TEM-EELS of Photo-excited MWCNTs Using a Pulsed Electron Beam

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Spin-polarized pulse transmission electron microscope (SP-TEM) can generate a picosecond pulsed electron beam by using an ultrafast pulse laser for electron beam generation. We have developed and demonstrated the time-resolved EELS measurement using a pump probe method for electron energy loss spectroscopy (EELS) in the SP-TEM. In this method, excited state of the specimen is generated by a pulsed laser, and pulsed electron beam which has a certain delay from the photo-excited moment illuminates the excited specimen to capture the relaxation process of the excited state. To realize the pump-probe method, we newly developed a mirror system for illumination of a pumping laser directly to the specimen. The mirror was set to a downstream of condenser lens system in the vacuum ambient of SP-TEM. The pumping laser is reflected by the aluminum mirror inside the SP-TEM and is focused on a specimen where is same as the electron beam position in the specimen plane.

In this study, multiwall carbon nanotubes (MWNTs) was employed for the specimen because the MWNTs show interest optical properties for electron-electron interaction, electron-phonon interaction and change of EEL spectrum at inner-core excitation region due to the photo-excitation. In this experiment, the wavelength and the intensity of the pumping laser were changed to search an effective condition. The photo-excitation dependence of the EEL spectrum of the K edge appearing around 280 eV was observed. The dependence was conducted by subtraction of EEL spectrum with pumping laser and that without pumping. Acquisition of EEL spectra was carried out in the SP-TEM with sweeping the excitation wavelength from 910 nm to 700 nm. The results show that intensity ration between π and σbines at K-edge spectrum was changed due to the photo-excitation. Measurements of the excitation process revealed that the spectrum change occurred near the excitation wavelength of 708 nm which is photon energy of 1.75 eV.