SPIN DYNAMICS IN NANOSCALE SYSTEMS

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Research interest in magnetic nanostructures and spintronics has shifted increasingly towards dynamic properties. This is motivated by the fact that the switching time of magnetic hybrid multilayers used in mass data storage devices, magnetic random access memories (MRAM), and spintronics devices is a real technological issue. Spin relaxation processes in metallic structures will be summarized and demonstrated on several ultrathin film structures. It will be shown that the intrinsic Gilbert damping in metallic films is caused by noise in the spin orbit interaction. In ultrathin films the Gilbert damping is affected by interface electron band contributions resulting in inverse dependence on the film thickness. In multilayer films involving FM/NM/FM structures (FM-ferromagnet, NM-normal spacer) the spin dynamics becomes affected by non-local spin transport. A gyrating magnetic moment creates a spin current in surrounding normal metal layers and leads to non-local interface spin damping. Landau-Lifshitz-Gilbert (LLG) equations of motion are modified by spin pumping and spin sink effects. Time Resolved Magneto-Optical Kerr effect (TRMOKE) allows one to investigate propagation of spin currents. The stroboscopic time-resolved measurements (with the time resolution of 1 ps and sub micron spatial resolution) were carried out using Fe/Au/Fe/GaAs(001) structures which were in proximity of a co-planar transmission line driven by a CW microwave signal which was synchronized with the TRMOKE fs wide laser pulses. Spin currents generated by spin pumping at the Au/Fe interface were investigate from the ballistic to spin diffusion limit by using the Fe/Au interface as a spin detector.

Ultrathin films are often accompanied by lattice defects resulting in extrinsic contributions to magnetic relaxation processes. It will be shown that one can distinguish the intrinsic and extrinsic contributions by studying the ferromagnetic resonance (FMR) linewidth as a function of microwave frequency and angle of the magnetization with respect to the film surface. The role of extrinsic damping will be demonstrated in crystalline epitaxial GaAs/Fe/Pd(001) and MnSbNi(001) Heusler alloy structures. The Pd lattice has a large lattice mismatch with respect to Fe. The lattice strain was partially released by a self-assembled rectangular network of misfit dislocations. Stacking faults in Heusler alloys lead to bulk ordered lattice defects. It will be shown that these nano-networks of lattice defects can lead to a strong extrinsic magnetic damping which is be described by two magnon scattering mechanism. The two magnon scattering can surpass significantly the intrinsic Gilbert damping. FMR measurements on Fe/Pd(001) and MnSbNi(001) Heusler alloy structures were carried out from 4 GHz to 73 GHz. The contribution of two magnon scattering to the FMR linewidth was found strongly anisotropic following the symmetry of crystallographic defects. This suggests that the scattered spin waves propagated mostly along the planes of crystallographic defects.

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