

## Ion desorption from carbon nanotubes induced by soft X-ray illumination

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### Introduction

One of the issues of technological and fundamental importance in single-walled carbon nanotubes (SWNTs) is defects because physical properties of SWNTs should be strongly affected by the presence of defects in the one-dimensional structures. A recent study [1] showed that some defects in SWNTs can be introduced by irradiation with electrons of energies far lower than the knock-on damage threshold. More recently, some of the present authors [2] found that defects are generated in SWNTs even by soft X-ray illumination without significant momentum transfer. In the present study, we have investigated the ionic desorption from SWNTs that is induced by soft X-ray illumination in the C1s core-excitation energy range.

### Experimental

Commercial SWNT powder, purified by refluxing in hot hydrogen peroxide and dispersed in dichloroethane, was deposited onto a Si substrate. The soft X-ray experiments were conducted at BL-13C operated in the single-bunch mode using monochromatic soft X-rays of  $10^{10}$  photons/s·cm<sup>2</sup> in intensity. The mass of desorbed ions was analyzed by a TOF spectrometer designed for coincidence spectroscopy [3]. Ion desorption spectra were measured as a function of the photon energy used for soft X-ray illumination, in one set of measurements for individual ions detected by TOF and in another for total ions collected by the TOF tube. All the experiments were conducted at room temperature under a ultra high vacuum (UHV) condition ( $< 3 \times 10^{-7}$  Pa).

### Results and Discussions

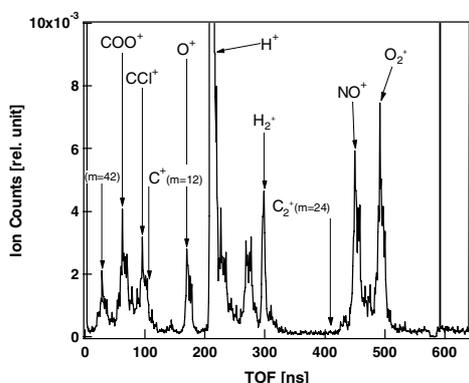


Fig. 1 Time of flight spectrum of ion species desorbed from a SWNT sample illuminated with 292 eV photons.

Figure 1 shows a typical TOF spectrum obtained when the sample was illuminated at  $E = 292$  eV, indicating that desorbed species are consisted of various ions such as  $H^+(m=1)$ ,  $H_2^+(m=2)$ ,  $O_2^+(m=32)$  and  $COO^+(m=44)$  which are considered to originate in chemical groups introduced during the oxidative treatment by hydrogen peroxide. An important fact to be stressed is that  $C^+(m=12)$  and  $C_2^+(m=24)$  ions were *not* detected in the experiments, which means that the simple desorption of carbon atoms from the nanotubes is not the mechanism of the defect formation by soft X-ray illumination.

The solid curve in Fig. 2 shows the normalized efficiency spectrum for desorption of ions dominated by  $H^+$ . The circular marks and the broken curve indicate the desorption efficiency spectrum of  $H^+$  ions and the X-ray absorption spectrum (XAS), respectively. The desorption efficiency spectrum exhibited a resonant structure near the C1s core absorption edge and a non-resonant component at energies higher than 300 eV.

The ion yield spectra were not significantly different between ion species. The inset shows the linear correlation of desorption rate (TIY) with the photoelectron yield (PEY) in high photon energies ( $> 300$  eV). It appears that the ion desorption in this energy range is triggered by normal Auger processes.

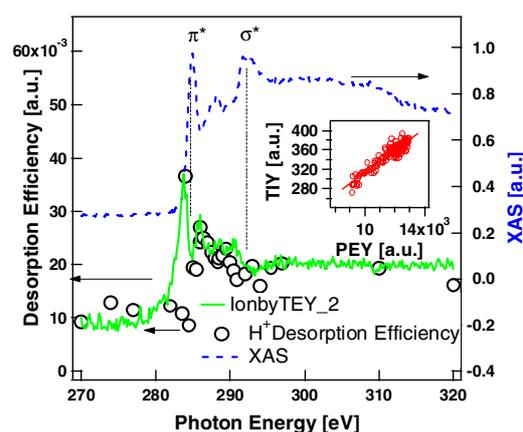


Fig. 2 Desorption efficiency spectrum (green) and XAS (dotted blue)

### References

- [1] S. Suzuki et al., Jpn. J. Appl. Phys. 44, 133 (2005).
- [2] Y. Mera et al., submitted.
- [3] E. Kobayashi et al., J. Phys.:Cond. Matter 18, S1389 (2006).

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