Materials Science

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X-ray absorption and magnetic circular dichroism study of C_{60}-Co hybrid films

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Introduction

In recent years, there has been growing attention to molecular spintronics which aims to realized spin devices utilizing π-conjugated organic molecules (OMs) and nanocarbons (NCs), e.g., graphene, having long spin relaxation times/lengths and tunable electronic properties in the molecular level. Evidence of the large spin-polarization (P) at the interfaces between OMs, NCs and ferromagnetic metals, however, has not been successfully reported in the molecular-based spin valves suffering from the problems of identification and control of the transport process around the interface region, despite the importance for realizing highly efficient spin-injection into OMs and NCs.

We have found that a giant tunnel magneto resistance (TMR) effect of MR=$\Delta R/R_{max}$=80-90% ($\Delta R/R_{min}$=400-900% in the other definition) occurs in the granular structured hybrid films of C_{60} and Co prepared by the alternate-/co-deposition under UHV conditions [1-2]. It was also revealed that the hybrid films are composed of the C_{60}-Co compound matrix ($C_{60}Co_5$), which behaves as an insulating region, and Co nanoparticles [3,4]. These preliminarily studies predict a possibility of a significant spin-polarization at the C_{60}-Co compound/Co interface. Electronic analysis of the C_{60}-Co compound which would be playing an important role in the spin-dependent electron tunneling process is essential for understanding the nature of the giant TMR effect.

In the present study, the electronic and spin states of the C_{60}-Co compound ($C_{60}Co_4$) are investigated using X-ray absorption (XAS) and magnetic circular dichroism (MCD) spectroscopies.

Experimental results

Fig. 1(a) shows the typical MCD spectrum of the C_{60}Co4 film in the Co 2p→3d ($L_{3,2}$-edge) region measured under the high magnetic field (H=60kOe) and low temperature (T=6K). As shown in the MCD spectra, the peak position (hν=778.0eV) lies at the lower energy side compared to that of the pure Co film (hν=778.2eV). Judging from our previous study [4], the MCD signal is attributed to the spin-polarization of the Co 3d-derived states localized in the C_{60}-Co compound. Fig. 1(b) shows the H-dependences of the spin and orbital magnetic moments (M_{spin} and M_{orb}) calculated from the integrated MCD intensities and the sum rules. M_{spin} increases linearly with increasing H at small H, and show saturation tendency at high H, as expected for paramagnetism. Meanwhile, M_{orb} is almost vanished due to the possible quenching effect induced by the C-Co bond.

Fig. 2 shows the T-dependence of the inverse magnetic susceptibility (χ^{-1}) calculated from the total magnetic moments M_{tot} (M_{tot} = M_{spin} + M_{orb}) measured at small H. A fit with the Curie-Weiss law is displayed by the dashed line. It is found that the magnetic susceptibility is well expressed by the Curie-Weiss law. The Curie temperature takes a negative value of about -5K, which indicates a weak anti-ferromagnetic interaction between the Co 3d spins in the compound. Such spin-spin interactions within the C_{60}-Co compound and possibly at the C_{60}-Co compound/Co nanoparticle interface in the granular structured films can affect to the saturation behavior of the MR magnitude and the hysteresis in the MR curve observed in the low temperature region (T<10K) [5].

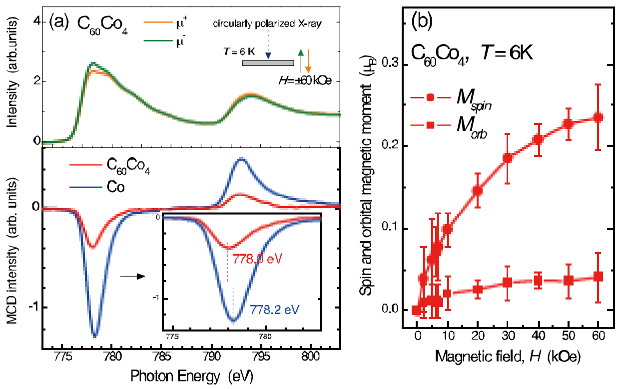

Fig. 1. (a) Co 2p→3d (L_3-edge) MCD spectrum of the $C_{60}Co_4$ and Co films measured under H=60kOe and T=6K, and (b) H-dependences of the spin and orbital magnetic moments (M_{spin} and M_{orb}) for the $C_{60}Co_4$ film.

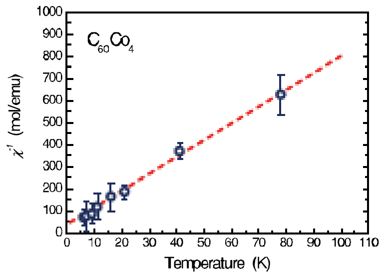

Fig. 2. Temperature dependence of the inverse magnetic susceptibility (open circle), and fitting curve with the Curie-Weiss law (dashed line).

References

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