23BG007 BL-7

Preparation of Pt Thin Film on MgO (001) and Observation of Its Electronic Structure

T. Asano[a], K. Sumida[b], K. Kunitomo[a], T. Okuda[b], and K. Miyamoto[b]

[a]*Graduate School of Advanced Science and Engineering, Hiroshima University, 1-3-1 Kagamiyama, Higashi-Hiroshima 739-8526, Japan*
[b]*Hiroshima Synchrotron radiation Center (HSRC), Hiroshima University 2-313 Kagamiyama, Higashi-Hiroshima 739-0046, Japan*

Keywords: Pt thin film, Spin Hall effect, Photoemission spectroscopy

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 compared to the semiconductors and allows the use of spin-polarized current supplied by the ferromagnetic metal [1]. Among many metals, elemental Pt is extensively investigated both experimentally and theoretically [2,3]. 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 work, as a first step towards the development of the experimental method, we fabricated Pt thin films and investigated the electronic structure by PES measurements. The Pt thin films were prepared by using electron beam evaporation source with a carbon crucible on a MgO(001) substrate at room temperature. The MgO substrate was annealed in oxygen atmosphere (~10^{-1} Pa) at ~200°C for 60 min., and then, annealed at 600°C for 240 min. in vacuum prior to the Pt deposition.

To observe the electronic structure of the fabricated Pt/MgO film, we performed the PES measurements at BL-7 of Hiroshima Synchrotron Radiation Center utilizing various incident photon energies from 30 to 160 eV. Figure 1 shows Pt 4*f* core level spectrum taken at $h\nu$ = 155 eV. Two peaks derived from the spin-orbit split Pt $4f_{5/2}$ and $4f_{7/2}$ are clearly seen at binding energy (E_B) of 74.4 and 71.1 eV. To obtain more detailed information, the experimental result was fitted by Doniac-Šunjić function with Shirley background function [see blue curve in Fig. 1]. From this fitting result, asymmetric parameters were determined to be 0.018 for $4f_{5/2}$ and 0.043 for $4f_{7/2}$. These values are very small as a metal, suggesting that the density of states (DOS) near the Femi level (E_F) is small.

The red curve in Fig. 2 shows the experimentally observed valence band PES spectrum taken at $h\nu$ = 70 eV. We can see broad peak structures around E_B = 1.6 and 4.5 eV. Moreover, a dip structure is recognized at E_B = 3.2 eV. To compare the valence band spectrum, we carried out the first-principles calculation for the face-centered-cubic Pt using WIEN2k program including the spin-orbit coupling. Based on the calculation, it was found that the *d* orbital component is dominant in the valence band rather than the *s* and *p* orbitals. Moreover, photo-onization cross-section of *d* orbital is dominated in the vacuum ultraviolet region. Therefore, in Fig. 2, we compare the PES spectrum with the Pt *d* partial DOS. Here, the calculated Pt *d* partial DOS was multiplied by the Fermi-Dirac distribution function at 300 K and convoluted by a Gaussian function (experimental resolution). Comparing the experimental and theoretical results, we notice that the locations of the peak and dip structures and the band width are qualitatively reproduced. However, a very

sharp peak predicted by the calculation in the vicinity of E_F was not observed in the experiment. This suggests that the interface and/or surface structure of the fabricated Pt film on MgO substrate makes the electronic structure differ from the electronic structure in the bulk Pt.

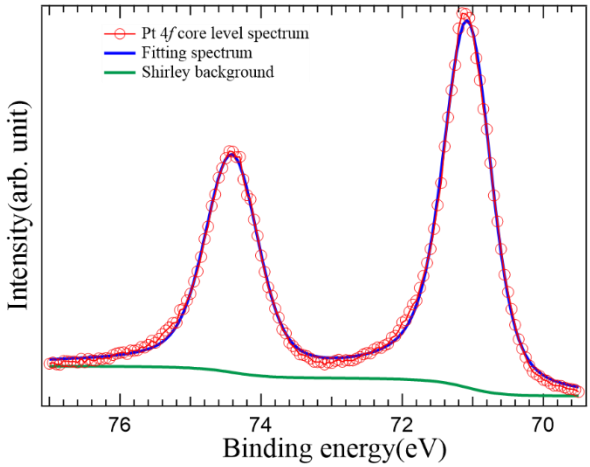

FIGURE 1. Pt 4*f* core level spectrum (red circles) taken at $h\nu = 155$ eV. The blue curve represents the fitting result using the Doniach-Šunjić function and active Shirley background (green curve).

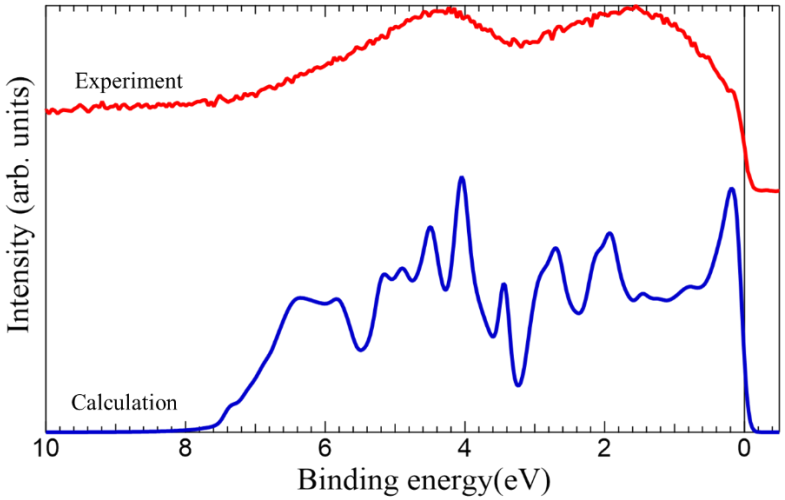

FIGURE 2. Observed photoemission spectrum taken at $h\nu = 70$ eV (red) and the calculated Pt *d* partial DOS (blue). The calculated DOS is multiplied by the Fermi-Dirac distribution function and convoluted by a Gaussian function.

In conclusion, we are successful to prepare Pt thin film on MgO(001) using electron beam evaporate source with a carbon crucible. Around E_F, the observed electronic structure on Pt thin film is differrent from calculated spectrum based on the bulk Pt. In general, the performance of the spin Hall effect is closely related to the electronic structure, so this finding of discrepancy may be important information for improving the performance of the spin Hall effect for Pt thin film on MgO(001).

REFERENCES

1. G. Schmidt, *et al*, Phys. Rev. B **62**, R4790(R) (2000).
2. T. Kimura *et al*., Phys. Rev. Lett. **98**, 156601 (2007).
3. G. Y. Guo, *et al*., Phys. Rev. Lett **100**, 096401(2008).
4. Y. K. Kato, *et al*, Science **306**, 5703 (2004).