§14. Reflection of Low-energy Hydrogen Particles Injected into Highly-oriented Carbon Nanotube

Yamaoka, H. (Harima-RIKEN),
Kato, S., Nishikawa, Y., Kenmotsu, T., Wada, M. (Doshisha Univ.),
Tanaka, N., Sasao, M. (Tohoku Univ.),
Nishiura, M., Tsumori, K.,
Matsumoto, Y. (Tokushima Bunri Univ.)

Recently, carbon nanomaterials such as nanotube and graphene attracts wide interests because of their unique physical characters and great potential for the applications. It is also interesting to note that we may find nanostructure carbons around the first wall of the vacuum chamber in fusion devices. Various kinds of carbon dusts are formed resulting from the plasma and carbon-wall interaction.

We have been developing a system capable of injecting low energy particle less than 10 keV into a material surface at any angle to study basic processes of plasma surface interaction [1-3]. We have measured reflection properties from metal and carbon targets. As other sample surfaces of this system we chose above carbon nanotube (CNT), which is synthesized by ourselves.

We prepared a sample of CNW by chemical vapor deposition on a Si crystal by running a 200 W RF mixed gas discharge of H_2 and CH_4 for 30 minutes in a separate plasma chamber. The film deposition system can produce layers of amorphous graphite, packed graphite, vertically-aligned CNTs and carbon nanowalls by tuning the deposition conditions. Target temperature and the bias voltage applied to the target were found critically important in determining surface morphology of the film. The sample was exposed in the air before setting to the analyzer chamber of the measurement system. We succeeded to develop CNTs with vertically-aligned structure on the substrate and thus we could study a basic scattering process with ideally aligned system. The detail of the experimental system has been reported elsewhere [2,3].

A few keV hydrogen ion beam is injected onto the target. Angle dependence of scattered hydrogen ions is analyzed by the magnetic momentum analyzer beside the target. Note that in this incident beam energy range the sputtering yield is much smaller compared to the fraction of the reflected particles. We found the clear difference between the vertically- and horizontally-oriented systems: the reflected particle intensity of the CNT shows sharp peak, while that of carbon sheet and HOPG (horizontally-oriented pyro-graphite) are much broader, indicating structure effect.

Figure 1 shows the measured angle-dependence of the reflected ion intensity and that calculated by the Monte Carlo simulation code ACAT (Atomic Collision in Amorphous Target) to investigate the effect due to surface roughness based upon a fractal dimension model. The experimental result shows a sharp peak around mirror angle. After baking the peak shifts to larger angle and the width of the peak broader. We could reproduce the sharp peak well; simulation shows much broader peaks for amorphous carbon targets and surface roughness has made width of the peak even broader. To simulate the highly-oriented system, we modified the model by taking into account of the aligned CNT structure. A preliminary result is shown in Fig. 2. This result indicates that the target structure is an important factor to determine the reflection property. Further detailed studies for both experiment and simulation are undergoing.

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2) N. Tanaka *et al*., J. Nucl. Mater. **390-391**, 1035 (2009).
3) M. Wada *et al*., Plasma Devices and Operations **17**, 132 (2009).

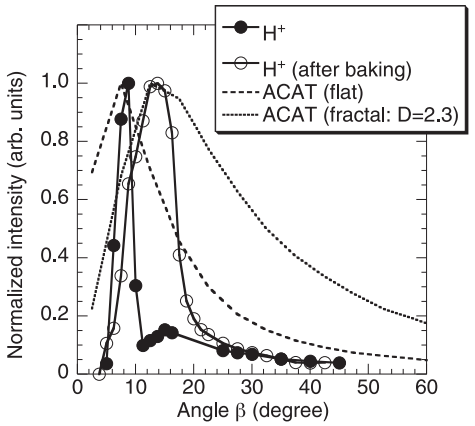

Fig. 1 Characteristics of the reflected H^+ ions for 1 keV H^+ beam injection on CNT target (solid lines). Results of the ACAT simulation are also shown (dashed and dotted lines).

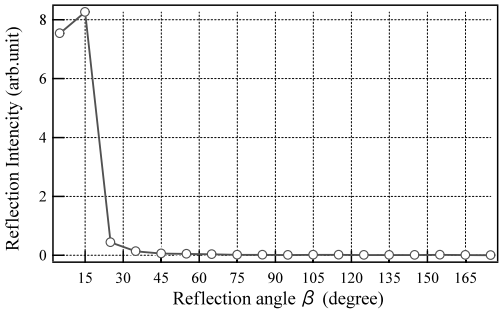

Fig. 2 Preliminary result of the ACAT simulation taking into account the aligned structure of the CNT target.