Theory of spin transfer torques in magnetic insulator based tunnel junctions

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PhD may follow: Yes

Summary :

This internship (stage) will be devoted to theoretical investigations of spin dependent transport in magnetic nanostructures using advanced quantum calculation and numerical techniques. The main goal will be to study voltage dependence properties of spin transfer torques in magnetic insulator based tunnel junctions using Green function techniques within tight-binding approximation. The calculations will be performed on Spintec computer cluster nodes using transport simulation codes (Fortran 90) developed by quantum theory group at Spintec. Results obtained will be analyzed with possibility to be published in international scientific journals. Most importantly, you will learn advanced calculation techniques; learn/improve your programming/computational skills and prepare yourself for future career. This internship may be continued as a PhD thesis.

Full description :

This internship (stage) is on theoretical investigations of spin dependent transport in magnetic tunnel junctions using advanced calculation techniques.

Magnetic tunnel junctions (MTJ) comprising two ferromagnetic layers with magnetizations M and Mâ€™ separated by the insulator (Fig. 1) play a crucial role in current and future developments of spin electronics (spintronics), such as magnetic random access memories (MRAM), hard disk drives, logic devices etc. This is due to observation in MTJs of high tunnel magnetoresistance (TMR) ratios, i.e. relative change of resistance when magnetic configuration is switched from parallel to antiparallel (Fig. 1a).

The discovery of a new spintronic phenomenon called spin transfer torque (STT) makes possible controlling magnetic configuration of the tunnel junction by passing spin polarized current through it instead of applying magnetic field (Fig. 1b). It makes possible thereby creation of new generations of MRAM where both read and write operations can be performed with spin polarised current. Thus, it is indispensable to get an insight into dependence of STT in magnetic tunnel junctions as a function of applied voltage.

In our previous works [1] we calculated and predicted voltage dependence properties of both STT terms (T|| and T) for normal insulator (e.g. MgO) based MTJs. These predictions have been later confirmed experimentally and theoretically.

Recently, new class of MTJs based on magnetic insulators with the concept of spin filtering has been proposed with potentially huge TMR ratios suitable for future logic devices. It is based on idea that different barrier height for the spin up and spin down electrons (Fig. 2) produces a strong difference in transmission (and current) for electrons with two spin directions. The nature of STT torque behaviour in such MTJ is unknown and needs to be investigated.

- This internship (stage) will be devoted to theoretical investigations of voltage dependence of STT in magnetic insulator based MTJs using quantum transport approaches (Green functions + tight-binding).
- The calculations will be performed on Spintec computer cluster nodes using transport simulation codes (Fortran 90) developed by quantum theory group at Spintec.
- Results obtained will be analyzed with possibility to be published in international scientific journals. Strong collaboration with labs in France and USA is previewed.

References for further reading on our work:

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[1] I. Theodonis et al, Phys. Rev. Lett. 97, 237205 (2006); M. Chshiev et al. IEEE Trans. Mag. 44 (11) (2008); A. Kalitsov et al, Phys. Rev. B 79, 174416 (2009); A. Manchon et al, J. of Phys.: Cond. Mat. 20, 145208 (2008) ; S.-C. Oh et al, Nature Physics 5, 898 (2009).

Ce stage pourra Ãªtre poursuivi en thÃ¨se

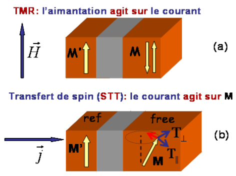

Fig. 1: Schematic representation of principle of two spintronic phenomena in magnetic tunnel junction: (a) in case of tunnel magnetoresistance, magnetic configuration of magnetizations **M** *and* **M'** *is switched from parallel to antiparallel by application of magnetic field* ***H****; (b) spin transfer torque vectors* **T||** *and* **T⊥**, oriented as **M**x(**M**x**M'**) and (**M**x**M'**), respectively, *allows controlling free layer's magnetization* **M** *by passing current* ***j*** *through the MTJ. Red arrow denotes damping.*

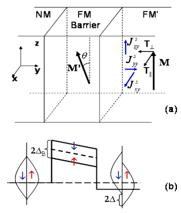

Fig. 2: Schematic representation of (a) magnetic tunnel junction with non collinear orientation of magnetizations of the barrier and FM electrode. J^s *represents elements of spin current tensor used for STT calculations; (b) the corresponding potential profile with* ΔB and Δ *representing exchange band splitting within magnetic insulator and ferromagnetic electrodes, respectively.*

Requested skills :

motivation for theoretical/numerical studies, quantum mechanics and programming/computing