SUMMARY OF Ph.D. DISSERTATION

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Title

A study on interaction among charge current, spin current, and magnetization dynamics in metallic thin film systems

Abstract

A spin current, a flow of electron spins in a solid, promises the achievement of novel electronic devices based on electron spins. In this thesis, the interaction between spin currents and magnetization dynamics is investigated systematically using the direct and inverse spin-Hall effects in metallic systems. This thesis consists of eight chapters as follows.

Chapter 1 is an introduction, including the background and purpose of this thesis.

Chapter 2 describes the preparation methods of the samples used in this thesis. The analytical method of magnetization dynamics is also presented in this chapter.

Chapter 3 describes the generation and detection of spin currents in ferromagnetic/paramagnetic bilayer systems. A spin current generated by magnetization precession is detected electrically using the inverse spin-Hall effect. The microwave power and the magnetic field angle dependences of the inverse spin-Hall signal in a $Ni_{81}Fe_{19}$/Pt film are well reproduced by a phenomenological model of the direct-current spin pumping.

Chapter 4 describes the phenomenological formulation of spin currents generated by magnetization dynamics. The model calculation based on the Landau-Lifshitz-Gilbert equation combined with the standard model of the spin pumping indicates that the generation efficiency of spin currents induced by magnetization precession is equal to the elliptical orbit area of the magnetization precession, which is maximized when the precession trajectory is distorted. The validity of these results is demonstrated from experiments on the magnetization angle dependence of the inverse spin-Hall effect induced by the spin pumping in a $Ni_{81}Fe_{19}$/Pt thin film system.

Chapter 5 is devoted to the experiments on modulation of magnetization dynamics using a spin current. Spin relaxation in a $Ni_{81}Fe_{19}$/Pt film is manipulated electrically using the spin-Hall effect. The model calculation based on the Landau-Lifshitz-Gilbert equation including the spin torque well reproduces the experimental results. The experimental results and the model calculation demonstrate that the measurement of the spin relaxation modulation induced by spin current injection enables the quantitative measurement of spin currents without assuming any microscopic material parameters; this method acts as the spin-toque meter.

Chapter 6 describes the interaction between spin currents and spatially modulated magnetization dynamics. A spin current generated by spin wave resonance is observed in $Ni_{81}Fe_{19}$/Pt thin wire arrays using the inverse spin-Hall effect. The experimental results indicate that the amplitude of the inverse spin-Hall signal is proportional to the spin-wave resonance absorption intensity, showing that this method enables the electric measurement of spin dynamics in nanostructured magnetic systems. In the same system, spin-wave-relaxation modulation is observed using the spin-Hall effect. The experimental results show that the spin-wave-relaxation modulation enables the highly-sensitive detection of spin currents.

Chapter 7 describes the experiments on the interaction among photon spins, spin currents, and charge currents. The conversion of light-polarization information into an electric signal is achieved using the photo-induced inverse spin-Hall effect in a Pt/GaAs hybrid structure.

Chapter 8 is devoted to the conclusion of this thesis.