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Anatomy of interfacial spin-orbit coupling in Co/Pd multilayers by XMCD and band-structure calculation

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Co/Pd multilayers (MLs) are candidate spintronics materials possessing perpendicular magnetic anisotropy (PMA) which can be utilized for the high-density recording technology [1]. The 4*d* transition metal (TM) system of Pd is well recognized as the sustainable elements of 5*d* TM system when combined with the magnetic 3*d* TMs. In order to understand the mechanism of PMA in Co/Pd MLs, the contributions of orbital magnetic moments of each element have to be clarified explicitly. Bruno theoretically proposed the orbital moment anisotropy in TM multilayers as a second perturbation of spin-orbit interaction [2]. However, even in the strong spin-orbit coupled cases using 4*d* or 5*d* TMs, the validity of this picture has been still debated [3]. Our aim in this study is to discuss both orbital and spin moments of Co and Pd for PMA in different anisotropy samples by using angular-dependent X-ray magnetic circular dichroism (XMCD) in Co *L*-edge and Pd *M*-edges.

We prepared two kinds of samples of Co/Pd multilayered structures: Co (0.69 nm)/Pd (1.62 nm) for PMA and Co (1.03 nm)/Pd (1.62 nm) for PMA and in-plane anisotropy, respectively, with stacking five periods on the Si substrates [4]. Sample surfaces were sputtered by Ar ions before the XMCD measurements in order to remove the oxygen contamination. We performed XMCD experiments at BL4B, UVSOR, Institute of Molecular Science. Total electron yield mode was adopted. A magnetic field of ±5 T was applied along the direction of the incident polarized soft x-ray.

We observed XMCD signals in Pd *M*-edges after the removal of surface contamination as shown in Fig. 1. Although the X-ray absorption spectroscopy (XAS) line shapes overlap with those of O *K*-edge absorption, clear XMCD signals induced by the proximity with Co layers are observed. Although precise XAS line shapes in Pd *M*-edges are necessary for the determination of absolute values of spin and orbital moments, the XMCD line shapes provide the ratio of orbital moments to spin moments. The Pd *M*-edge XMCD line shapes in both PMA and in-plane samples almost remain unchanged. For PMA and in-plane samples, Pd XMCD line shapes almost similar contrary to the case of Co, suggesting that the finite orbital moments in Pd do not contribute to the PMA. On the other hand, clear Co *L*-edge XAS and XMCD with angular dependence reveal the enhancement of orbital moments in the surface normal direction because of PMA. Furthermore, we compare the interfacial orbital moments with band-structure calculation assuming the similar ML structures. We discuss the orbital moment anisotropy at the interface in Co/Pd multilayers.

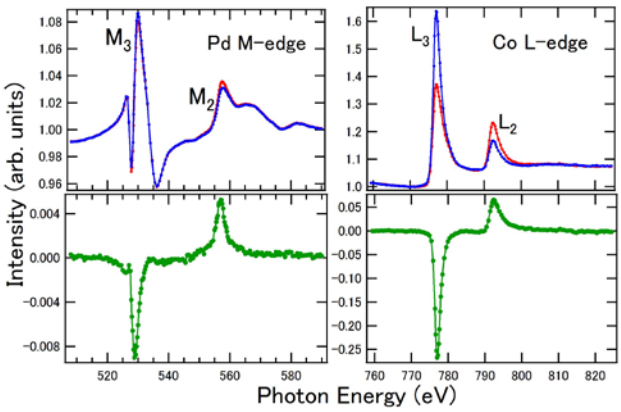

Fig. 1, XAS and XMCD of Pd *M*-edge and Co *L*-edge in perpendicularly magnetized Co (0.69 nm)/Pd (1.62 nm) multilayer.

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