Nonlinear-Optical Studies of Spin-Injection Devices

HAIBIN ZHAO

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Advisor: Gunter Luepke, Associate Professor of Applied Science

Abstract

This thesis presents optical characterizations of interfaces in ferromagnetic heterostructures and thin films used for spin polarized electronic devices. In these experiments, femtosecond laser spectroscopies are exploited to investigate the interface magnetization reversal, spin precession, and band offset, which are crucial in determining the performances of spintronic devices.

First, magnetization-induced second-harmonic-generation (MSHG) is applied to study interface magnetism in a hybrid structure containing a noncentrosymmetric semiconductor - Fe/AlGaAs. The reversal process of Fe interface layer magnetization is compared with the bulk magnetization reversal. In Fe/AlGaAs (001), the interface magnetization is found to be decoupled from the bulk magnetization based on the different switching characteristics – single step switching occurs at the interface layer, whereas two-jump switching occurs in the bulk. In contrast, the interface layer in Fe/AlGaAs (110) is rigidly coupled with the bulk Fe, indicating a strong impact of electronic structure on the magnetic interaction despite the same chemical composition. Furthermore, a time-resolved MSHG study demonstrates a coherent interface magnetization precession in Fe/AlGaAs (001), implying the feasibility of fast precessional control of interfacial spin. The interface magnetization precession exhibits a higher frequency and opposite phase for a given applied field compared to the bulk magnetization precession.

Second, uniform magnetization precession in the $La_{0.67}Ca_{0.33}MnO_3$ (LCMO) and $La_{0.67}Sr_{0.33}MnO_3$ (LSMO) films grown on different substrates are investigated by time-resolved magneto-optic Kerr effect. The parameters of magnetic anisotropy are determined from the field dependence of the precession frequency. The strain-free LCMO films grown on $NdGaO_3$ exhibit a uniaxial in-plane anisotropy induced by the tilting of the oxygen octahedra in $NdGaO_3$. An easy-plane magnetic anisotropy is found in the tensile-strained films grown on $SrTiO_3$, whereas the compressive-strained film grown on $LaAlO_3$ exhibits an easy normal-to-plane axis.

Third, a table-top internal photoemission system is developed to measure the band offsets across semiconductor heterointerfaces by utilizing an optical parametric amplifier as the bright light source. The conduction band offsets ΔE_c = 660 meV and 530 meV at the $CdCr_2Se_4$-GaAs and $CdCr_2Se_4$-ZnSe interfaces are determined from the threshold energies of the photocurrent spectrum. The band offset is shown to be reduced by engineering the interface bonding and stoichiometry.