^{119}Sn Mössbauer Study of Cu/Co and Au/Co Multilayers

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Mössbauer absorption spectroscopy has been applied for ^{119}Sn microprobes located in Cu (or Au) layers of Co/(Cu or Au) multilayers. By observing hyperfine field, it has been confirmed that spin polarization exists in the middle of the spacer layer with the thickness of 20 Å. The hyperfine field is significantly larger in Au than in Cu.

Keywords: Magnetic hyperfine fields/ Sn Mössbauer spectroscopy/ Metallic multilayers/ Giant magnetoresistance

Since the discovery of antiferromagnetic interlayer coupling in Fe/Cr/Fe sandwiches [1] and the corresponding giant magnetoresistance (GMR) effect in Fe/Cr multilayers [2], the role of non-magnetic spacer metal layers inserted between magnetic layers has been a subject of intensive studies. The oscillation of interlayer coupling strength is attributed to the Fermi surface nesting of the spacer metal but the mechanism still remains an open question. There have been various measurements to study the properties of magnetic layers. However, the tools to observe directly the magnetic behaviors of spacer layers are very limited and therefore the nature of spacer layers is often speculated from the results on magnetic layers. Studies on spacer layers so far reported are NMR [3] and X-ray dichroism experiments [4], both of which have insisted on the existence of magnetic excitation in Cu layers of Co/Cu multilayers.

In the present study, the Mössbauer spectroscopy has been applied to observe spin polarization in non-magnetic spacer layers sandwiched in between ferromagnetic layers by using ^{119}Sn as a microprobe. Mössbauer absorber samples were prepared by introducing ^{119}Sn in Cu or Au layers in Co/Cu or Co/Au multilayers. Since a Sn atom itself is non-magnetic, a Sn hyperfine field, if observed in the absorption spectra, is an evidence of spin polarization in the non-magnetic spacer layers transferred by conduction electrons. In order to measure the absorption spectra, the samples are required to include a certain amount of the Mössbauer isotope. In the present experiment, the nominal thickness of ^{119}Sn probing layers is 1.5 Å.

Several Co/Cu and Co/Au multilayer samples including 1.5 Å ^{119}Sn probing layers were prepared by vacuum deposition method. Samples prepared on polyimide substrates and those on glass ones are used respectively for Mössbauer and X-ray diffraction measurements. The structure of the prepared sample, for example, is; [Co (20 Å)/Cu (10 Å)/^{119}Sn (1.5 Å)/Cu (10 Å)]×8. For comparison, a non-doped sample, Co (20 Å)/Cu (20 Å), was also prepared in the same procedure, which showed MR ratio of 17% at 300 K. The MR ratio of the sample

SOLID STATE CHEMISTRY —Artificial Lattice Alloys—

Scope of research

By using vacuum deposition method, artificial multilayers have been prepared by combining various metallic elements. The recent major subject is the giant magnetoresistance (MR) in magnetic/non-magnetic multilayers. Non-coupled type MR multialyers including two magnetic components are found to have high sensitivities in low fields. Fundamental magnetic properties of large MR multilayers have been studied by applying Mössbauer spectroscopy, using Fe-57, Sn-119, Eu-151 and Au-197 as microprobes and by neutron diffraction. Multilayers are also prepared on microstructured substrates and their novel magnetic and MR properties are being investigated.

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with 1.5 Å Sn layer, 3% is considerably smaller than the standard value. However, the profile of MR curve of the doped sample is very similar to that of non-doped one and therefore the antiferromagnetic interlayer coupling is believed to exist in the doped sample.

Figure 1a shows the ^{119}Sn absorption spectrum at 300 K for the sample with the illustrated structure. The ^{119}Sn probing layer has been located in the middle of 20 Å Cu layer sandwiched in between Co layers. The line profile of the spectrum is very broad but can be interpreted as a superposition of two parts; a non-magnetic fraction and another one with a hyperfine broadening. The broadening corresponds to a magnetic field of 16 kOe. The fraction with the broadening is enhanced in the spectra of samples whose Sn probing layer is located closer to the Cu/Co interface. Therefore the origin of the broadening is suggested to be a magnetic hyperfine splitting.

Figure 1b shows the spectrum for a sample whose interface is doped with 2 Å Cr layers (The structure is illustrated in the figure). Although the thickness of Cu layer is the same, 20 Å, the interface-doped sample does not show any MR effect. Therefore, it is suggested that an antiferromagnetic interlayer coupling is cut by inserting a Cr layer in between Co and Cu layers. Consistently, the ^{119}Sn Mössbauer spectrum is a sharp single line, indicating that no spin polarization exists in the middle of 20 Å Cu layer. From these results, the existence of spin polarization in the Cu layer, at the distance of 10 Å from the interface with Co, is confirmed. The non-magnetic fraction coexisting in Fig. 1a is interpreted as Sn microclusters. If several Sn atoms are coagulated, the spin polarization in Cu layer would not be transferred at the Sn sites. Another interpretation is as follows: The spin polarization is spacially oscillating and the hyperfine field should be zero at the site where the spin polarization is zero. If it is the case, the relative amount of non-magnetic fraction may depend on the magnetic structure, being paralell or anti-parallel. We have measured the spectra for parallel magnetization with applying an external field but the non-magnetic fraction does not show any change. Therefore, it is not probable

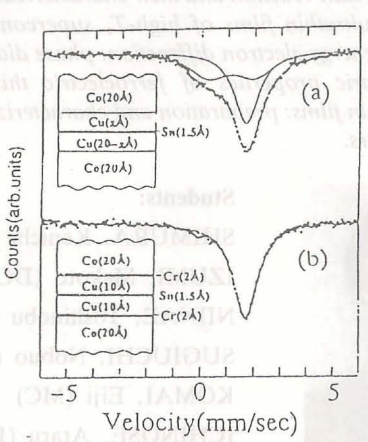

Figure 1. ^{119}Sn Mössbauer absorption spectra at 300 K of (a) [Co (20 Å)/Cu (10 Å)/^{119}Sn (1.5 Å)/Cu (10 Å)]×8. (b) [Co (20 Å)/Cr (2 Å)/Cu (10 Å)/^{119}Sn (1.5 Å)/Cu (10 Å)/Cr (2 Å)]×8.

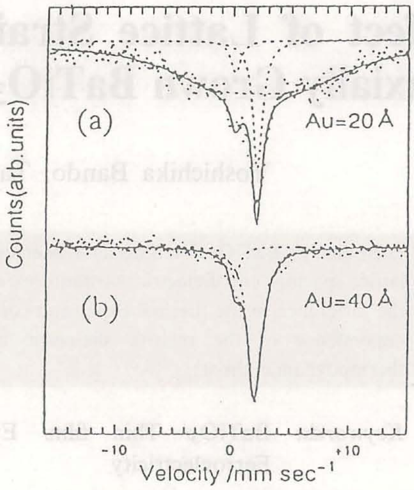

Figure 2. ^{119}Sn Mössbauer absorption spectra at 300 K of (a) [Co (20 Å)/Au (10 Å)/^{119}Sn (1.5 Å)/Au (10 Å)]×16. (b) [Co (20 Å)/Au (20 Å)/^{119}Sn (1.5 Å)/Au (20 Å)]×16.

that the non-magnetic absorption is originated from an intrinsic properties of the spacer layers.

Similar experiments have been carried out for Co/Au multilayers in order to elucidate the difference of spin polarization in Cu and Au layers. The probing layers, 1.5 Å ^{119}Sn, are located in the middle of 20 Å Au and 40 Å Au layers sandwiched between in Co layers. As shown in Fig. 2a, the spectrum for the 20 Å has a magnetic hyperfine structure, while the 40 Å sample shows only a single line pattern without a magnetic hyperfine broadening. These results suggest that the spin polarization originated from an adjacent ferromagnetic Co layer extends in a Au layer for more than 10 Å but less than 20 Å. Similarly to the case of 20 Å Cu, a non-magnetic fraction coexists in the spectrum for 20 Å Au. A remarkable contrast between the results on Sn impurities in Cu and Au layers is the magnitude of hyperfine field, which suggests a difference between an induced hyperfine field at Sn nuclei by 4s electron spin polarization in Cu and that by 6s electron spin polarization in Au. The spectrum for ^{119}Sn in the middle of 20 Å Au layer sandwiched between Co layers exhibits a very large broadening, which corresponds to about 70 kOe. This value is much larger than the hyperfine field of Sn impurity in bulk Co at 0 K (25 kOe) [5]. It is therefore suggested that a core electron spin polarization at Sn atom is induced via 6s electron of Au layer.

In summary, using ^{119}Sn Mössbauer probe, the spin polarization in a non-magnetic metal layer is able to be detected. However, the resolution is not enough to study the oscillatory behaviors of spin polarization.

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