Research Group for Mechanical Control of Materials and Spin Systems

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The research objective of our group is to develop new methods for controlling spin currents by combining electron spins and mechanical rotation, and/or by coupling spins and NMR techniques. That is to expand spintronics frontier using mechanical motion and NMR method. Our goals are :

1) Magnetization manipulation in terms of mechanical rotation.
2) Detection of a spin current generated from rotating objects using the spin Hall and spin torque effect.
3) Detection of spin transfer between nonmagnetic and ferromagnetic layers by NMR.

Ferrromagentic enhancement in Barnett effects measured with a highly stabilized rotator at high temperatures

To overcome the difficulty of detecting the tiny effective magnetic fields induced by rotations, improvements of the high-speed rotation system are needed for the reduction of the magnitude of environmental fields. The residual magnetic field less than 10 mOe has been achieved by improving the electromagnetic shielding of the system. Figure 1 is a plot of magnetizations of a ferrite sample after a series of experiments for observing the Barnett effect. The sample is cooled after heating to 500 (above the Curie temperature 480) with or without the rotations. Squares are the magnetization of the sample without the rotations, and circules are those with the rotations where the rotational speed is 0.5 kHz. We observed the systematic shifts of the magnetization by rotation (Fig. 1). This implies that the effective magnetic field induced by the rotations modulates the net magnetization, consistent with the Barnett effect affected by the magnetic transition instability

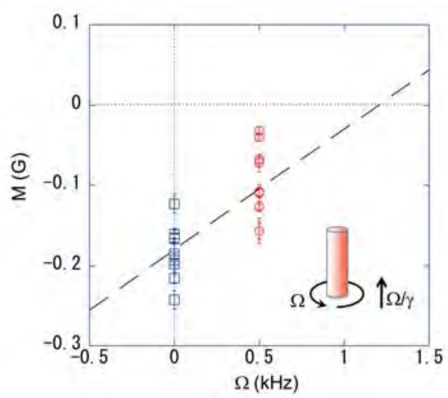

Fig. 1 Magnetization of a sample by rotations with the angular speed of Ω.The dotted line represents $M=\chi(\Omega/\gamma+H_{env.})$. Sample: anisotropic ferrite magnet with the dimension of 5 mm long and φ1 mm in diameter, $H_{env.}$ = −0.01 Oe.

Spin pumping induced by the FNR in a Pt/Co_2MnSi hetero junction

Transfer of spin angular momentum from a precessing localized spin to the conduction electron is called the spin pumping. The spin pumping from ferromagnetic magnetization has already been established, and it has been used as a basic technique for the spin current generation. However, the microscopic mechanism has not been elucidated yet, particularly underlying physics of the interface spin exchanges. In order to take further steps to understand the phenomena, we have been trying to generate a spin current using the spin pumping from resonating nuclear spins. An experimental strategy in this category is rather simple; we have tried to detect a current in the nonmagnetic metallic layer attached to a ferromagnetic layer via the inverse spin Hall Effect (ISHE) which converts a spin current into an electric current. Here the spin pumping is driven by ferromagnetic nuclear resonance (FNR) which coupled strongly to the magnetic moment of electrons via the hyperfine coupling in the order of 10-100 T/μ_B. The ferromagnetic layer used in the present study was Heusler compounds Co_2MnSi, because it contains ^{59}Co and ^{55}Mn nuclei whose natural abundances are 100%, being appropriate for FNR. A spin current generated by the spin pumping that is driven either by the ^{59}Co and ^{55}Mn FNR is detected by the ISHE in the Pt layer.

Figure 2(a) shows the schematic illustration of the setup for the measurement of spin pumping using ^{59}Co and ^{55}Mn FNR. The sample is an array of Pt(7 nm)/Co_2MnSi(20 nm) thin rectangular films with width of 0.8×9 mm^2 in size. These films were wired in series fashion in order to obtain the amplified voltage arising from the ISHE. The sample assembly was inserted into an RF-coil, where the RF field for FNR was applied parallel to the electrodes on the Pt layer. In order to align the ferromagnetic domains, 270 Oe fields were applied within the film plane and were rotated with respect to the direction of the RF field. The FNR spectra associated with the ^{59}Co and ^{55}Mn nuclei in Pt(7 nm)/Co_2MnSi(20 nm) are shown in Fig. 2(b). The fractional change in the voltage across the FNR frequencies is shown in Fig. 2(c). The electromotive force spectrum exhibits two broad peaks around the frequency 200 and 350 MHz, corresponding to the ^{59}Co and ^{55}Mn FNR spectra. Although these peaks are broaden compared with the FNR spectrum especially in ^{59}Co FNR, which is attributed to the surface effect, this voltage signal implies that the FNR generates a spin current into the Pt layers.

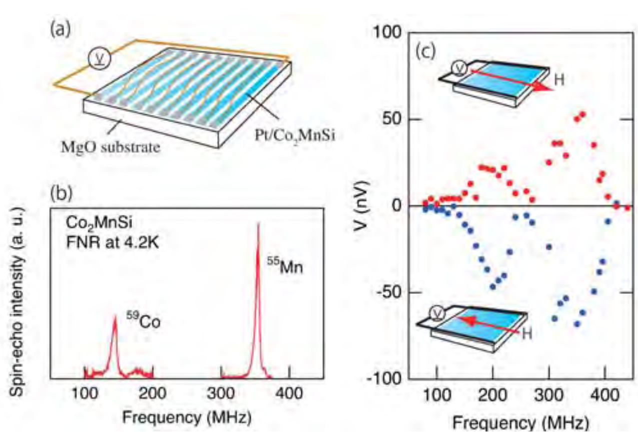

Fig. 2 (a) A schematic diagram of the sample set-up. (b) FNR spectra of ^{59}Co and ^{55}Mn. (c) The electromotive force between electrodes on the Pt layer arising from ^{59}Co and ^{55}Mn FNR.