§14. Surface Roughness and Temperature Effect on Ion Reflection from Si and Graphite Following Low-energy H$^+$ Beam Injection

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Low energy particle interaction with matters has attracted many interests in areas covering fundamental and technological research such as surface characterization, surface manipulation, nanotechnology, film growth and others. Particular interest in hydrogen-material system, including a formation of both positive and negative ions, has been stimulated by the development of plasma confinement devices with the study of plasma-wall interactions, diverter physics, and negative ion sources. We have studied the fundamental process of beam-surface interactions by measuring particles scattered from the solid surface following low energy (a few keV) light ion injection. 1) Both positive and negative ions from several samples, such as Mo, W, graphite, and carbon nano wall were observed and we found that the surface structure affected the reflection property. 2) This study aims particularly to study the effects of surface roughness and temperature to the properties of hydrogen ions reflected following 1 keV H$^+$ beam injection.

We prepared a Si crystal, a rough-finished Si (a few μm roughness), and a graphite sample. The H$^+$ beam energy was kept at 1 keV and beam current was 10-40 nA at the target throughout this series of the experiment. The reflected ions were measured by a magnetic momentum analyzer consists of a pair of magnetic coils and a multi-channel plate set on a turntable. This analyzer system enables energy and angle resolved measurements of reflected ions.

Reflection angle dependence of the reflected ion energy and intensity at several incident angles were measured. The reflected ion intensity in the rough-finished Si was largely reduced compared to that in the Si crystal at the incident angle of $\alpha = 10^\circ$ as shown in Fig. 1(b). The angular distribution of the rough-finished Si was slightly broader than that of Si crystal at $\alpha = 10^\circ$ and that of the graphite was much broader than the others. Figure 1(c) shows a comparison between the rough-finish Si and graphite. The graphite has a piled-up structure of small pieces horizontally. The result shown in Fig. 1(c) suggests that this structure has a similar effect on the reflected ion intensity angle distribution as the diffuse scattering in the rough-finished Si. Thus the structure and surface roughness affect on the scattering ion intensity and angle distribution particularly at lower incident angles. We also studied temperature dependence of the reflected ion intensity for these samples. Temperature-dependence of the H$^+$ ion intensity reflected from the Si crystal and graphite are shown in Fig. 2. Both the Si crystal and rough-finished Si did not show clear temperature dependence, while reflected H$^+$ ion intensity decreases and H$^-$ ion intensity increases as increasing the temperature of the graphite sample. The temperature-induced change in the reflected ion intensity may be due to the retention or thermal effect.

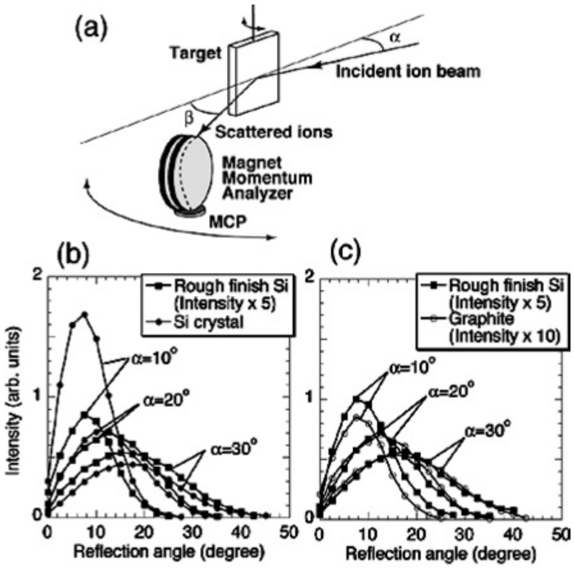

Fig. 1: (a) Definition of the incident angle (α) and reflection angle (β) with respect to the target surface. (b) β-dependence of the H$^+$ ion intensity reflected from rough-finish Si and Si crystal. (c) β-dependence of the H$^+$ ion intensity reflected from rough-finish Si and graphite.

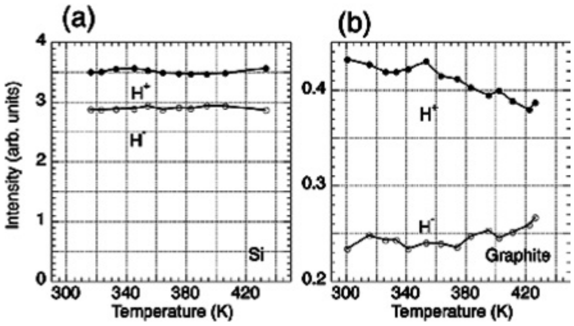

Fig. 2: Temperature-dependence of the H$^+$ ion intensity reflected from (a) Si crystal and (b) graphite.

1) M. Wada *et al.*, *Plasma Device and Operations* **17**, 132 (2009).

2) T. Kenmotsu *et al.*, *J. Plasma and Fusion Res. Ser.* **8**, 442 (2009).