Mössbauer and photoemission spectroscopies for Fe/Au(111) interfacial perpendicular magnetic anisotropy

J. Okabayashi[1], S. Li[2], S. Sakai[2], Y. Kobayashi[3], T. Mitsui[2], K. Tanaka[4], and S. Mitani[5]
[1]The Univ. of Tokyo, [2]QST, [3]Kyoto Univ., [4]IMS, [5]NIMS

Interfacial magnetic proximity can be a novel technology for developing and enhancing the spin-related phenomena. Designing of interfacial orbital hybridization becomes a key issue. Especially, the hybrid structures combining different sin-orbit coupling strengths result in perpendicular magnetic anisotropy (PMA). It is well known that the PMA has a high potential for high-density magnetic recording media. Although the PMA originates from the anisotropic orbital moments, related another mechanism including quadrupoles at the interfaces is also thoroughly investigated recently [1]. Here, we focus on Au(111)/Fe structure as a magnetic metal of Fe and non-magnetic Au metal interface because the proximity brings interfacial PMA through the Rashba-type spin-orbit band splitting of 110 meV in Au(111) surface.

Since the Au(111) surface exhibits large Rashba-type splitting, which is detected by angle-resolved photoemission spectroscopy (ARPES) [2], the novel properties using this surface has been expected. The Mössbauer spectroscopy (MS) for Fe using synchrotron radiation also becomes a powerful tool by using enriched ^{57}Fe isotope substitution, which enables the detections of polarization dependence. Further, ARPES also detects the band dispersions in solids directly, which probes the Au surface states and their changes by Fe deposition. In this presentation, we adopt MS and ARPES to investigate Au/Fe interfacial PMA by elucidating the layer-resolved electronic and magnetic properties.

We synthesized the samples of Au (1 nm)/ Fe (0.5 nm)/ Au(111) sandwiched structures by molecular beam epitaxy, which exhibits PMA. For 3-monolayer-thick Fe sandwiched by Au, where ^{57}Fe is only 1 ML on Au, MS spectra exhibit clear sextet magnetic splitting. Second and fifth peaks disappear at p-polarized beam and six peaks appear in case of non-polarized beam, resulting in the PMA at the interface. Since the values of hyperfine field are different from those in Fe bulk and Fe/MgO interface cases [3,4], interfacial electronic structure of Fe layer facing on Au is modulated and the hybridization between Au *sp* and Fe 3*d* states is essential for PMA. Small quadrupole component is also deduced which is specific in the interfacial layer through the electric-field gradient from Au layer. By using in-situ ARPES, at the initial growth stage, the valence-band structures of Au are modulated by the Fe deposition and cannot be explained by the simple summations of Au and Fe line shapes, suggesting the interfacial hybridization between Fe and Au. We discuss the detailed interfacial electronic and magnetic structures by MS and ARPES.

[1] J. Okabayashi et al., *Sci. Rep.* 8, 8303 (2018).
[2] M. Hoesch et al., *Phys. Rev. B* 69, 241401 (2004).
[3] A. Kozioł-Rachwał et al., *Sci. Rep.* **7**, 5993 (2017).
[4] J. Balogh et al., *Phys. Rev.* B **87**, 174415 (2013).