Research Group for Mechanical Control of Materials and Spin Systems

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The research objective of our Group "Mechanical Control of Materials and Spin Systems" is to develop new methods for controlling spin currents by combining electron spins and mechanical rotation, and/or by coupling spins and nuclear magnetic resonance (NMR) techniques. To achieve this, we expand spintronics frontier using a high-speed rotation technique and NMR method. Our goals are

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

Voltage generation from mechanical motion based on a fluid spin-pumping

We have succeeded in generating voltage from a mechanical motion of a liquid metal; a fluid spin-pumping through vorticity gradient in the liquid metal. The injected spins are converted to a voltage via the inverse spin Hall effect (ISHE).
Figure 1 illustrates a schematic diagram of a voltage generation using a jet emission method. The liquid metal is sprayed on a spin detection layer (a Pt thin film) by a commercial airbrush. Figure 2 shows results of the voltage measurement in the fluid spin-pumping based on the jet emission method. A voltage is generated during the liquid metal being sprayed and its sign changes as the flow direction is reversed [Fig.2(a) and (b)].

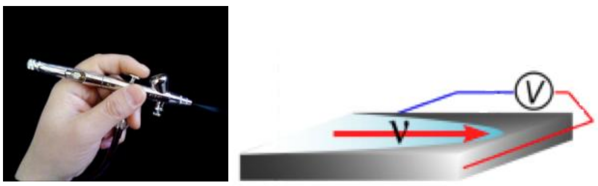

Fig. 1 Setup for a fluid spin-pumping.

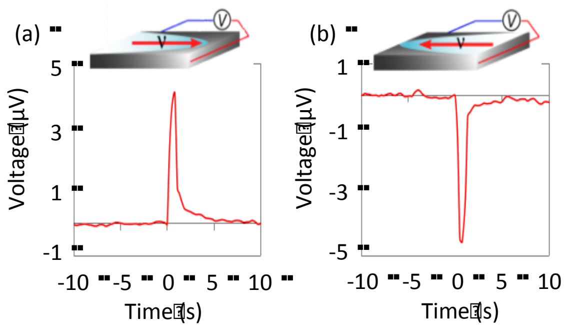

Fig.2 A result of the jet emission experiment.

The mechanism of the fluid spin-pumping can be depicted as follows (corresponding illustrations are shown in Fig. 3):

1) Very high speed motion (~10m/s) of liquid droplets can be achieved by a jet emission method.
2) After the droplet touchdowns on a film, it starts sliding.
3) From the boundary condition of the droplets' speed at the droplet/film interface, v_x =0, the gradient of v_x develops perpendicular to the film within a length scale determined by the viscosity, leading to a finite vorticity ω of fluid.
4) Here, the vorticity can be regarded as an effective magnetic field (Barnett field) H_{eff}.
5) The gradient of H_{eff} injects a spin current into a Pt film and the spin current can be detected as an ISHE voltage along the flow direction.

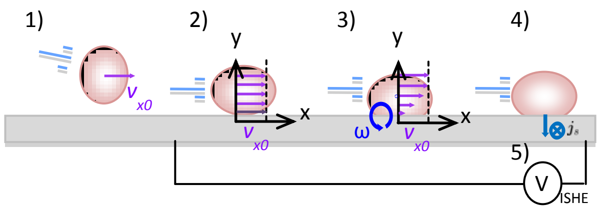

Fig. 3 Schematic diagram of the fluid spin-pumping.

This scenario explains the sign change of the observed voltages; the inversion of the velocity reverses the polarity of the vorticity, and hence the spin polarization of the injected spin current, resulting in the sign change of the ISHE signal.
In the jet emission method, however, it is difficult to control the speed of the droplets v_{xo}, which hinders quantitative estimation of experimental results. To analyze the measured voltage V_{ISHE} more precisely, we have developed a new method using a flow in a narrow channel. We have also constructed a theoretical framework based on hydrodynamics, spin diffusion, and the physics of the ISHE. The measured voltages in the channels with different diameters can be well-described by the theory.
These findings bridge spintronics and fluid motion, and open up a new research field called *fluid spintronics*.

Detecting the interaction between a mechanical rotation and nuclear spins by using a spectroscopic method

In a rotating object, spins are subject to an effective magnetic field known as a Barnett field. This is a quantum mechanical analogue of the Coriolis force. By using NMR techniques we have succeeded in measuring the effective magnetic field that was predicted previously but has been elusive thus far. The coil spinning method, rotating the NMR measurement system and a sample simultaneously, has allowed us to access a shift of the NMR frequency due to rotation in various nuclear isotopes, demonstrating its high potential for further investigations of the coupling between nuclear spins and mechanical rotations