28A/2008G630

Photoemission Spectroscopy of Metallic and Semiconducting Single-Wall Carbon Nanotubes

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Introduction

In spectroscopic study concerning one-dimensional nature of single-wall carbon nanotube (SWCNT), mixture samples consisting of metallic and semiconducting SWCNTs have so far been used [1-3]. Recently, the separation of a large amount of metallic and semiconducting SWCNTs was succeeded by Yanagi *et al.* [4]. In this study, we investigated the electronic states in metallic and semiconducting SWCNTs by photoemission spectroscopy.

Experimental

The photoemission experiments were performed using synchrotron radiation at the beam line BL-28A of the Photon Factory, High Energy Accelerator Research Organization (KEK). The instrumental resolution was 35 meV at $h\nu$= 65 eV. The density gradient ultracentrifugation was used to achieve the separation of metallic and semiconducting SWCNTs [4]. The purity of the samples was estimated by optical absorption spectroscopy to be higher than 95 %.

Results and Discussion

Figure 1 shows the photoemission spectrum of metallic SWCNTs. We compared the photoemission spectrum with the optical spectra of the metallic sample and the mixture sample consisting of metallic and semiconducting SWCNTs. In Fig 1, the optical spectra were plotted with the energy reduced to 50 %. Furthermore, the spectra were shifted toward a higher binding energy by 0.17eV. As can be seen from the figure, the M_1 peak, which is due to one-dimensional van Hove singularities (VHSs) in metallic SWCNTs, corresponds to the 1.8 eV peak observed in the optical spectrum of metallic sample. We observe no structure corresponding to the S_1 or S_2 peaks, which are caused by the VHSs in semiconducting SWCNTs, observed in the optical spectrum of the mixture sample. We then compared the spectrum with the density of states based on the tight-binding model. The energy position and shape of the observed M_1 peak were well reproduced by the calculated density of states.

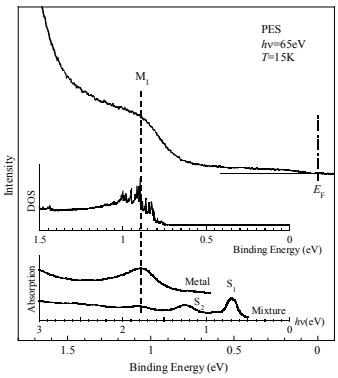

Figure 1 Photoemission spectrum of the metallic SWCNTs. The optical absorption spectra and the calculated density of states are shown.

Figure 2 shows the photoemission spectrum of semiconducting SWCNTs. We compared the photoemission spectrum with the optical spectrum of the semiconducting sample. In Fig 2, the optical spectrum was shifted toward a higher binding energy by 0.13 eV. As can be seen from the figure, the S_1 and S_2 peaks correspond to the 0.7 eV and 1.3 eV peaks, respectively, in the optical spectrum of semiconducting sample. We observe no structure corresponding to the M_1 peak. We then compared the spectrum with the density of states based on the tight-binding model. The energy position and shape of the observed S_2 peak were well reproduced by the calculated density of states. On the other hand, the intensity of the observed S_1 peak is very weak. This may be due to the bundle effect.

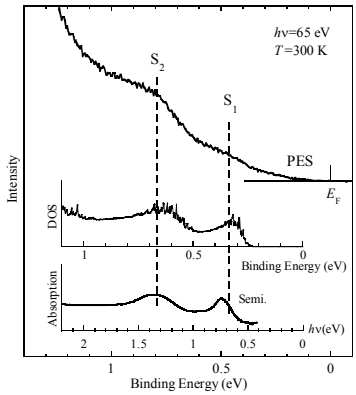

Figure 2 Photoemission spectrum of the semiconducting SWCNTs. The optical absorption spectrum and the calculated density of states are shown.

References

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