## §10. Low-energy Particle Reflection from Highly-oriented Carbon Nano-tubes

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To study basic process of particle interaction with the matter is important to understand the plasma-wall interaction. In the plasma chamber, interestingly, nano-materials have been found in the plasma dust. Fundamental understanding of particle interaction with nano-materials is, however, limited to energy transfer, radiation damage and possible hydrogen storage, although nano structure materials have been paid much attention due to physical properties, unique structure and future application. Thus the reflection properties as well as the absorption and re-emission of the incident particles for the nano-structure materials are still open question.

We have been developed an experimental system to study the fundamental processes of particle interaction with solid surfaces. [1, 2] Here we studied low energy particle ($< 10$ keV) interaction with nano-materials such as carbon nanowall and nanotubes (CNT), which are vertically oriented to the substrate. The CNT sample was prepared with chemical vapor deposition technique on a Si crystal-surface in a separate plasma chamber. Ni layer as catalysis was first coated on the Si surface through sputtering process. The CNT was grown on the surface at 600 °C by running a 200 W RF mixed gas discharge of $H_2$ and $CH_4$ for 30 minutes. Finally we obtained the vertically aligned CNW with thickness of about 1 $\mu$m.

Upper and lower panels in Fig. 1 show a SEM image (magnified by 1700) and TEM image of multi-wall nanotube with Ni atoms on the top. $H^+$ ions were injected on the CNW surface and angle and energy resolved measurements were performed for the reflected $H^+$ ions. Figure 2 shows an example of the incident beam energy dependence of the reflected $H^+$ particles at the incident angle of 8°, where the incident angle is defined to be the angle from the surface. The graphite or HOPG showed specular reflection with broad peak, but in the CNT we observe apparent geometrical structure effect on the particle reflection, strongly depending on the incident energies. The broad peaks are observed at higher reflection angle side and they shifts to larger angle side with increasing the incident beam energy. They may be due to the reflection from deep places in the CNT.

1) M. Wada *et al.*, *Rev. Sci. Instrum.* **73** (2008) 955.

2) N. Tanaka *et al.*, *J. Nucl. Mater.* **390-391** (2009) 1035.

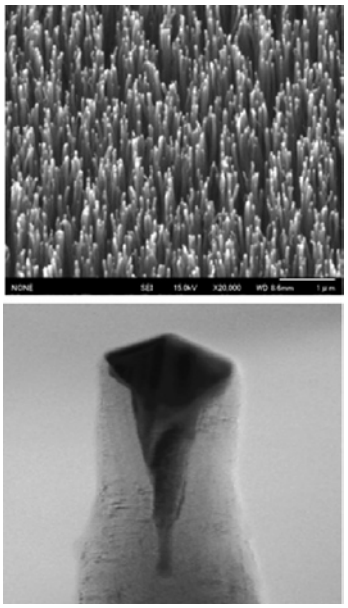

Fig. 1: Upper panel: SEM image of the vertically-aligned carobon nanotube on Si substrate. Lower panel: TEM image of multiwall carbon nanotube. On the top Ni atoms used as catalysis are observed.

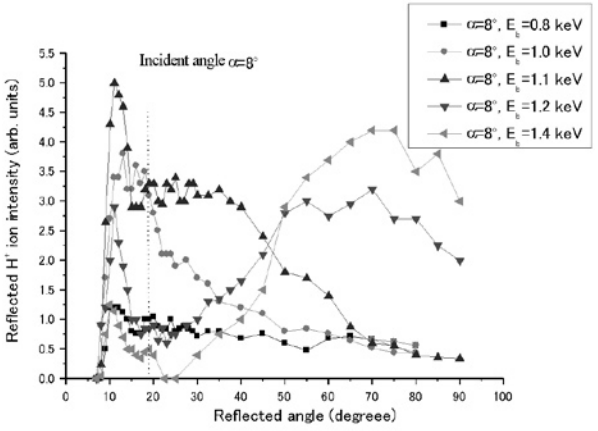


Fig. 2: Characteristics of the reflected $H^+$ ions with the incident energies around 1 keV on CNT target at the incident angle of 8°.