11D/2002G185

Photoemission Spectra of Single-Wall Carbon Nanotubes

Hiroyoshi ISHII*[1], Hiromichi KATAURA[1], Hidetsugu SHIOZAWA[1], Hideo KIHARA[1], Yasuhiro TAKAYAMA[1], Tsuneaki MIYAHARA[1], Shinzo SUZUKI[1], Yohji ACHIBA[1] and Masashi NAKATAKE[2]
[1]Tokyo Metropolitan University, Hachioji-shi, Tokyo 192-0397, Japan
[2]KEK-PF, Tsukuba, Ibaraki 305-0801, Japan

Introduction

A metallic single-wall carbon nanotube (SWNT) is considered to be an ideal one-dimensional (1D) conductor because the electronic states along the circumference of a SWNT are quantized [1, 2]. In such a system, a Tomonaga-Luttinger-liquid (TLL) state should be realized. In this study, we investigated the 1D electronic states in SWNTs by photoemission spectroscopy [3].

Experimental

The photoemission experiments were performed using synchrotron radiation at the beam line BL-11D of the Photon Factory, High Energy Accelerator Research Organization (KEK). The instrumental resolution was 50 meV. SWNT samples were prepared by the laser vaporization method. The mean diameters of SWNTs in the SWNT-A and SWNT-B samples are 1.37 nm and 1.25 nm, respectively.

Results and Discussion

Figure 1 shows the photoemission spectra of the SWNT-A sample and Au measured at $h\nu$=65 eV. The observed photoemission intensity decreases rapidly near the Fermi level (E_F). This spectral feature is different from that of Au (3D conventional metal).

As the origin of the peculiar spectral feature near E_F, we consider the suppression in density of states near E_F seen in a TLL state. The theoretical calculation for the TLL state in the metallic SWNT was performed on the basis of the bosonization theory of a 1D electron system; the calculation spectrum has a spectral function of $\omega^{0.4}$ at zero temperature, where ω is the energy measured from E_F [4].

The observed spectral features are not contradictory to the theoretical calculation of the TLL state. Figure 2 shows the photoemission spectra plotted on a log-log scale. The figure clearly indicates that the spectra have a power-law dependence on binding energy. From fitting with ω^{α}, the exponents were estimated to be 0.42±0.10 and 0.46±0.10 for the SWNT-A and SWNT-B samples, respectively. The theoretical calculation predicted the exponent of 0.4 for an isolated metallic SWNT [1, 4]. The power-law behaviors of the spectral function show good agreement with the theoretical calculation and consistent with the results obtained from previous transport experiments [5].

[1] R. Egger and A. O. Gogolin, Phys. Rev. Lett. 79, 5082 (1997).
[2] R. Saito, G. Dresselhaus and M. S. Dresselhaus, *Physical Properties of Carbon Nanotubes* (Imperial College Press, London, 1998).
[3] H. Ishii *et al*., Nature 426, 540 (2003).
[4] H. Yoshioka, Physica E 18, 212 (2003).
[5] M. Bockrath *et al*., Nature 397, 598 (1999).

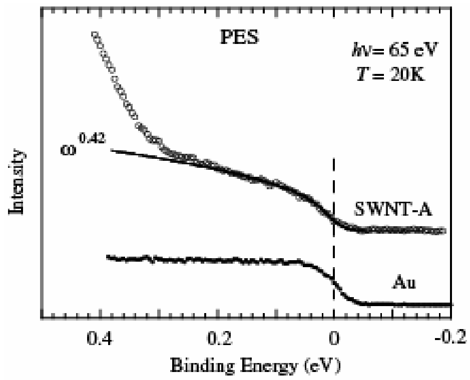

Figure 1: Photoemission spectra of SWNT and Au near the Fermi level. A solid line indicates $\omega^{0.42}$ broadened by the energy resolution.

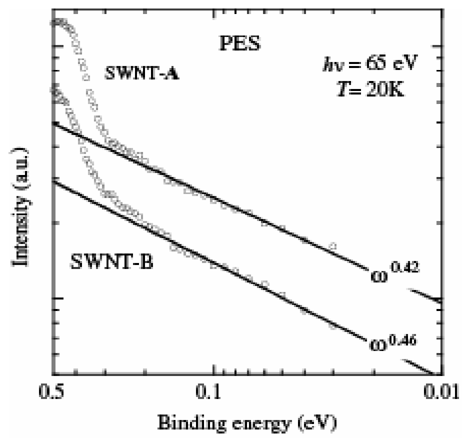

Figure 2: Photoemission spectra of SWNT samples plotted on a log-log scale.

* ishii@comp.metro-u.ac.jp