High energy-resolution electron energy-loss spectroscopy study of the electric structure of two-wall carbon nanotubes

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We have been developing a high energy-resolution electron energy-loss spectroscopy (EELS) microscope to study electric structures of specified small specimen areas [1]. The EELS microscope has been applied to multi-walled carbon nanotubes (MWCNTs) [2], bundles of single-walled CNT [3] and boron nitride (BN) nanotubes [4] to reveal interband transition energies and density of states of conduction bands. A high spacial-resolution EELS study of surface excitations of CNTs was reported by O.Stephan et al. [5]. Those EELS studies, however, could not observe intrinsic electronic structures for a specified structure of a nanotube, which is represented by a chiral vector. Intrinsic interband transition energies are smaller than about 3eV. To discuss intrinsic electronic structures of a specified nanotube structure, a combination of a structure determination by electron diffraction study and a high energy-resolution EELS measurement is necessary.

In the present study, we conducted EELS studies of electronic structures of double-walled CNTs (DWCNT). To detect a weak intensity, the CCD detector of our EELS microscope was changed from a front illumination type to a back illumination type. As a result, an efficiency of our detection system was improved by about 5 times. The structures (chiral indexes) of the DWCNTs were determined by comparisons of experimentally obtained electron diffraction patterns and simulated ones. Figure shows a spectrum obtained from one DWCNT with chiral indexes of (29,4) and (18,8). An energy resolution was 85meV. Peak structures are seen superposed on a broad intensity distribution of π-plasmon excitation as indicated by vertical lines. The structures at about 2eV and 3eV are consistent with a Joint density of states based on LCAO calculation by using the chiral indexes determined. EELS spectra of other DWCNTs with different chiral indexes showed interband transition peaks at different energies.

We successfully detected intrinsic interband transition peaks, which originate from a structure of CNT (chiral vector), for the first time by using an improved high energy-resolution EELS microscope.

References