# Cluster effect on the yield of Auger electrons emitted through Coster–Kronig transitions

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**Synopsis** We measured Auger electron yields emitted through Coster–Kronig transitions $1s^22p(^2P)nl$ – $1s^22s(^2S)\varepsilon l$' and $1s2p(^3P)nl$ –$1s2s(^3S)\varepsilon l$' from penetrating C-ions under bombardment of 3.5 MeV/atom $C^+$ and $C_2^+$ ions on C-foils. Auger electron yields for $C_2^+$-ion bombardment were suppressed compared with those for $C^+$ ion bombardment and relative Auger-electron yields $Y(C_2^+)/2Y(C^+)$ became larger as the principal quantum number $n$ of the initial states increased. The results show that scattered electrons with small relative velocity to projectile ions are strongly affected in molecular ion bombardment.

When fast molecular ions penetrate material, all constituent atoms impinge within a very small area of several angstrom radius. This simultaneous irradiation of multiple atoms affects many physical quantities, such as electronic stopping power, mean charge, sputtering yield and secondary electron yield. These effects are called cluster effects. Convoy electrons are electrons with the same velocity as ions transmitted foil (or gas) targets, emitted specifically to the beam direction. Recently, it was observed that convoy electron yields increase with the square of the number of constituent atoms of projectile ions for 0.5 MeV/atom $C_n^+$ ($n$ = 1 to 4) ion bombardments on C foils [1]. This rule was observed even with a thick 20.3-μg/cm$^2$ foil, in contrast with the cluster effect on stopping power, which disappears with much thinner foils. We have presumed this cluster effect on convoy electron yields results from interactions between projectile ions and scattered electrons inside solid. That motivated us to investigate highly excited states of transmitted ions which exist just below the continuum states. In this work, we measured Auger electron yields emitted from Rydberg states of transmitted ions to the beam direction under bombardment of fast $C_2^+$ ions on C-foils [2].

The experiments were conducted at the 20-MV tandem accelerator in the Nuclear Science Research Institute of Japan Atomic Energy Agency (JAEA). Ions of $C^+$ and $C_2^+$ were accelerated to an energy of 3.5 MeV/atom and impinged on amorphous carbon foils. Electron energies emitted to the beam direction were analyzed by a tandem-type 45° parallel-plate electrostatic spectrometer.

For both $C^+$ and $C_2^+$ ion bombardment, Auger electron peaks correspond to Coster-Kronig transitions $1s^22p(^2P_{3/2,1/2})nl$ – $1s^22s(^2S_{1/2})\varepsilon l$' and $1s2p(^3P)nl$ – $1s2s(^3S_1)\varepsilon l$' were clearly observed. It was also observed that Auger electron yields emitted from Rydberg states $1s^22p(^2P_{3/2,1/2})nl$ ($n$ = 5, 6, 7) for $C_2^+$-ion bombardment were suppressed compared with those for $C^+$-ion bombardment, and relative Auger-electron yields $Y(C_2^+)/2Y(C^+)$ became larger as the principal quantum number $n$ of the initial states increased. A similar trend was observed also in Auger electron yields from $1s2p(^3P)nl$ ($n$=7, 8). Convoy electrons and Rydberg states of transmitted ions are generated from scattered electrons with small relative velocity to ions when ions are exiting foil targets. The results show that these low-energy scattered electrons are significantly affected in molecular ion bombardments.

## References

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