Research Group for Mechanical Cotrol of Materials and Spin Systems

Group Leader: Eiji Saitoh

The research objectives of Spin Manipulation and Material Design Research Group are to develop new methods for controlling spin currents by combining electron spins and mechanical rotation, and/or by coupling spins and NMR techniques;

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 the coupling between nuclear spin and electron spin dynamics and/or current.

Utilizing the combination between spin and mechanical rotation will help us realize an actuator driven by a spin current in a nano scale and mechanical generator of spin currents.

Construction of experimental setups for spin manipulation by high-speed rotation and NMR technique

To control the spin current with the new methods, we newly constructed two experimental setups, one was a high-speed rotator, and the other was a NMR spectrometer. Figure 1 shows a schematic diagram and the constructed apparatus for magnetization manipulation experiments by high-speed rotation.

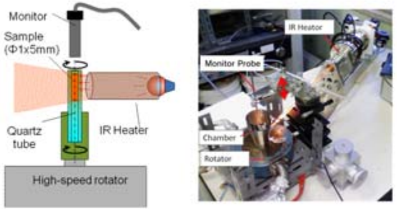

Fig. 1 A schematic diagram and the constructed experimental setup for magnetization manipulation experiments by high-speed rotation.

Spin pumping efficiency of half metalic Co_2MnSi

In the field of spintronics, the methods of generating a pure spin current are important techniques to drive devices such as spin-based magnetic memorites and computing devices. Spin pumping is a recently developed technique to generate a pure spin current. Efficiency of the spin pumping is determined by a spin mixing conductance, that depends on a difference in the population between up and down spins. Thus half metallic compounds, which have perfectly spin-polarized conduction electrons because of a semi-conducting gap in either the up- and down-spin channel at the Fermi level, are expected to show a high efficiency of the spin pumping. We evaluated the efficency of the spin pumping from a half-metallic Heusler alloy Co_2MnSi film using a ferromagnetic resonace (FMR) technique.

The sample is a Co_2MnSi/Pt bilayer film comprising a 20-nm-thick ferromagnet Co_2MnSi and a 7-nm-thick paramagnet Pt layer as illustrated in Fig. 2. The (100)-oriented epitaxial Co_2MnSi was grown on a MgO(100) substrate with the 0.5-mm thickness by a ultra high vacuum (UHV) sputtering system at ambient temperature, then annealed at 723 K to improve crystal quality and chemical ordering. The sample system is mounted on the center of a TE_{011} microwave cavity, where the magnetic field component of the microwave mode $\boldsymbol{h}_1$ is maximized. The frequency of microwave is 9.44 GHz.

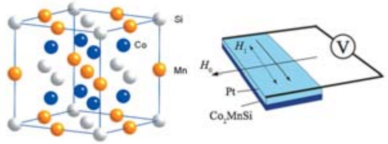

Fig. 2 A crystal structure of Co_2MnSi and a schematic illustration of the sample.

The upper panel of Fig. 3 shows the field swept FMR spectrum $dI(H)/dH$ and the lower one shows the field dependence of the potential difference between electrodes on the Pt film, respectively. At the center of resonance, a spin current generated by FMR in the Co_2MnSi layer is injected into the Pt layer. The pure spin current injected into the Pt layer from the Co_2MnSi layer is detected by the inverse spin-Hall effect (ISHE), which converts the spin current into an electric current. We estimated a damping constant of the Co_2MnSi/Pt bilayer film from an angular dependence of FMR spectra. Analyzing the damping constant efficiency of the spin pumping from the Co_2MnSi layer is evaluated. We found that a mixing conductance at the Co_2MnSi/Pt interface is comparable to that at a permalloy/Pt interface.

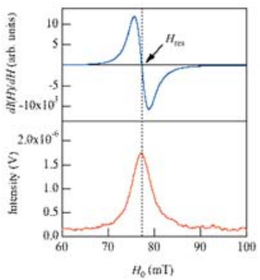

Fig. 3 The upper panel shows field dependence of the FMR signal $dI = dH$ for a Co_2MnSi/Pt bilayer film, where I denotes the microwave absorption intensity, and the lower shows field dependence of the potential difference between electrodes on the Pt film. The dotted line in the panel represent the resonant field of 772.6 Oe.

Reference

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Research Group for Reactions Involving Heavy Nuclei

Group Leader: Satoshi Chiba

The objectives of Research Group for Reactions Involving Heavy Nuclei are to develop experimental and theoretical methods to realize and validate the surrogate reaction technique to determine neutron-induced reaction cross sections of unstable nuclei such as minor actinides and branch-point nuclei of s-process nucleosynthesis. We specialise to surrogate reactions using heavy projectiles. Experimental apparatus to measure fission and capture cross sections were developed and installed at Tandem accelerator facility as shown in Fig. 1. At the same time, basic researches in related areas, especially, shell structure and reaction characteriscis of (heavy, fissionable) nuclei are also in our important scope. These results are published as a number of papers. Highlights of our activities during FY 2010 are summarized below.

Nuclear orientation in the reaction $^{34}S+^{238}U$ and synthesis of the new isotope ^{268}Hs

The synthesis of isotopes of the element hassium was studied using the reaction $^{34}S + ^{238}U \rightarrow ^{272}Hs^*$ [1]. At a kinetic energy of 152.0 MeV in the center-of-mass system one decay of the new isotope ^{268}Hs was observed. It decays with a half-life of $0.38^{+1.8}_{-0.17}$ s by 9479±16 keV α-particle emission. Spontaneous fission of the daughter nucleus ^{264}Sg was confirmed. The measured cross section was $0.54^{+1.3}_{-0.45}$ pb. The fission-fragment mass distributions changed from symmetry to asymmetry when the beam energy was changed from above-barrier to sub-barrier values, indicating orientation effects on fusion and/or quasifission. It was found that the distribution of symmetric mass fragments originates not only from fusion-fission, but has a strong component from quasifission. The result was supported by a calculation based on a dynamical description using the Langevin equation, in which the mass distributions for fusion-fission and quasifission fragments were separately determined.

In-beam γ-ray spectroscopy of $^{248,250,252}Cf$ by neutron-transfer reactions using a Cf target

The ground-state bands of ^{248}Cf, ^{250}Cf and ^{252}Cf have been established up to the 10^+, 12^+, and 10^+ states, respectively, by in-beam γ-ray spectroscopy using neutron-transfer reactions with a 153-MeV ^{18}O beam and a highly radioactive Cf target [2]. The deexcitation γ rays in ^{248}Cf, ^{250}Cf and ^{252}Cf were identified by taking coincidences with outgoing particles of $^{16-19}O$ measured with Si ΔE-E detectors, and by selecting their kinetic energies. Moments of inertia of ^{248}Cf, ^{250}Cf and ^{252}Cf were discussed in terms of the $N = 152$ deformed shell gap.

Theoretical investigation of the surrogate reaction method

Results of the surrogate reactions depend sensitively on the difference of populated spin distribution from that of desired neutron-induced reactions. The spin distribution, in turn, reflects reaction mechanisms and underlying nuclear structure. We therefore try to find a universal condition that surrogate reactions would yield the desired neutron cross sections. For this aim we discussed the surrogate ratio method, and it was found that we need not know the spin-parity distributions populated by surrogate reaction, if (1) there exist two surrogate reactions whose spin-parity distributions of decaying nuclei are almost equivalent, and (2) difference of representative spin values between the neutron-induced and surrogate reactions is not much larger than $10\hbar$, and (3) J^{π}-by-J^{π} convergence of the decay branching ratio is achieved (which can be verified by a statistical model) [3]. Successive theoretical works followed to confirm this conclusion. Experimental equipments were designed accoring to the above considerations.

To understand the reaction mechanism and verify the above conditions for the surrogate ratio method to work, we established a theoretical model which is based on the unified model. We performed a trajectory calculation on the time-dependent unified potential energy surface using the Langevin equation. Using the model, we calculated the spin of the compound nucleus in surrogate reactions $^{236,238}U(^{18}O, ^{16}O)^{238,240}U$. The results show the spin of compound nucleus is less than $10\hbar$ (namely, condition (2) is satisfied). We also calculated the spin distributions of decaying nuclei by these two reactions, and found that they were indeed equivalent (condition (1) is satisfied). The present results suggested the validity of the surrogate ratio method.

In approaching the surrogate reaction from the viewpoint of full quantum mechanics, nuclear-structure information on the projectile and target nuclei is strongly desired. We thus calculated the structure of oxygen isotopes with the shell model in the full *p-sd* valence space [4] because ^{18}O beam is used in our surrogate reactions. Since in previous microscopic calculations some low-lying states, known as multiparticle-multihole states excited across the $N = Z = 8$ shell gap, were too high compared with experimental data, we focused on the mechanism that lowers these states. It turned out that due to large correlation energy in ^{16}O the $N = Z = 8$ shell gap must be strongly reduced from the standard value which is based on the assumption of a closed shell for ^{16}O. This reduction plays a key role in accounting for the lowering of the multiparticle-multihole states.

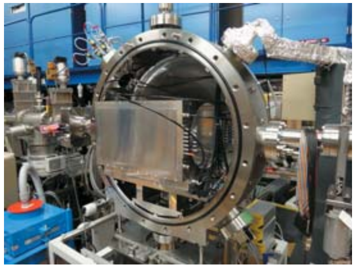

Fig. 1 Vacuum chamber and MWPC (multi-wire proportional counter) installed at Tandem accelerator facility in Tokai.

References

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