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The observation of electronic structures on Pt/Fe/MgO and the design of operand sample holder

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Spin Hall effect is an important physical phenomenon that generates spin-polarized currents and is essential for the development of spintronics devices. The spin Hall effect in metals has attracted attention because conductance mismatches are markedly suppressed at an interface with ferromagnet and compared to the semiconductors and allows the use of spin-polarized current supplied by the ferromagnet [1]. Among many metals, elemental Pt is extensively investigated by experiment and theory [2,3]. T. Kimura *et al.* reported that the Pt wire exhibits largest spin hall conductivity as large as 2.4×10^4 S/m at room temperature, which is 4 orders of magnitude larger than that of typical semiconductors, such as GaAs [2]. In order to inject spin-polarized current into ferromagnets more efficiently, the orientation of spin current must be precisely controlled, i.e., it is necessary to observe its spin orientation. In previous studies, the rough spin orientation of spin currents induced by spin Hall effects has been obtained by using the magneto-optical Kerr effect [4]. However, the experimental method to precisely detect the spin orientation induced by the spin Hall effect has not been established yet. One solution is *operando* spin-resolved photoemission spectroscopy (PES) measurements under an external electric field.

In this presentation, we introduce two key developments for realizing this experimental technique. The first key development is the preparation of a platinum thin film. The second one is the design of a sample holder for the *operando* measurements.

For the Pt(001) thin film preparation, a thin Fe buffer layer was epitaxially grown on a MgO(001) substrate by molecular beam epitaxy (MBE) at room temperature (RT), in an ultrahigh vacuum (UHV) chamber with a base pressure of 8×10^{-7} Pa. The deposition of Fe was done at the substrate temperature of 600 °C. At a next growth stage, Pt was deposited on the Fe layer at RT. The quality of the Pt/Fe/MgO sample was evaluated using low-energy electron diffraction (LEED) and angle-resolved photoemission spectroscopy (ARPES). ARPES measurement was done using He discharge lamp with photon energy of 21.218 eV (He Iα).

Figure 1(a) shows the LEED pattern of the Pt/Fe/MgO sample. A distinct 1 × 1 LEED pattern with 4-fold symmetry indicates the successful growth of Pt(001) thin film. Moreover, the Fermi surface with 4-fold symmetry (**FIGURE 1(b)**), and the observed clear band structure forming a large electronic band (not shown here) are another indication of the high-quality Pt(001) film.

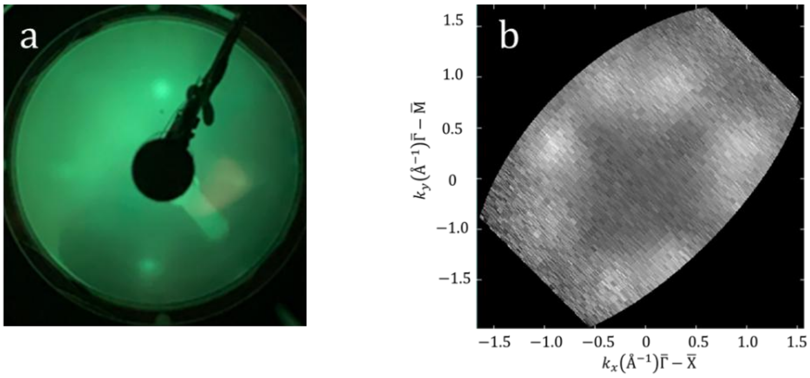

FIGURE 1. (a):(01)LEED-spot of Pt thin film sample at E_K = 73.4 eV**.** Pt film thickness is 22 nm. (b) Fermi surface of Pt(001)/Fe(001)/MgO(001) measured by ARPES at $h\upsilon$ = 20.218 eV. Pt film thickness is 36 nm.

For the *operando* measurement we have also developed the sample holder including the following two key functions:

1. Electrodes with a function to contact directly to the thin film sample in order to apply an electric field.
2. A function to heat the sample for preparation and cleaning.

We designed a sample holder that incorporates these two functions as shown in **FIGURE 2.** In our design, a filament for heating the sample is built into the sample holder.

In the future, we will develop the associated software, aiming to perform *operando* measurements of the spin Hall effect. More details will be presented in my poster.

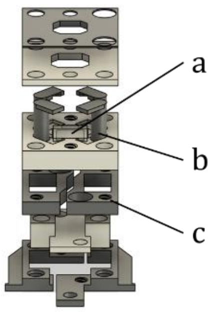

FIGURE 2. Sample holder design for *operando* measurements. a: Sample, b: Electrostatic field application terminal, c: Filament base.

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