[III-7]

Heavy Ion-Surface Scattering at Hyperthermal Energies (3-100 eV). Cs^+ Collisions on Si(111)

양 민철, 김 철훈, 강 헌
포항공과대학교 화학과

Knowledge of the interactions between energetic gaseous species and surfaces is important in film deposition, ion-assisted etching, and low energy sputtering. Several research groups have explored hyperthermal (< 100 eV) gas-surface scattering using both supersonic atomic [1,2] and ion beams [3-5]. In most of these works, the mass of a projectile is smaller than a target atom, and the studies of heavy atom collision is very rare [1,2]. In the present work, we have examined scattering behavior of a heavy projectile (Cs^+) from a light atom surface (Si).

We employed Cs^+ ions as a projectile as they scatter mostly as ions from Si due to a lower ionization energy of Cs than a workfunction of Si surface. A specially designed low enery ion-surface collision chamber [6] was used for the scattering experiment. Cs^+ ions were mass- and energy-selected, and then bombarded onto a Si(111) target at the energies of 3-100 eV. Ions scattered from surface were analyzed for their mass using a quadrupole mass spectromefer, and their kinetic energy was measured in both retarding field analysis (RFA) and time-of-flight (TOF) modes. The angle between an incident beam and a detector was fixed at 90^0, and the beam incidence direction was varied around 45^o to a target surface.

The mean final energy (E_f) of scattered Cs^+ ion is plotted as a function of incident beam energy (E_i) in Fig.1. The prominent features are summarized in the following. (i) The E_f/E_i ratio decreases sharply with E_i over the range 3-100 eV. (ii) The high E_f/E_i ratio for low E_i indicates that the energy loss to a surface is small. (iii) The "effective mass" of the surface reaches about 1000 amu (40 Si atoms) at E_i < 5 eV, implying that a very large number of surface atoms interact collectively with a projectile.

The nearly elastic nature of low energy Cs^+ scattering (high E_f/E_i ratio) indicates that scattering occurs via multiple, large impact parameter collisions between Cs^+ and surface Si atoms. It appears that the Si surface atoms interact collectively with low energy Cs^+. The collision time, defined as the time duration that Cs^+ moves to a next adjacent Si atom, becomes of the order of phonon frequency ($\nu_{Debye} = 1.3 \times 10^{13}$ sec^{-1}) for low energies. Under such conditions the collective motions of surface atoms may become possible during the collision.

We have carried out molecular dynamics (MD) classical trajectory calculations [7] for hyperthermal Cs^+ collisions with a model Si surface which has a closely packed structure. From the calculation it is found that low E_i Cs^+ ions scatter from the top layer of Si, the sublayer atoms remaining very much undisturbed. Penetration of Cs^+ ions into sublayers becomes possible only at the highest E_i examined. Another finding is that the E_f/E_i ratio depends much on the lattice

potential parameters, but little on the mass of solid atoms. This implies that surface atom mass has little effect on the E_f during heavy projectile-surface collisions.

References

[1] E. Kolodney, A. Amirav, R. Elber, and R. B. Gerber, Chem. Phys. Lett. 113, 303 (1985)

[2] C. T. Rettner, J. A. Barker, and D. S. Bethune, Phys. Rev. Lett. 67, 2183 (1991).

[3] E. Hulpke and K. Mann, Surface Sci. *133*, 171 (1983).

[4] A. D. Tenner, K. T. Gillen, T. C. M. Horn, J. Los, and A. W. Kleyn, Phys. Rev. Lett. *52*, 2183 (1984).

[5] R. L. McEachern, D. M. Goodstein, and B. H. Cooper, Phys. Rev. B *39*, 10503 (1989).

[6] K. H. Park, B. C. Kim, and K. Kang, J. Chem. Phys. *97*, 2742 (1992).

[7] C. Kim, H. Kang, and S. C. Park, Nucl. Instrum. Methods in Phys. Res. B., in press.

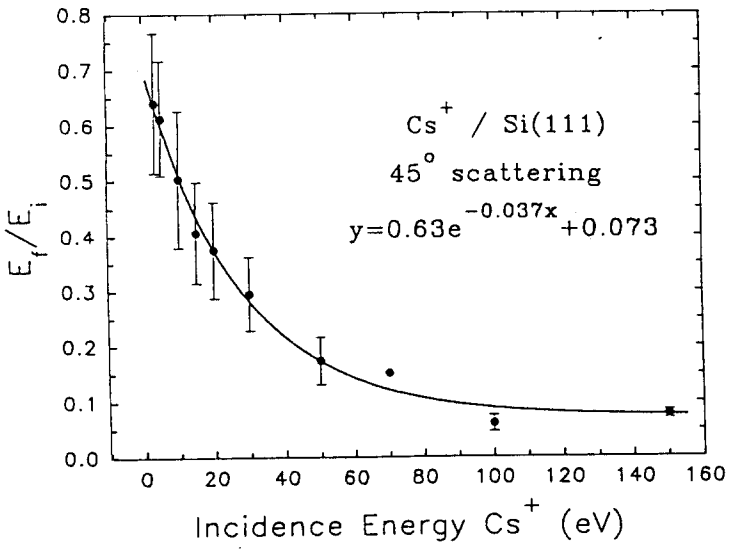

Fig. 1