Transfer of a spin current through an antiferromagnetic insulator

Prof. Dr. Andrei Slavin
Department of Physics, Oakland University, Rochester, MI, USA

Recent experiments [1] have shown that antiferromagnetic dielectrics (AFMD) could be good conductors of a spin current, but the mechanism of this interesting phenomenon was not understood. In the experiment [1] the ferromagnetic resonance (FMR) at the frequency of 9.65 GHz was excited in the ferromagnetic (FM) layer of the multilayered structure FM-AFMD-Platinum (YIG-NiO-Pt), and the voltage of the inverse spin-Hall effect (ISHE) was measured in the Pt layer depending on the thickness of AFMD layer. Unexpectedly, it was found, that with the increase of thickness of the AFMD layer the ISHE voltage, first, increased, and, then, exponentially decayed with the characteristic penetration depth of $\lambda \sim 10$ nm. Moreover, the FMR frequency is rather low compared to the frequencies of antiferromagnetic resonance in the AFMD layer. Thus, the eigenmodes in the AFMD cannot be the carriers of spin current.

We propose a possible mechanism of spin transfer through the AFMD with a biaxial anisotropy. In our model the magnetization precession in FM layer excites two orthogonal non-eigen evanescent modes in the AFMD spin subsystem. The efficiency of the process can be rather high due to the exchange mechanism of the excitation at FM-AFMD interface. We demonstrate that the excited evanescent modes can transfer spin angular momentum to the AFMD-Pt interface. The decay

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lengths of two evanescent modes are defined correspondingly by two constants of the anisotropy. Furthermore, the anisotropy of the AFMD defines the coupling between the spin subsystem and the crystal lattice of the AFMD. We show, that due to this coupling the current of angular momentum from the crystal lattice to the spin subsystem of the AFMD is possible, so that the AFMD acts as spin current amplifier. The enhancement or the suppression of the spin current by the AFMD lattice depends on the phase shift $\phi$ between the evanescent modes and, thus, can be controlled by the method of excitation. It should be noted, that the amplification of the spin current by the AFMD crystal lattice is possible only for a sufficiently small thickness of AFMD layer. The developed theory enables one to formulate the requirements to the AFMD material and to the boundary conditions at the contact between the FM and AFMD layers under which the AFMD layer can be used as an “amplifier” of the spin current. We also note that the exchange-dominated mechanism of the spin angular momentum transfer from FM to AFMD has been recently discussed in [2].

References: