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Measurements of Potential Sputtered H^+ with 2D Position Sensitive Detector

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Abstract

In order to study the sputtering mechanism of light atoms by slow highly charged ions, H^+ ions sputtered by Xe^{7+} from an untreated C target were measured with a two-dimensional (2D) position sensitive detector. The kinetic energies of Xe^{7+} at the moment of surface impact were 700 eV to 4200 eV incident at 45 degrees with respect to the target normal. We found that (1) the 2D position distribution of sputtered H^+ ions, which reflects the initial angular and energy distributions, has a single peak with its position shifting toward upstream side of the incident ions, (2) this shift increases with decreasing incident energy, and (3) the estimated width of the energy of the sputtered H^+ in the direction parallel to the target is much wider than that of sputtered heavy ions.

1. Introduction

When a slow highly charged ion (HCI) approaches a solid surface, multiple electron transfer occurs due to its large potential energy. In the case of an insulator target, target atoms on the surface are ionized, and are ejected by their mutual Coulomb repulsion, which results in potential sputtering. In our previous study [1], it was found that (1) the yield of potential-sputtered H^+ showed a strong charge dependence, $\sim Q^5$, where Q is the charge state of the incident ion, when the surface was covered by several layers of hydrocarbons, and (2) the energy distribution normal to the target surface had a peak at ~4 eV. These observations have been successfully explained by the classical over-barrier model which took into account two-electron removal from a chemical bond containing a hydrogen atom [2,3]. These experimental and theoretical approaches indicate that H^+ is emitted before the HCI collides with the target. In order to acquire further information on the sputtering mechanism of H^+, we have constructed a new measurement system capable of the simultaneous detection of the two-dimensional (2D) position and the TOF (time of flight) of sputtered ions.

2. Experiment

A schematic diagram of the experimental setup is shown in Fig. 1. Low-energy highly charged ions were extracted from a mini-EBIS (Electron Beam Ion Source) [4] and were charge-state- and mass-selected with a Wien filter. The beam was then periodically pulsed with a deflector and finally guided into a UHV chamber.

In the UHV chamber, an untreated C target was mounted on a rotational and linear feed-through and a 48 mm ϕ position sensitive detector (PSD) was mounted on a turn table. The PSD consists of triple microchannel plates and a wedge-and-strip anode with a Ge layer. The uniformity of the efficiency and the linearity of the image were checked with an ^{241}Am α-source. In order to decelerate the primary ions and at the same time to accelerate the secondary ions, a mesh with a pitch of 30 wires per inch was placed over the target surface, parallel to it with a 10 mm distance. The target was biased at +400 V and the mesh was grounded. The tilt angle θ (see Fig. 1) was set so that the incident angle with respect to the target normal at the moment of the surface impact was always 45 degrees, regardless of the incident energy.

We define the coordinates as shown in Fig. 1, i.e., the XY plane is on the detection surface of the PSD which is parallel to the target surface, and the Y-axis is parallel to the rotational axis of the target. The origin of the coordinate is set at the peak of the 2D position distribution of sputtered heavy ions. The TOF of the sputtered ion was determined using the beam chopping signal and the secondary ion signal from the Ge layer, which was used to identify the species of secondary ions.

During the measurements, the pressure of the target chamber was $\sim 1 \times 10^{-8}$ Torr. As the beam current was low ($\sim 10^4$ counts per second), macroscopic charge-up of the target was negligible.

3. Results and discussion

It was observed that H^+ and heavy ions such as Na^+, K^+, and $C_nH_m{}^+$ were the dominant species of the sputtered ions from the untreated C target. Some secondary ions might be ejected

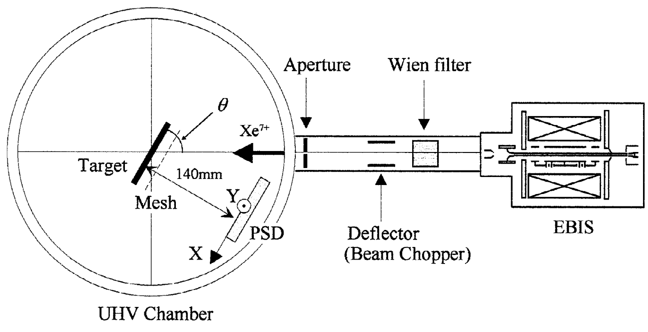

Fig. 1. A schematic diagram of the experimental setup.

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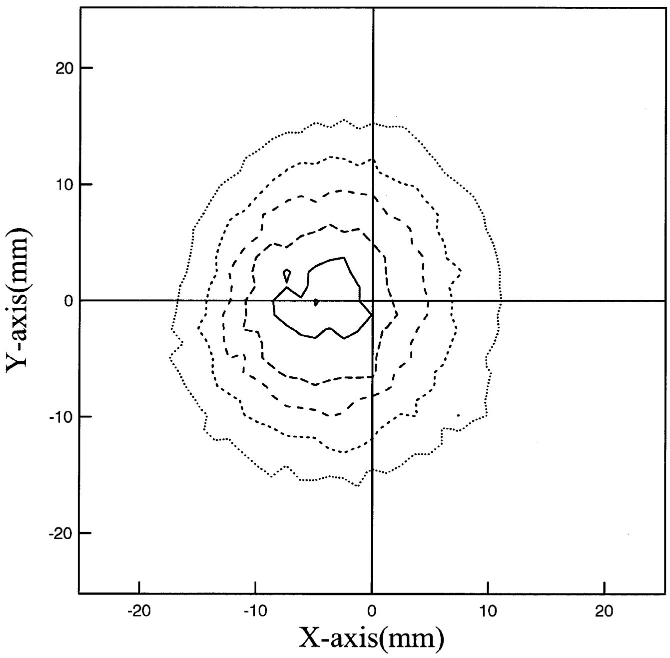

Fig. 2. 2D position distribution of H^+ sputtered by 700 eV Xe^{7+} with the incident angle 45 degrees at the moment of the surface impact.

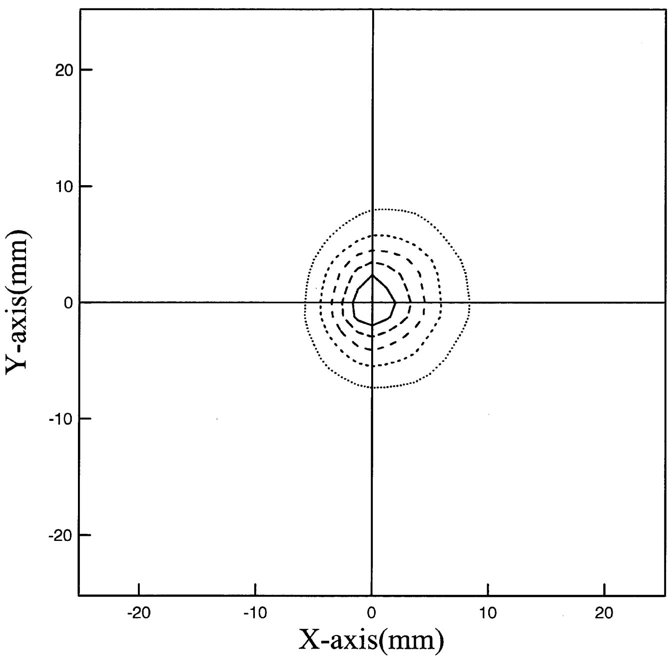

Fig. 3. 2D position distribution of heavy ions sputtered by 700 eV Xe^{7+} with the incident angle 45 degrees at the moment of the surface impact

also from the mesh, which could be easily separated by the TOF.

The 2D position distributions of H^+ and of heavy secondary ions for 700 eV Xe^{7+} impact are shown in Fig. 2 and Fig. 3, respectively. It is seen that the 2D position distribution of H^+ has a single peak, and the peak position shifts toward upstream side of the incident ions.

The peak width of H^+ is found to stay nearly constant when the incident energy of Xe^{7+} is increased from 700 eV to

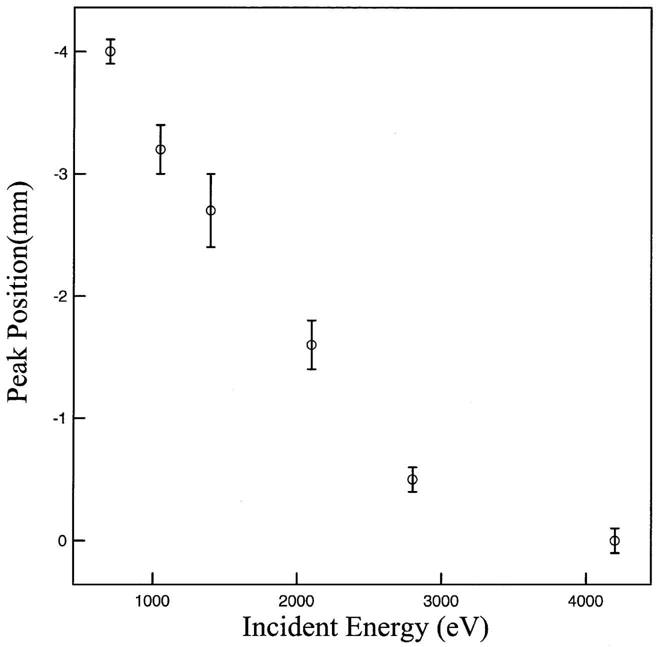

Fig. 4. Sputtered H^+ peak position in the X direction as a function of the incident energy of Xe^{7+}. Incident angle with respect to the target normal at the moment of the surface impact was 45 degrees regardless of the incident energy.

2800 eV. The half width of transverse energy is estimated to be ~2.8 eV, which is much wider than that of the heavy elements (<0.6 eV).

The peak shift of the H^+ for 700 eV Xe^{7+} corresponds to the average transverse kinetic energy of ~0.3 eV. As shown in Fig. 4, this shift decreases with increasing incident energy. This result indicates that the H^+ emitted from the target surface is strongly influenced by the electric field of the incident ion. Because the incident ion is moving toward $+X$ direction and flies over the ejected H^+, the H^+ is thrust in the $-X$ direction (upstream side). Such an effect is expected to become more important for lower incident energy of Xe^{7+}, which is consistent with the observation. It is noted that the quantitative analysis of the observed shift will provide a measure of the charge state evolution of highly charged ions around 10Å or less above the surface.

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