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Photoemission Spectroscopy of Metallofullerene and C_{70} Fullerene Peapods

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Introduction

The electronic structures of metallofullerene or fullerene peapods (PPDs), which are single-wall carbon nanotubes (SWCNTs) encapsulating metallofullerenes or fullerene, respectively, have been intensively studied both theoretically and experimentally. However, only a few photoemission studies have been performed so far [1, 2]. In this study, we have measured the electronic structures of $M@C_{82}$ PPDs (M= La, Gd, Dy) and C_{70} PPD using photoemission spectroscopy [2].

Experimental

The photoemission experiments were performed using synchrotron radiation at the beam lines BL-11D and BL-28A of the Photon Factory, High Energy Accelerator Research Organization (KEK). The instrumental resolution was 50 meV at $h\nu$= 65 eV. SWCNT samples were prepared by the laser vaporization method.

Results and Discussion

Figure 1 shows the photoemission spectra of the C_{70} peas and C_{70} film. The spectrum of C_{70} peas was obtained by subtracting the pristine SWCNT spectrum from the C_{70} PPD one. The peaks were obtained at binding energies of 2.5, 6 and 8 eV. The peak at 2.5 eV is due to the highest occupied molecular orbital (HOMO) level. The energy positions of these peaks are nearly equal to respective corresponding peak positions of the C_{70} film spectra. From the theoretical calculation, Otani et al. predicted the downward shift of the HOMO level by about 2 eV, caused by the hybridization between the C_{70} π states and the nearly free-electron (NFE) states of SWCNTs [3]. However, such a large shift cannot be observed, indicating that the hybridization is negligibly weak. This result is consistent with the photoemission results for C_{60} PPD [1].

Figure 2 shows the photoemission spectra of the $M@C_{82}$ peas and $La@C_{82}$ film [4]. The peak structures were observed at 3 and 7.5 eV. These structures shift toward E_F by about 0.7 eV, compared with the corresponding structures in the $La@C_{82}$ film spectrum. In the spectrum of $La@C_{82}$ peas, the singly occupied molecular orbital (SOMO) peak was observed near E_F. From the comparison between the pristine SWCNT and $La@C_{82}$ PPD spectra, it can be seen that the structures originating from the SWCNT in $La@C_{82}$ PPD shift toward E_F by 0.1 eV. These facts indicate that charge transfer occurs from the SWCNTs to the $La@C_{82}$ peas, which is consistent with the prediction of the theoretical calculation [5].

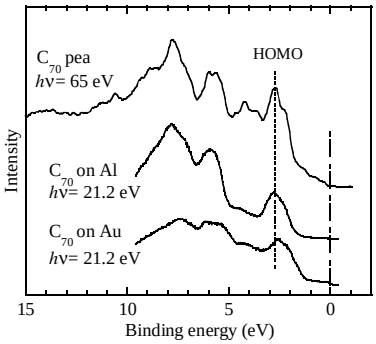

Figure 1 Photoemission spectra of the obtained C_{70} pea and C_{70} films. The C_{70} films were prepared by evaporating onto clean Au and Al substrates.

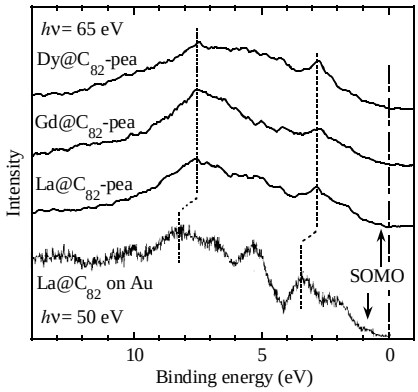

Figure 2 Photoemission spectra of the obtained $M@C_{82}$ peas (M= La, Gd, Dy) and $La@C_{82}$ film.

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