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Tb 4*f* electron states at the interface of Fe/Tb multilayers

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[Fe (1.0nm) /Tb (0.4nm)], [Fe (5.7nm) /Tb (0.8nm)], [Fe (5.9nm) /Tb (2.0nm)] multilayers and Fe films were fabricated with molecular beam epitaxy under $1x10^{-10}$Torr at SVBL, Gunma University. The Fe/Tb multilayers were covered with Ag 3 nm capping layer to avoid oxidation. X-ray photoelectron spectroscopy (XPS) measurements were carried out at BL11D of KEK-PF, Japan. As a reference, XPS measurements for bluk Tb and bulk Fe were carried out using Perkin Elmer ESCA5600 at Cooperative Research Center, Gunma University.

In order to estimate the effective inelastic mean free path (EIMFP) of the samples, we measured on iron 4nm and 8nm films which were deposited on Si wafer substrate. We can observe not only Fe 3*p* peak, but also Si 2*p* peak in both the films at incidence photon energy 150eV. The EIMFP, λ, is estimated from the following procedure. We take a ratio, $R = S_{Si} / S_{Fe}$, where S_{Si} and S_{Fe} is an integrated intensity of Si 2*p* peak and Fe 3*p* peak respectively. We fit to the ratio, R, using the equation, $R(t_{Fe}) = R_0 \exp(- t_{Fe}/\lambda)$, where $R_0 = R(t_{Fe}=0)$, and t_{Fe} is the Fe thickness. We estimate λ at 6.8 nm which is about ten times longer than estimated value by Tanuma, et al.[1]. Because the EIMFP of Ag, Fe and Tb is regarded as almost the same in this incidence photon energy of 150eV [1], we suppose that the EIMFP of Fe/Tb sample is 6.8nm. Then we can estimate a ratio of photoelectron from each layer in the Fe/Tb multilayers, as shown in Table 1.

Sample	Ag	Fe	**Tb**
Fe(1.0nm)/Tb(0.4nm)	40%	46%	**16%**
Fe(5.7nm)/Tb(0.8nm)	40%	56%	**4%**
Fe(5.9nm)/Tb(2.0nm)	40%	52%	**8%**

Table 1. Estimated ratio of detected photoelectron for each element in Fe/Tb multilayers.

To extract the contributuin of Tb layer, resonance photoemission spectroscopy at the Tb $N_{4,5}$-edge ($4d \rightarrow 4f$) were measured. In order to subtract a background contribution, off resonance spectrum at 141.4eV (Background) is subtracted from on resonance spectrum at 152.8eV (Signal + Background) for each sample as shown in Fig. 1. Two peaks are observed around 2eV (Peak A) and 7~10eV (Peak B). These peaks reflect the profile of the bulk Tb 4*f* spectrum which is shown in Fig. 1. The position of Peak A and B corresponds to Tb $4f_{7/2}$ and $4f_{5/2}$ states.

A ratio of Peak A to B is similar to bulk Tb in [Fe(5.9nm)/Tb(2.0nm)] multilayer. But Peak A's are enhanced in thin Tb samples of [Fe (1.0nm) /Tb (0.4nm)] and [Fe (5.7nm) /Tb (0.8nm)] multilayers. The Tb atoms of the thin Tb layer can be regarded as the atoms at the Fe/Tb interface in [Fe (1.0nm) /Tb (0.4nm)] and [Fe (5.7nm) /Tb (0.8nm)] multilayers. Then enhancement of peak A is due to the Tb atom at the Fe/Tb interface. Because the position of Fe 3*d* states is the same as the position of Tb $4f_{7/2}$ states, Tb $4f_{7/2}$ states can hybridize with Fe 3*d* states in Fe/Tb multilayers. Then It is possible that the enhancement of Tb 4*f* states is caused by the hybridization between Fe 3*d* states and Tb 4*f* states at the Fe/Tb interface, which may be related with the perpendicular anisotropy.

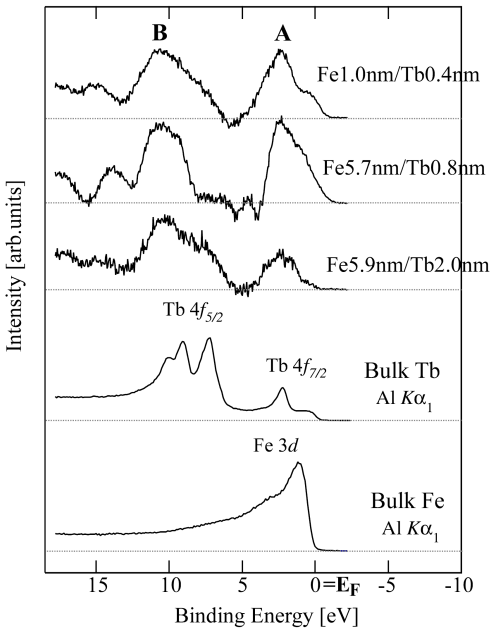

Fig. 1. Tb 4*f* states of Fe/Tb multilayers. Tb and Fe valence band spectrum of bulk Tb and bulk Fe was inserted as a reference.

References

[1] S. Tanuma, et al., Surf. Interface Anal., **11**, 57 (1988), and **17**, 911 (1988).

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