Oral

SPIN WAVE GENERATION IN MAGNETIC NANOJUNCTIONS

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It has been predicted theoretically [1,2] and also confirmed experimentally [3-5] that a sufficiently large electric current flowing through a nanojunction in a magnetic multilayer structure can excite spin waves of a certain resonance frequency about 10 – 50 GHz. It has been also proposed to use this effect as a spin wave generator of high-frequency radiation (swaser). The main idea of the corresponding theory is already well understood, and is related to the current-induced spin torque acting locally on the magnetic layer, leading to the instability of a homegeneous magnetization in the layer.

However, many important details concerning the creation of spin torque and the mechanism of spin wave excitation are not well investigated so far, and they are still a subject of hot discussions. The main problem is that several key factors should be taken into account. These are the heating of electrons by current (in the experiments the density of current is of order of 10^8 A/cm^2), the correct estimation of the spin accumulation and the spin torque acting on magnetic moments, the details of spin wave energy spectrum in the nanolayer, and, finally, the microscopic mechanism of electron-magnon interaction leading to the direct creation of magnons accompanying the usual thermal excitation of low-frequency magnons.

Here we present a theory based on a semiclassical approach to the ballistic transport of electrons through the magnetic multilayer structure. It includes the effects of heating by electric current and the spin accumulation in nanolayers [6,7]. We used the Boltzmann kinetic equation to calculate the distribution function in the approximation nonlinear in electric field. It allows taking into account heating of electrons by current. Both the phonon and magnon-emission relaxation are included. In the ballistic regime of long spin-orbit relaxation length with respect to the characteristic lengths of the structure, we have calculated the profile of electrochemical potentials for spin up and down electrons, and the distribution of the electron spin density in the structure.

Within our approach both mechanisms of magnon generation are included – by electron-magnon scattering and by the thermal excitation. However, the dominating mechanism is the magnon radiation accompanying the transition of electrons between different spin subbands. This mechanism turns out to be of main importance for the case of very thin magnetic nanolayers, which makes possible low-energy transitions of electrons due to the absence of momentum conservation for electrons scattered from a thin barrier.

We have calculated the spectral distribution of the current-generated magnons for the parameters of a five-layer structure with alternating magnetic-nonmagnetic layers of a few nanometer width. The parameters and the geometry correspond to a realistic experimental structure.

The magnons are mostly generated as localized spin-wave modes in the nanojunction region. The frequency of generated waves depends mainly on the dimension of the lateral confinement and current density. The latter dependence is due to the accumulated spin density at the magnetic layer creating the spin torque. Our theoretical results are in good accordance with the existing experiments.

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