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Defect Formation in Ultraviolet-Irradiated Multi-walled Carbon Nanotubes

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Carbon nanotubes have a nanoscale tube-like structure formed by twisting graphene with two-dimensional spread of carbon atoms. Carbon nanotubes have very unique properties, and their properties are determined by factors such as diameter, number of turns, and angle of winding. In particular, multi-walled carbon nanotubes have a layered structure consisting of multiple concentric cylinder-shaped graphene, which is easier to synthesize and has better mechanical stability than single-walled carbon nanotubes. In addition, defects introduced in the structure greatly affect physical properties such as electrical conductivity, therefore research on defect formation in carbon nanotubes has been conducted.

In previous studies for graphene, it has been found that UV irradiation in various atmospheres causes defects in graphene [1]. In this study, carbon nanotubes were irradiated with UV for 1 minute in air, and C *K*-edge X-ray absorption fine structure (XAFS) measurements were performed to reveal the chemical state of defects.

The samples of commercially available multi-walled carbon nanotube sheets with and without UV irradiation were compared. XAFS measurements were performed at the BL-8 of SR Center, Ritsumeikan University, equipped with a grazing incidence monochromator with a varied-line-spacing plane grating. C *K*-edge XAFS spectra were obtained in both partial electron yield (PEY) and total electron yield (TEY) modes with a micro-channel plate detector with retarding grids set to -150 V and a drain current, respectively. The incident angle of SR with respect to the surface normal was varied. The measurements were performed at room temperature under the ultrahigh vacuum of $\sim 1\times10^{-7}$ Pa.

Figure 1 shows the PEY and TEY C *K*-edge XAFS spectra of pristine and 1 minute UV irradiated multi-walled carbon nanotube sheets. The peaks at 284.7 eV, 287.2 eV, and 288.1 eV originate from $\pi^*(\mathrm{C=C})$, $\sigma^*(\mathrm{C-H})$, and $\pi^*(\mathrm{C=O})$, respectively [2]. For the untreated multi-walled carbon nanotube sheet, the peak of $\sigma^*(\mathrm{C-H})$ was observed (red line), whereas for the sample irradiated with UV, the corresponding peak disappeared and a new peak of $\pi^*(\mathrm{C=O})$ was observed (blue line). The intensity of this peak was more pronounced in the PEY spectrum than in the TEY one. These results indicate that the C=O bond was formed on the sample surface by UV irradiation.

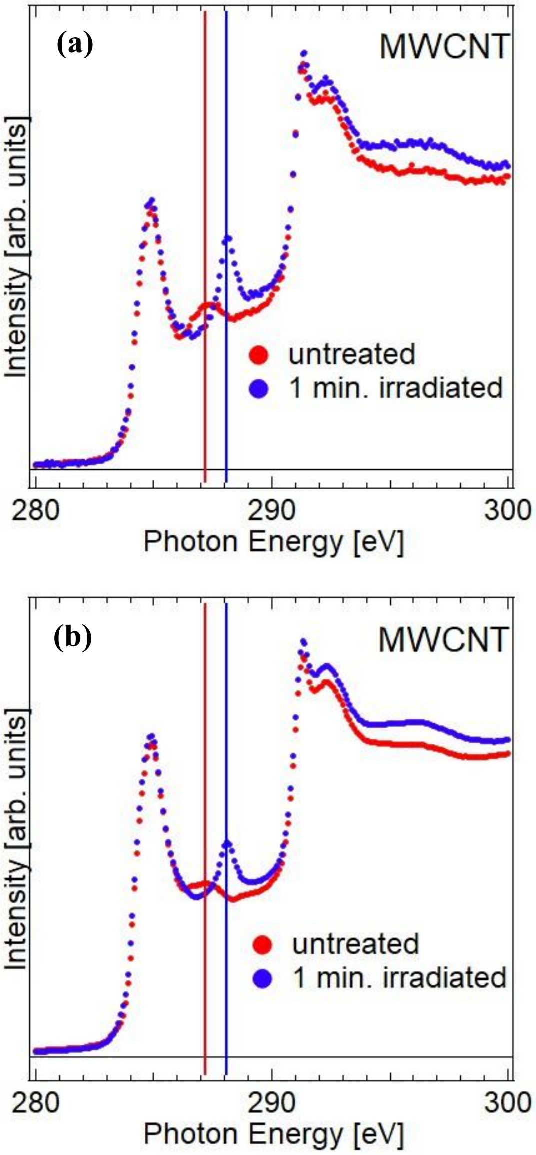

Fig. 1 C *K*-edge XAFS spectra of pristine graphene and graphene irradiated with UV light for 1 min. (a) PEY mode. (b) TEY mode.

References

[1] G. Imamura, K. Saiki, Chem. Phys. Lett. **587**, 56 (2013)
[2] R.A. Metzler et al., J. Am. Chem. Soc. **132**, 11585 (2010).