Modeling spin transfer induced dynamics; Interplay between micromagnetics and other simple models

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I. Abstract

Over the last years, significant progress has been made in modeling spin transfer torque phenomena in different systems, but a full quantitative understanding of these phenomena is still far from being complete. Micromagnetic simulations are an extremely useful tool in interpreting experimental results and gaining new insights into the physics of these processes, but sometimes they give important discrepancies with experiments, whereas oversimplified models, such as macrospin models, yield a better agreement. In this talk we will argue, by means of several examples, that both approaches are useful and complementary if one is aware of their limitations.

For instance, when modeling current induced domain wall motion in nanowires a simplified one dimensional linear model can be derived from the Landau-Lifshitz equation assuming that the wall behaves like a rigid object and that the tilt angle inside the wall is small [1]. This simple model gives a lot of insight into the physics behind domain wall motion and predicts some features observed experimentally, but it cannot take into account variations in the domain wall thickness and internal structure, which are important in some cases [2]. It will be shown, however, that the one dimensional linear model gives very good quantitative agreement with experimental data when studying the depinning process of a domain wall by means of an AC current, provided that micromagnetic simulations are used to obtain some input parameters of the model, such as domain wall width and the characterization of the pinning potential [3].

When simulating pillar devices, on the other hand, it is noticeable that sometimes micromagnetic simulations give poorer agreement with experiment than macrospin models. As pointed out by Berkov and Miltat [4], this means that we do not understand some crucial physical properties of the system and some further research is needed. We will focus our attention on the investigation of current induced oscillations in asymmetric pillar devices in the diffusive transport limit where, under certain circumstances, an anomalous angular spin torque dependence is found [5]. Our analysis reveals that certain effects emerging from macrospin approximation, such as the occurrence of out-of-plane precession, are just model artifacts and its validity for system under study is questioned.

Finally, I will briefly discuss the challenging problem of simulating current induced oscillations in the point contact geometry. In this case, macrospin models are inaccurate when predicting frequency vs. current curves, since they do not take into account for spin wave radiation outside the point contact area.

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