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§13. Time-of-flight Analyzer System to Detect Reflected Particles from a Solid Surface Following Low-energy Particle Injection

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Information on interactions of low-energy particles with solid surfaces is important in designing first walls and diverters for fusion reactors. In a burning plasma such as the one in ITER, the interaction between the material surface and thermalized low-energy ions in the range from a few to 10 keV affects the overall plasma confinement and transport. The precise process of edge plasma behavior, however, has still not been fully clarified due to lack of data set for particle reflections at solid surfaces.

We have been developing an experimental system to study the fundamental processes of particle interaction with solid surfaces and used it to obtain the data set for plasma-surface interaction. With this system we have measured reflected ions for single or poly crystals (Si, Mo, C, V-alloy) following the low-energy (1-3 keV) beam injections [1, 2]. The angular distributions and energy spectra of positive and negative ions reflected from the materials had been measured by using a magnetic momentum analyzer. The results showed the reduction in energy of the reflected ions from the incident ion energies and a strong angular dependence of the intensity of reflected ions at a given incident angle. We have noticed in these experiments that the reflected particles mainly consist of neutrals rather than ions, and recognized the importance to measure the properties of the reflected neutral particles. Hence we employed a time-of-flight (TOF) analyzer installed complementarily to the existing magnetic momentum analyzer.

Figure 1 shows our system to study beam-surface interaction equipped with the TOF analyzer. As an application of the TOF analyzer, we show the results of the measurements for a polycrystalline W: angular dependences of the reflected neutral particle in their energy and intensity. We also performed the measurements of the reflected ions by the magnetic momentum analyzer. Figure 2 shows the results of the measurements by the TOF and magnetic analyzers. The energies of the reflected neutrals are much smaller than the incident ion energies, suggesting multiple scattering in the target. No angular dependence is observed under the condition that the sum of the incident and reflected angles is constant. The intensity of the reflected neutrals takes the maximum around the mirror angle.

1) M. Wada *et al*., Rev. Sci. Instrum. **73** (2002) 955.
2) H. Yamaoka *et al*., J. Nucl. Mater. **337-339** (2005) 942.; Rev. Sci. Instrum. **77** (2006) 03C301.; J. Nucl Mater. **363-365** (2007) 1304.; Rev. Sci. Instrum. **79**, 02C701 (2008).

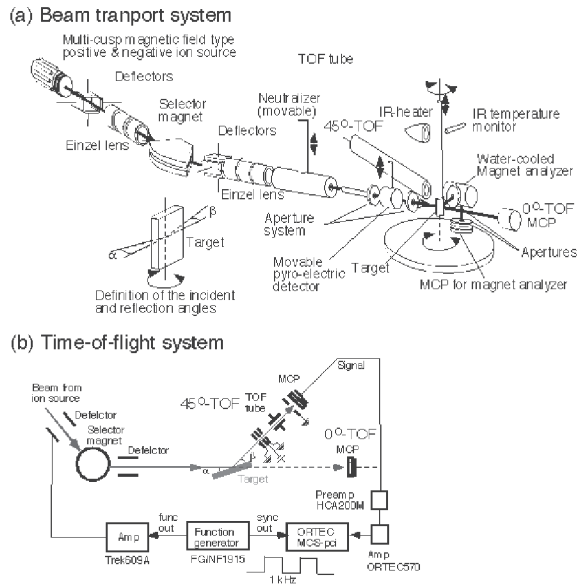

Fig. 1 (a) Schematic diagram of the experimental setup with the definition of incident and reflection angles. (b) Time-of-flight detection system.

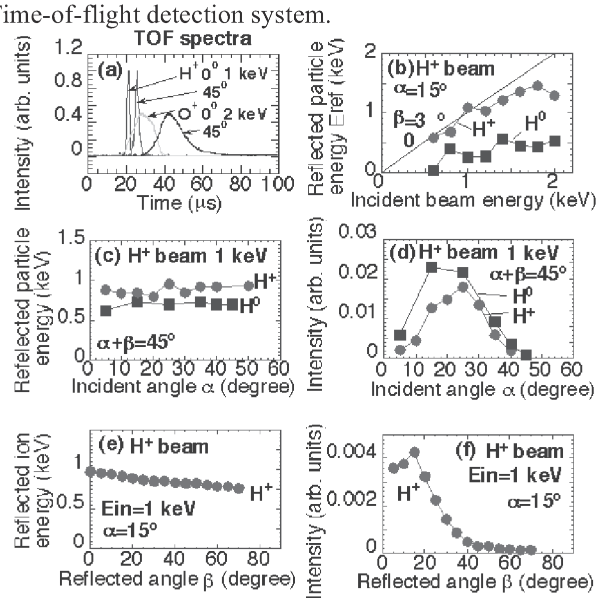

Fig. 2 Characteristics of the reflected particles for 1 keV H^+ beam injection on W target: (a) Examples of TOF spectra of H^0 and O^0 for 0^o-TOF and 45^o-TOF. (b) Incident beam energy dependence of the reflected particle energy at $\alpha=15^o$ and $\beta=30^o$. Solid line is proportional curve. Incident angle dependences; (c) the reflected particle energies and (d) intensities under $\alpha+\beta=45^o$. Reflected angle dependences; (e) the reflected ion energy and (f) the ion intensity at $\alpha=15^o$.