Micromagnetic study of magnetization dynamics in diffusive regime limit.

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I. Introduction

Diffusive electron transport in an asymmetric spin valve with two magnetic films having different spin asymmetries as well as different spin diffusion lengths may exhibit anomalous spin-transfer torque angular dependence, which markedly differs from ballistic transport [2] case. Calculations based on Ref. [1] for a non-standard Co(8nm)/Cu(10nm)/Py(8nm) 155x100nm^2 spin valve result in a torque which vanishes not only in collinear but also in a certain non-collinear magnetic configuration of the Co and Py films (Fig. 1). As a result, current of appropriate orientation destabilizes both parallel and antiparallel magnetic configuration, leading also to excitation of precessional modes in the absence of external magnetic field [3].

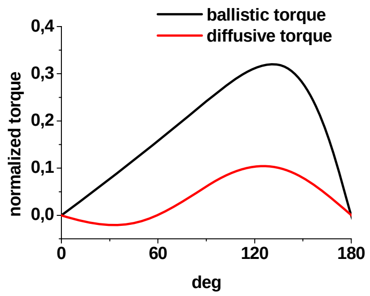

Fig. 1 Torque calculated in diffusive and ballistic transport limit.

II. Macrospin Model

In the macrospin approach, we numerically solve Landau-Lifshitz-Gilbert equation with the effective field consisting of demagnetizing field, uniaxial anisotropy, external field, and interlayer dipolar coupling (ICF),

$$\vec{h}_{eff} = \vec{h}_{demag} + \vec{h}_{anis} + \vec{h}_{ext} + \vec{h}_c \qquad (1)$$

The last term has been calculated micromagnetically for the whole spin valve structure and adapted for macrospin model, i.e. it is assumed to be uniform and in-plane (value from the center of the ellipse was taken).

It has been shown that current above a certain threshold value can either support steady state precession or lead to a static state. In the absence of external field, border between these two scenarios is sensitive to even minor changes in the torque shape.

Without external field and ICF, frequency of the in-plane precession shows a blue shift with current. However, when including ICF, out of plane precessions accompanied by a blue shift occur. If an external field is applied under certain angle both regimes can be supported and a transition from red to blue shift at a critical current is observed.

III. Micromagnetic Model

The macrospin approximation seems to successfully explain results of recent experimental studies [3]. Nevertheless, in order to compare numerical and experimental results it is important to employ the full micromagnetic model, with its detailed description of non-uniform ICF, exchange interactions, current induced Oersted field, and magnetization inhomogenities:

$$\vec{h}_{eff} = \vec{h}_{demag} + \vec{h}_{anis} + \vec{h}_{ext} + \vec{h}_c + \vec{h}_{exch} + \vec{h}_{oer} \qquad (2)$$

In the absence of external field, results of macrospin and micromagnetic models agree qualitatively. However, when ICF is included, a disagreement not only in frequency values but also in general trends is observed (Fig. 2).

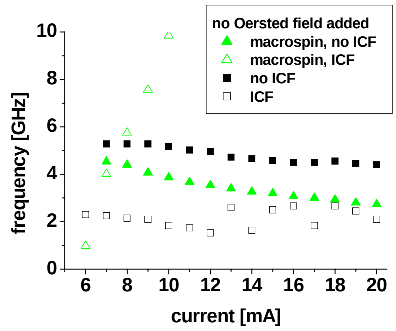

Fig. 2 Frequency vs. current for macrospin (triangles)and micromagnetic model (squares).

In order to understand why the macrospin model ceases to reproduce micromagnetic trends, further analysis has been performed. First, the micromagnetic model has been applied to pillars with reduced cross section and the influence of the size of computational cell has been investigated. Furthermore, systematic study of the influence of damping and exchange constant as well as of the orientation of external field has been carried out.

References

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