§5. Contribution of Kinetic Energy to Secondary Electron Emission Yields from Clean Cu Surfaces at Low Energy Projectile Ion Impact

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Studies of the secondary electron emission (SEE) processes in collisions of low kinetic energy ions with solid surfaces are of great importance not only in basic atomic physics but also in applied fields such as plasma-wall interactions in fusion devices. In low energy projectile ion impact on solid surfaces, the SEE yields γ are given by

$$\gamma = \gamma_{KE} + \gamma_{PE}, \qquad (1)$$

where γ_{KE} and γ_{PE} are the kinetic emission and the potential emission, respectively. In the present study, we would like to focus our attention to the analysis of γ_{KE}.

The SEE yields γ from clean Cu surfaces induced by low energy ion (H^+, Ar^+, Ar^{2+}, Kr^+ and Kr^{2+}) impact were measured using a cylindrical double-wall cup under an ultra high vacuum chamber ($\sim 10^{-10}$ Torr) [1]. The target surfaces were cleaned by Ar^+ sputtering and the surface cleanness was examined by Auger electron spectroscopy.

Figure 1 shows the present results of the SEE yields for Kr^+ and Kr^{2+} ion impact on clean Cu surfaces as a function of the impact energy. In this figure the experimental results at higher energies obtained by Baragiola et al. [2] are also shown. As seen in Fig. 1, it is noticed that our experimental results at low energies for Kr^+ ion impact smoothly merge with their results at high energies. For all the projectile ion species investigated, as the impact energy decreases, the SEE yields decrease and finally reach constant values which can be due to the potential emission. The SEE yields are also found to increase with the ionic charge over the whole impact energy range investigated.

The γ_{KE}, which is deduced by subtracting γ_{PE} from "total" SEE yields, is shown in Fig. 2. It seems that these kinetic emission parts, γ_{KE}, for singly and doubly charged ions lie on the single curve. It is clearly seen from Fig. 2 that the kinetic emission is independent of the incident ion charge, suggesting that the incident ionic charge does not play any significant role for the kinetic electron emission from the metal targets as expected. It is also noted that the ion impact energy dependence varies at low and high energies and clear kinks are seen. At low energy region, γ_{KE} for clean Cu surfaces shows the apparent thresholdlike behavior and decreases roughly as $v^{3.5}$ when the projectile ion velocity (v) decreases. Because, in general, γ_{KE} are proportional to the electronic stopping power S_e of the projectile ion in solids, these results indicate that S_e also decreases very rapidly as the projectile velocity decreases. This sudden decrease of the S_e at low energies is theoretically understood to be due to the non-negligible size of the excitation/ionization energy of the target elements, which is the lower limit of the integration of the energy transferred to the target, over the projectile kinetic energy.

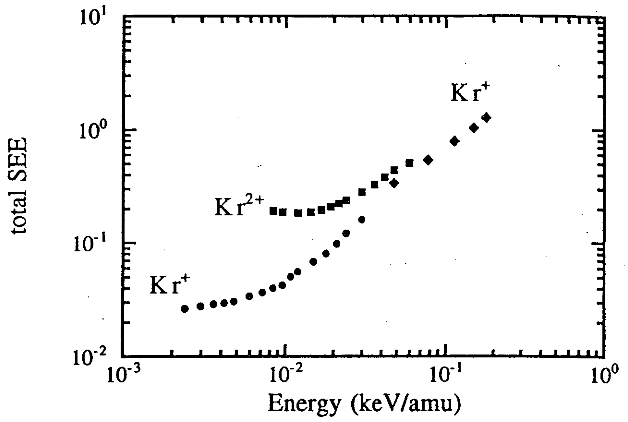

Fig. 1. Impact energy dependence of total SEE yields for Kr^+ (circles) and Kr^{2+} (squares) ion impact on clean Cu surface. Also shown are total SEE yields under Kr^+ ion impact on clean Cu surface investigated by Baragiola et al. (diamonds)[2] at high energies.

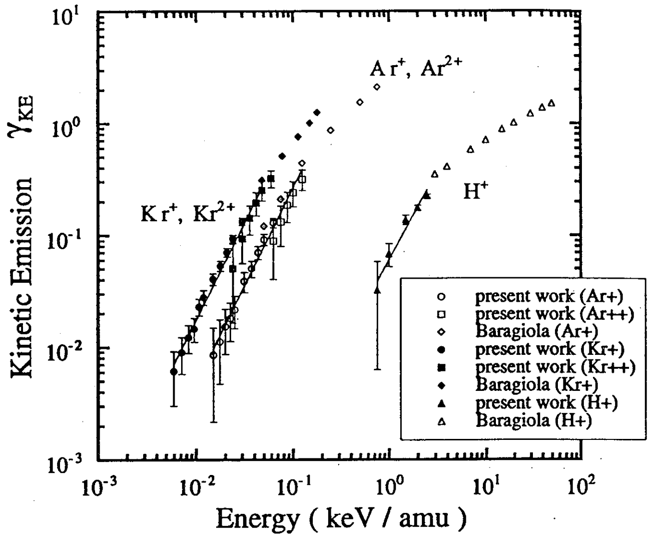

Fig. 2. γ_{KE} under singly and doubly charged ion impact on clean Cu target. And the kinetic emissions at higher energies taken from the data of Baragiola et al. [2] are also shown. Note that practically no difference is observed in the kinetic electron emission between singly and doubly charged ion impact.

References

1) Hosaka, K. et al. : Nucl. Instr. Meth. B **149** (1999) 414.
2) Baragiola, R.A. et al. : Sur. Sci. **90** (1979) 240.

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