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Photoemission Spectroscopy of Single Wall Carbon Nanotubes with Small Diameters

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Introduction

Spectroscopic study concerning one-dimensional properties of single walled carbon nanotubes (SWCNTs) has performed so far using samples with diameters of 1.2~1.4 nm [1-3]. In this study, we prepared a CoMoCAT SWCNT sample with a diameter of 0.8 nm and investigated the one dimensional electronic states of SWCNTs by high resolution photoemission spectroscopy.

Experimental

The photoemission experiments were performed using synchrotron radiation at the beam line BL-28A of KEK-PF. The total energy resolution was about 26 meV at $h\nu$= 65 eV. A CoMoCAT sample, which was prepared by the chemical vapor deposition (CVD) using Co-Mo catalysts, consists of tubes with chiral indexes of (6, 5), (7, 5) and (7, 6). The diameters of these tubes were estimated to be about 0.8 nm.

Results and Discussion

Figure 1 shows the comparison of the optical absorption spectrum of the CoMoCAT sample with the calculated densities of states (DOS) of (6, 5), (7, 5) and (7, 6) tubes. In Fig. 1, the absorption spectrum was plotted with the energy reduced to 50 %, because the optical transitions occur between mirror image spikes of density of states owing to the van Hove singularities (VHSs) [1]. As can be seen from Fig. 1, the S1 and S2 peaks located at 1.25 eV and 2.2 eV, respectively, can correspond to the VHSs of (6, 5) tube. The result indicates that the present CoMoCAT sample mainly consists of (6, 5) tube.

Figure 2 shows the photoemission spectrum of the CoMoCAT sample. In Fig. 2, the spectrum subtracted appropriate background was shown and the calculated density of states was shifted toward a higher binding energy by 0.2 eV. As shown in Fig. 2, broad structures were observed at binding energies of 0.75 and 1.3 eV. From the comparison of the photoemission spectrum with the results of tight-binding calculation, it can be seen that the S1 and S2 peaks are due to the spikes caused by the VHSs of (6, 5), (7, 5), (7, 6) tubes. At the binding energy of 1.7 eV, a very broad structure was observed. In the calculated density of states, however, no structure appears in the corresponding energy region. In the SWCNT with a small diameter, the strong curvature may induce changes in the electronic structure [4].

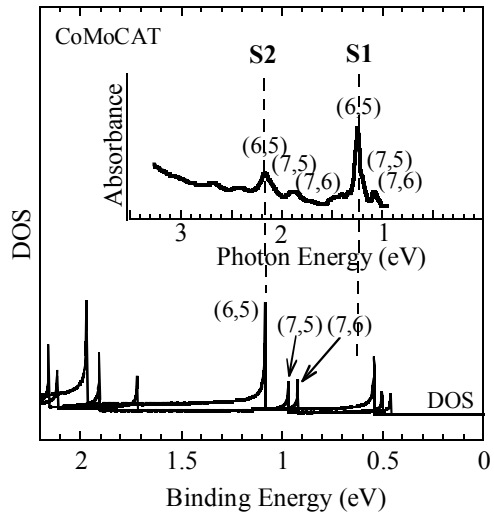

Figure 1 Optical absorption spectrum of the CoMoCAT sample and the calculated densities of states (DOS) of (6, 5), (7, 5) and (7, 6) tubes.

References

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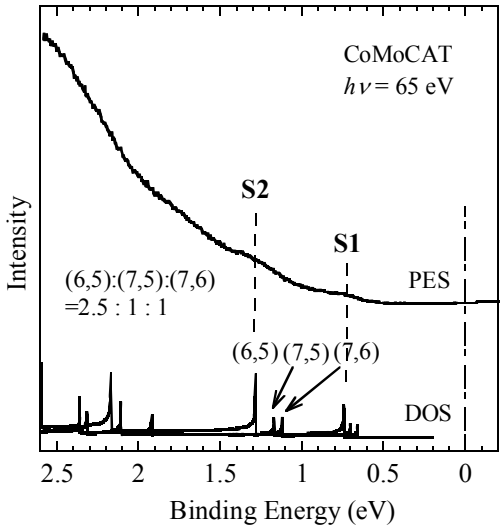

Figure 1 Photoemission spectrum of the CoMoCAT SWCNT sample. The calculated density of states is also shown.