

XPS and NEXAFS studies of C₆₀-Co films with giant tunnel magnetoresistance

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In recent years, investigations on molecular spin electronics which control a transport of spin-polarized carrier through organic molecules including C₆₀, carbon nanotubes (CNTs) and graphene have been performed intensively.[1] Very recently, we have found that C₆₀-Co mixture films where Co nanoparticles are dispersed into a matrix of the C₆₀-Co compound show the large tunnel MR effect of 80-90% at low temperature.[2,3] The observed MR ratios cannot be explained by the spin polarization of crystalline Co (~40%), and hence it is expected that the electronic and magnetic structures of the C₆₀-Co compound play a significant role to the spin-dependent transport in the C₆₀-Co films. In the present work, we studied about local electronic states of the C₆₀-Co films by X-ray photoelectron spectroscopy (XPS) and near-edge X-ray absorption fine structure (NEXAFS) spectroscopy. [4]

C₆₀-Co mixture films were prepared by the co-deposition method under the UHV condition (10⁻⁷Pa). The experimental set-up for co-deposition consists of a Knudsen-cell for C₆₀ (99.99%, sublimated) and an electron beam evaporator for Co (99.99%). The C₆₀-Co films with compositions of C₆₀Co_x (x: the number of Co atoms per a C₆₀ molecule), and thickness of 50 nm were deposited on Ag films on MgO (001). A pure C₆₀ film was prepared in a similar way. The prepared samples were transferred to an experimental chamber without breaking the UHV condition. XPS measurements were performed at Photon Factory BL-27A of High Energy Accelerator Research Organization (KEK-PF) employing Mg K_α (hν=1253.6eV) and Y M_ζ (hν=132.3eV) X-ray sources. NEXAFS measurements were performed at BL-7A of KEK-PF. The NEXAFS spectra were obtained by the total electron yield method.

Figure 1 and 2 show the XPS spectra in the valence region and the C1s NEXAFS spectra for the C₆₀ film and the C₆₀-Co film (C₆₀Co₃) composed of the C₆₀-Co compound.[5] In Figure 1, five peak components (A₁-A₅) associated with the molecular orbitals (MOs) of C₆₀ are confirmed in the C₆₀ film. In the C₆₀-Co films, the A₃-A₅ peaks lying in the range of E_B = 5-9eV show comparable shifts from the positions in the C₆₀ film. Meanwhile, the structure close to the Fermi level (E_B<5eV) shows significant differences from the C₆₀ film, as represented by the peak components of B₁-B₅. The B₂ and B₄ peaks seem to be corresponding to the A₁ and A₂ peaks from the shifted quantities. Investigations on the C₆₀-Ti and C₆₀-Rb composites [6,7] have pointed out that, when metal atoms form covalent bonds with carbon atoms, new

peaks appear close to the Fermi level (E_B~3-5eV) or close to the HOMO level of C₆₀ (A₁). Judging from these reported results, the observed peaks of B₁, B₃ and B₅ in the C₆₀-Co film are reasonably ascribed to the hybridized states between the C₆₀ π and Co 3d orbitals. The comparable shifts of the A₃-A₅ peaks in the C₆₀-Co film indicate the cage distortion of C₆₀, possibly by the hybridized bond formation. The π-d hybridization is confirmed in the absorption spectra. In Figure 2, the first peak of the C₆₀-Co film is shifted toward the higher energy side and the peak width is wider than the LUMO peak of the C₆₀ film. This peak broadening and shift indicate the formation of the covalent bonds with the charge transfer (back donation) between C₆₀ π and Co 3d orbitals.

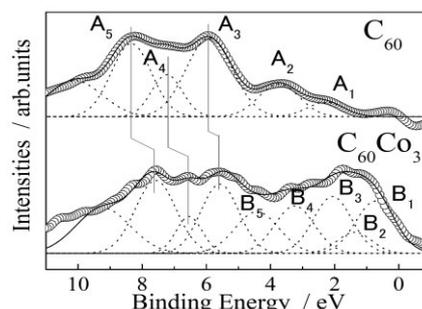


Figure 1 XPS spectra of the C₆₀ and C₆₀-Co films (C₆₀Co₃) in the valence region

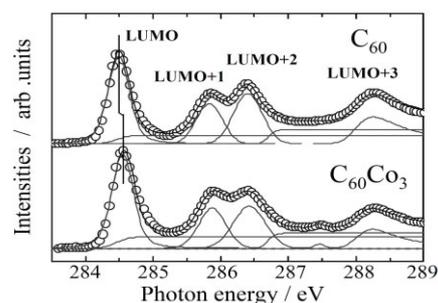


Figure 2 NEXAFS spectra of the C₆₀ and C₆₀-Co films (C₆₀Co₃) by C1s core excitation.

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