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Magnetic Dynamics by the Spin-Orbit Interaction

We can find in nature some scattering processes that change the total angular momentum of involved (quasi-) particles. In this talk, I would like to present this type of scattering occurring in a conduction carrier system and its applications for spintronics. When the spin-orbit (SO) interaction is sufficiently strong, the dispersion relationship of conduction carriers depends on the spin orientation. This causes the change in total spin angular momentum of carrier system when applying an electric field to the carriers. In a conductive ferromagnet where the conduction electrons' spins couple to the localised spins via the exchange interaction, the applied electric field can therefore create an internal magnetic field. Using this mechanism at GHz frequencies, we induced magnetic torques in a GaMnAs micro-bar [1], which drives ferromagnetic resonance. Several sets of the experiments revealed that the magnitude and the symmetry of the excitation field, which will be compared with a microscopic model. In addition, I will show recent progresses in understanding of the nature of the torques [2]. 1. D. Fang, H. Kurebayashi et al., Nature Nanotech. 6, 413 (2011). 2. H. Kurebayashi et al., in preparation.

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STT-MTJ-Based Implication Logic Circuits for Non-Volatile Logic-in-Memory applications

Leakage power has become a major concern as CMOS technology is scaled down. Introducing non-volatility into logic is a promising solution offering zero standby power and instant-on applications. Magnetic Tunnel Junction (MTJ) technology is an attractive candidatedue to its unlimited endurance, CMOS compatibility, and fast switching speed. Furthermore, spin-transfer torque operated MTJs (STT-MTJ) eliminate the physicalmismatch between reading and writing, subject to standard MRAM (writing via magnetic field, reading via current), and is receiving attention as the next generation of highly scalable and low power non-volatile memory.

A STT-MTJ-based logic circuit implementing a fundamental Boolean logic operation called material implication (IMP) allows extending the functionality of non-volatile memory circuits to incorporate logical computations. The operation ‘s IMP t’ (reads ‘if s, then t’) is equivalent to ‘(NOT s) OR t’ and forms a computationally complete logic basis in combination with the FALSE (writing logic 0) operation to compute any Boolean function. Due to an easy integration of MTJs on top of a CMOS circuit into a one transistor/one MTJ (1T/1MTJ) cell, the IMP logic gates can be extend to large-scale non-volatile circuits. Since the 1T/1MTJ cell is the basic element for STT-MRAMs, an array of STT-MRAM can be used as a magnetic logic circuit. This provides an intrinsic non-volatile logic-in-memory architecture with zero-standby power without any need for data transfer between separate memory and logic units, which opens the way towards architectures beyond Von Neumann.