

### The soft X-ray emission spectroscopic study of single-walled carbon nanotube

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It is well accepted that carbon nanotube (CNT) can be a metal or a semiconductor depending on its structure. On the other hand, soft X-ray spectroscopy is a good method to study an electronic state of solid. Polarization dependence can reveal the symmetry of the electronic state. However in CNT case, we cannot find such kind of report because there are few well-aligned CNT samples. In this study, we employed two kinds of well-aligned samples, one is Single-Wall CNT (SWNT) and the other is Multi-Wall Carbon nanoTube (MWCT) and performed soft X-ray spectroscopy on them. The SWNT is synthesized inside a zeolite single crystal (AlPO<sub>4</sub>-5), and it is thinnest CNT in the world. This means that we can expect the SWNT have well separated quantized electronic state. Figure 1 shows C1s absorption spectra for two configurations. For both spectra, we observed peak structure around 285eV and broad structure about 292 ~ 296 eV. Former one can be assigned to a  $\pi^*$  state and the later one can be understood as a  $\sigma^*$  state. The polarization dependence is observed around 283 ~ 284 eV and 288 ~ 291 eV. Since we need more detailed analysis above 291 eV, the difference between two configurations is not sure. We observed no sharp structure. The reason might be attributed to the resolution and/or the sample degradation. We should confirm the reason by another measurement.

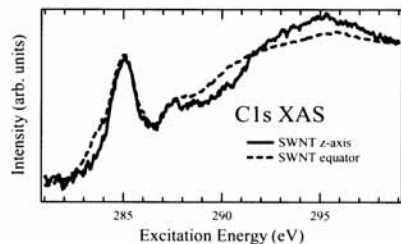


Fig.1 C1s XAS of SWCT.

We have also investigated C1s recombination emission of vertically aligned MWCT to compare with that of Highly Oriented Pyrolytic Graphite (HOPG). Fig. 2 displays a comparison of (a) C1s absorption and (b) the recombination emission obtained at various experimental geometries to show remarkable difference in polarization dependence between HOPG and MWCT. As shown in Fig. 2 (b), a strong low energy tail was found in in-plane emission for HOPG and in equatorial emission for MWCT, indicating a large lattice distortion in HOPG toward graphene sheet, whereas in MWCT toward out of wrapping graphene sheet.

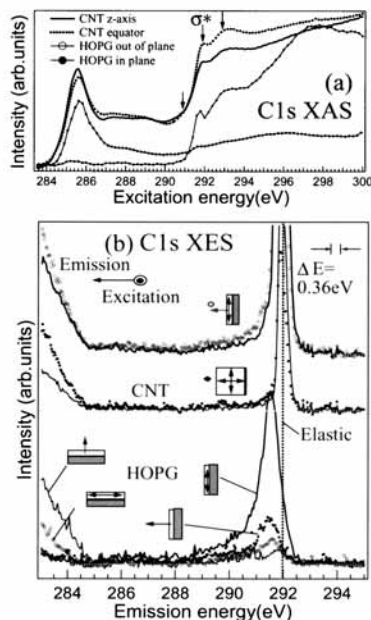


Fig.2 C1s (a)XAS and (b)XES of HOPG and MWCT.

### Chemical short rang order of liquid silicon-germanium alloys

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Ge-Si alloys form a solid solution in entire concentration range and the lattice constant varies in Vegards' law. Since the optical gap also changes with concentration, the Si-Ge alloy is recently expected to be available as new devices and optics. We have planned to measure x-ray diffraction spectra of liquid Si-Ge alloys to investigate local structure and chemical order in the liquid alloy. Si and Ge have a diamond structure in a solid phase but on melting they become a liquid metal and the nearest coordination number increases up to 6. It is interesting to study how the local structure changes with composition in this alloy. In this report, we describe results of x-ray diffraction measurements for liquid Si-Ge alloys.

X-ray diffraction measurements were carried out at BL28B2 beamline. A white x-ray beam provided by a bending magnet was incident on the sample and the scattered x-rays were detected and energy analyzed by a pure-Ge solid state detector (SSD). The incident x-ray beam was collimated to 0.2mm x 0.2mm using a slit in the transport chamber. After the collimation with two receiving slits of 0.3mm x 0.3mm and 0.5mm x 0.5mm, the scattered x-rays were detected by the SSD. We measured x-ray diffraction spectra of liquid Ge50Si50 and Ge70Si30 alloys near the melting points. As the temperature is raised, the heater was broken probably because vaporized sample was chemically reacted with tungsten wire.

Figure 1 shows a structure factor,  $S(k)$ , of liquid Ge50Si50 at 1270°C. Here  $k$  is a wave number ( $k=4\pi\sin\theta/\lambda$ ;  $\lambda$  is a wave-length of x-

ray). The first peak has a shoulder at larger  $k$  side and oscillations up to the fourth peak are clearly observed. X-ray absorption fine structure (XAFS) was measured for liquid Ge-Si alloys by Inui et al. [1] and the concentration dependence of the Ge-Ge and Ge-Si bonds was reported. The bond length obtained from XAFS spectroscopy appeared to be much shorter than the real one. Data analysis is now in progress to estimate exact bond lengths in the liquid alloys.

[1] M. Inui et al. J. Synchrotron Rad., **8** 767-769.

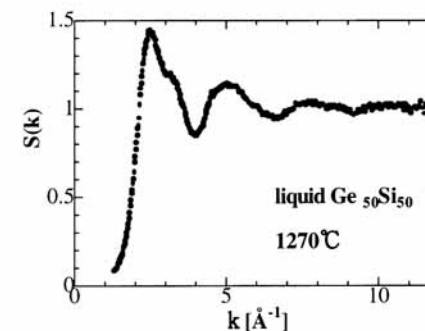


Figure 1