Dynamic Spin Switching of Magnetic Films and Tunnel Junctions

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Spin dynamics has been investigated intensively in various kinds of fields. Most popular one is an initial permeability at high frequency. Also, magnetic after-effect such as thermal fluctuation of fine magnetic particles and disaccommodation in soft magnetic materials were extensively studied in the past.

When we apply an external force with the same frequency as that of the system being examined, the system absorbs the external energy and the precession enhances. It is called resonance in general. Among the various resonances, ferromagnetic resonance (FMR) has been used as a good tool to evaluate material constants such as saturation manetization or spin damping parameter by analyzing a resonance curve. In this talk first instinctive understanding of Gilbert spin damping and spin pumping will be explained. Then, experimental data for enhancement of Gilbert damping parameter (*G*) evaluated from FMR spectrum [1,2,3] and spin precession measured by a time resolved pump-probe method for Permalloy thin film will be introduced [4]. Finally, magnetization reversal observed by air-coplanar probe [4] will be given.

Three series of films, NM/Py(d_{Py})/NM (NM=Cu, Ta, Pd, Pt), Cu/Py(3nm)/ Cu(d_{Cu})/ Pt(5nm) and Cu/Py(3nm)/Cu(d_{Cu}) were fabricated by magnetron sputtering on the substrate of corning 7059 glass. The base pressure was less than $5x10^{-7}$ Torr and the deposition of films was carried out in 7 mTorr. The thickness of d_{Py} and d_{Cu} layers ranged from 2 to 10 nm and 0 to 1500 nm, respectively. The out–of–plane angular dependence of FMR was measured using an X-band (9.77 GHz) ESR spectrometer with a goniometer. The Gilbert damping parameters, *G*, for NM=Pt and Pd were much larger than the bulk value of Py and were dependent on the thickness of Py. *G* for NM=Cu and Ta were same as the bulk value. While, *G* for Cu/Py/Cu/Pt films was about twice as large as that for Cu/Py/Cu films even at d_{Cu}=10 nm and decreased gradually as d_{Cu} increased. At d_{Cu}=200-300 nm, *G* for Cu/Py/Cu/Pt and Cu/Py/Cu films became the same value. All these experimental data for *G* can be explained by spin pumping effect between Permalloy and non-magnetic substance at interface.

For the detection of the detailed magnetization precession, time-resolved pump-probe MOKE signal was measured. The current pulses generated by an optical switch were synchronously triggered by a mode-locked Ti-sapphire fs-laser with 800 nm of wavelength. Magnetization measurements were carried out through polarization analysis of the reflected light in an optical bridge. A static external magnetic field H_{static} was applied to the easy axis direction, while the impulse field of 2 Oe was applied to the hard axis direction. The signal was fitted well with the calculation using Landau- Lifshitz-Gilbert (LLG) equation of motion with the damping parameter G of 1x10$_8$ s$_{-1}$, which corresponded to the value obtained for the Py film measured using a ferromagnetic resonance.

For the electrical detection of the magnetization reversal, a home-made probing apparatus using air-coplanar probes was set up. It has two external coils which supply dc fields in the hard and easy axis directions. Ferromagnetic tunnel junctions (MTJs) were prepared using sputtering. The stacking structure was Sub./Ta(3nm)/Cu(20nm)/Py (3nm)/IrMn(10nm)/CoFe(5nm)/Al(0.7nm)-O/Py(15nm)/Cu (20nm)/Py(10nm), and the junction area was 10 ∝m x 10 ∝m. A pulse generator was used to create current pulses with less than 500 ps rise time through the upper electrode of the MTJs. The magnetization change due to the pulse fields could be determined by measuring the voltage between the both electrodes using a fast oscilloscope. The time to switch the magnetization decreased to 500 ps with increasing the field pulse amplitude up to 100 Oe with no hard axis field. The time to switch the magnetization became short and the reversal became clear with increasing the hard axis field. The transition time estimated using Landau-Lifshitz-Gilbert (LLG) equation of motion of the exact experimental conditions agreed well with the experimental measurements.

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