Influence of acoustic phonons on the magnetic anisotropy in GaMnAs magnetic semiconductors

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One of the main problems in spintronics is related to the possibility of effective control of the magnetization via some non-magnetic parameters[1]. It is also especially important to achieve such a control on very fast time. In magnetic GaMnAs semiconductors a strong coupling between magnetic and elastic properties is evident.[2] Therefore strain control seems to be a good candidate for such an effective tool to switch rapidly the magnetization orientation.

It was reported recently in several experimental papers about an effect of the static strain in GaMnAs semiconductor[3] on the magnetic anisotropy, and a similar dynamic effect when the strain is produced by short laser pulses[4]. Also, it was demonstrated[5] a possibility to use non-equilibrium acoustic phonons generated by picosecond laser pulses for the irreversible switch of magnetization between different easy axis orientations. The effect was observed in a 100 nm thick film of (GaMn)(AsP) magnetic alloy semiconductor on a GaAs substrate. The direction of magnetic easy axis in the film is determined by strain as well as shape anisotropy. In particular, a thin film of GaMnAs on a GaAs substrate exhibits a compressive strain. The concentration of phosphor atoms was chosen to give a small tensile strain, the effect of which is to offset the shape anisotropy, reducing the energy barrier between in-plane and out-of-plain easy axis configurations[5].

In our work we present a theoretical description of the influence of both coherent and incoherent acoustic phonons on the magnetic anisotropy of magnetic semiconductors. Our theory is based on the six-band Kane model of the electron energy spectrum describing the valence band with $k \cdot p$ Hamiltonian[6] including the hole-phonon interaction term. We include the effect of incoherent phonons through the hole self-energy in the six-band model, and assume a strong laser-pulse-induced flux of non-equilibrium acoustic phonons. We present the results of numerical calculations of magnetic anisotropy performed for both GaMnAs and (GaMn)(AsP) magnetic alloy semiconductors. Our results demonstrate the essential role of incoherent phonons.

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