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Electric-field manipulation of magnetization vector direction[1]

HIDEO OHNO, RIEC, Tohoku University / ERATO JST

Ferromagnetism and magnetization in Mn-doped III-V semiconductors can be manipulated by various means; by changing its carrier concentration by electric fields [1] or by spin- current flowing along with the electric current [2]. This material system is thus an excellent system to study the physics involved in manipulation of magnetism as well as exploring new ways to control magnetization. Here, we show that electrical control of magnetization direction can be done through manipulating electronically the magnetic anisotropy energies [3]. The basic idea behind the effort is to control the population of carriers on spin-split anisotropic valence bands that governs the magnetic anisotropy energies, which should result in change of the direction of magnetization. In order to measure the magnetic anisotropies under a gate that applies the electric-field to the ferromagnetic semiconductor channel, we used the planar Hall effect. Analyses showed that there are biaxial as well as uniaxial anisotropies. As the sheet carrier concentration is reduced by applying electric- field to the channel, the uniaxial anisotropy field reduced its magnitude and eventually changed its sign, whereas no significant change was apparent in the biaxial anisotropy field. From the electric-field dependent anisotropy fields, one can show that the angle of the magnetization direction in the absence of magnetic fields is modulated by electric-fields by 10 degrees. This opens up a new and unique opportunity for manipulating magnetization direction solely by electronic means, not resorting to magnetic-field, spin-current, mechanical stress, nor multiferroics. The conditions for switching the magnetization direction will also be discussed. The work was done together with D. Chiba, F. Matsukura, M. Sawicki, Y. Nishitani, and Y. Nakatani.

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