter, the larger is the anisotropy constant K_u (we have considered values of 0.6x10^4, 0.6x10^5 and 0.6x10^6 J/m^3). In presence of OOP anisotropy, on the other hand, uniform IP states evolve to OOP Néel-type domain walls, which are tilted for DMI increasing (the DMI parameter varies from 0.5 to 4.5 mJ/m^2). If the initial states are a skyrmion, last but not least, it remain stable when the DMI parameter is above a critical value, which decreases with the increase of K_u, underlining a trade-off between the contributions of anisotropy and DMI.

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