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Manipulation of ferromagnetic state by means of spin-orbit interactions

LEONID ROKHINSON, Purdue University

The current state of information technology accentuates the dichotomy between processing and storage of information, with logical operations performed by charge-based devices and non-volatile memory based on magnetic materials. The major obstacle for a wider use of magnetic materials for information processing is the lack of efficient control of magnetization. Reorientation of magnetic domains is conventionally performed by non-local external magnetic fields or by externally polarized currents. Efficiency of the latter approach is greatly enhanced in materials where ferromagnetism is carrier-mediated. In such materials control of carriers' polarization provides an alternative mean to manipulate orientation of magnetic domains. In some crystalline conductors the charge current couples to spin via intrinsic spin-orbit (SO) interactions and generates electron spin polarization. Unlike the Oersted field, the SO-induced polarization is spatially localized and can be controlled by local electric fields. This non-equilibrium electron spin polarization couples to magnetic moments of magnetic ions and is capable of controlling magnetization of the ferromagnet. We show that magnetization can be reversibly manipulated by SO-induced polarization of carrier spins generated by the injection of unpolarized currents. We demonstrate domain rotation and hysteretic switching of magnetization between two orthogonal easy axes in a model ferromagnetic semiconductor GaMnAs.