Modeling dynamic, direct and inverse magnetoelectric effects

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I will present the numerical model that solves Landau-Lifshitz-Gilbert equation coupled with the charge-spin transport equations in Comsol Multiphysics in the s-d approximation. The model takes into account the effects of: spin-transfer torque, spin dephasing, spin pumping, spin-dependent conductivity, spin-dependent potential and voltage-controlled magnetic anisotropy. Time-dependent as well as eigenfrequency studies are possible. The model is especially useful to simulate the magnetoelectric effects (spin-dependent potential, voltage-controlled magnetic anisotropy) in the presence of the spin or charge accumulation at ferromagnetic metal – normal metal or ferromagnetic metal – dielectric interfaces. In the presentation I will show that the time-varying charge accumulation in the ferromagnetic metal produces spin current while, conversely, the time-varying spin accumulation in the ferromagnetic metal (generated by the inverse spin Hall effect or spin pumping) produces charge current via the dynamic magnetoelectric effects. In particular, we show by numeric simulations that spin-dependent screening at dielectric-ferromagnetic metal interface contributes to the spin-polarized current generation in the system subjected to the ac voltage [1]. Then, we show that spin current driven by spin-dependent screening may be used to modulate spin-wave amplitude in bilayer ferromagnetic system [2]. Finally, we combine ab initio calculations of electronic density of states at MgO/Fe interface with continuous model for charge transport [3]. We show that the voltage-driven electron charge accumulation at MgO/Fe interface leads to the Stoner instability because of the electronic interface resonant states. This instability manifests itself in the spin-current and spin accumulation femtosecond pulses which are present because of the contribution of the dynamic spin-dependent potential to the spin-polarized current.

References:

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