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LETTER TO THE EDITOR

Multiple collisions of Ar and Cu atoms on a Cu surface

Synopsis

Observations have been made of the second scattering of projectile and target atoms after a collision of keV Ar^+ ions on the surface of a Cu single crystal. A simple potential model explains the results.

Recently the occurrence of double scattering peaks in the energy spectrum of ions scattered from metals was shown experimentally [1]) and also investigated theoretically [2]). In these experiments the ions were scattered into an energy analyzer by two consecutive collisions on the metal surface. The energy of ions scattered twice is larger than the energy obtained in a single collision for the same total scattering angle ϑ, so the double scattering phenomenon reveals itself by structure in or splitting of the Ar peak in the energy spectrum. The intensity of the doubly scattered particles is predicted to be inversely proportional to the primary energy. This type of double scattering was also observed in our experiments for the case of 30–90 keV Ar^+ ions on a (110) surface of Cu (fig. 1).

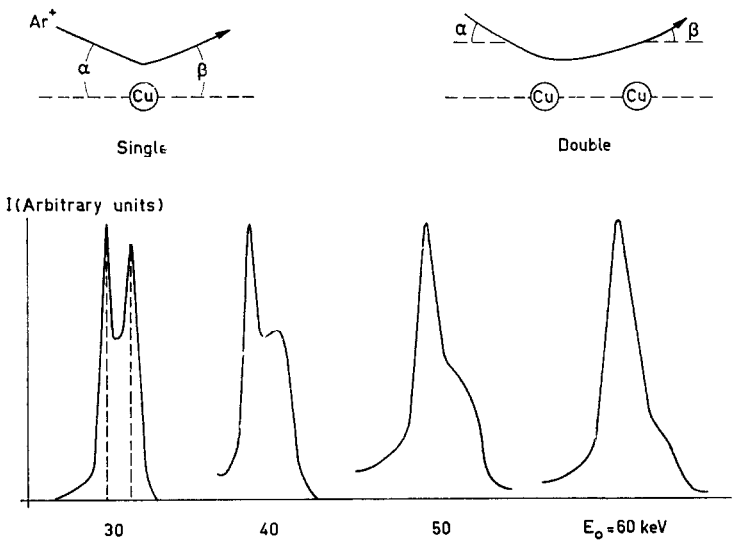

Fig. 1. Energy spectra of singly and doubly scattered Ar ions. The Ar^{2+} peak in the energy spectrum is shown for different primary energies.
Experimental conditions: $\alpha = \beta = 12.5°$.
The distance between the dotted lines corresponds to an energy difference of 1 keV.

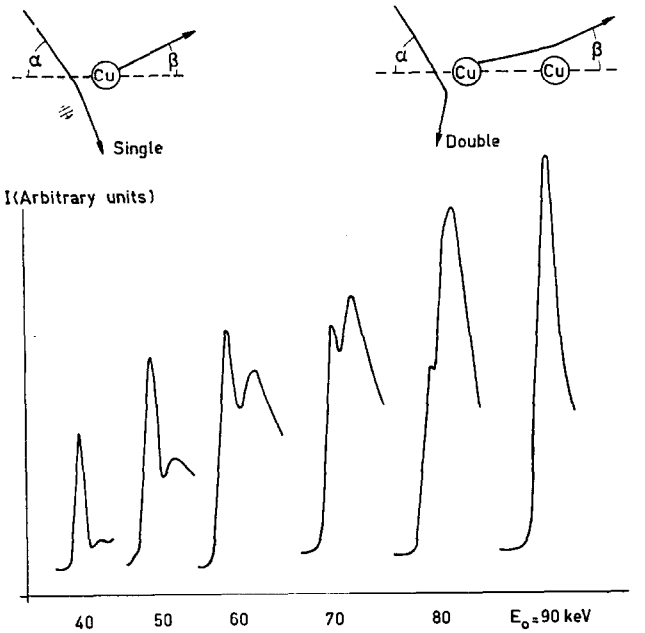

Fig. 2. Energy spectra of singly and doubly scattered Cu ions. The Cu^+ peak in the energy spectrum is shown for different primary energies.
Experimental conditions: $\alpha = 45°$, $\beta = 17.5°$.

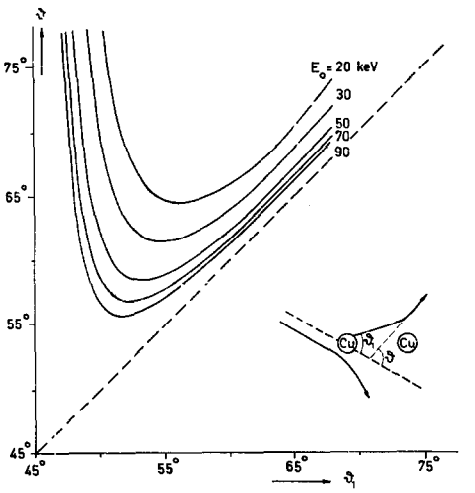

Fig. 3. Relation between total scattering angle ϑ and first scattering angle ϑ_1, for different primary energies.
The potential is $V(r) \sim 1/r^2$.

Another type of double scattering is indicated in fig. 2. A recoil Cu atom experiences another collision with a neighbouring atom. This is observed by the doubling of Cu peaks in the energy over charge spectrum of scattering products. Experimental conditions were 30–90 keV Ar^+ ions on a (100) surface of Cu.

An interesting aspect is the appearance of the doubly scattered Cu ions only for scattering angles larger than a minimum angle, depending on primary energy. This is a result of the shadowing effect of the second scattering center.

For a given potential one can calculate[3) 4)] the relation between the total scattering angle ϑ and the scattering angle in the first collision ϑ_1 (fig. 3). The minimum in this curve gives the "shadowing angle" ϑ_{min}. From figure 3 one can also conclude that there is a minimum primary energy necessary to find particles doubly scattered into a total scattering angle ϑ. For instance, with a primary energy of 30 keV, double scattering into $\vartheta < 62°$ cannot be observed. The calculated results for ϑ_{min} and E_{min} for two potential models and the experimental values are given in table I.

TABLE I

	pot. $1/r^2$	pot. $1/r^3$	observed
ϑ_{min} ($E_0 = 60$ keV)	58°	63°	60°
E_{min} ($\vartheta = 62.5°$)	25 keV	60 keV	30 keV

One may conclude that a potential $V \sim 1/r^s$, with $2 < s < 2.5$ describes the interaction between two Cu ions for weak collisions rather well.

The distance between the singly and doubly scattered Cu^+ peaks in the energy spectrum is predicted to decrease with increasing primary energy. This was also found experimentally. In the limit of high primary energy the single and double peaks become indistinguishable.

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REFERENCES

1) Mashkova, E. S., Molchanov, V. A., Parilis, E. S. and Turaev, N. Yu., Phys. Letters **18** (1965) 7.
2) Parilis, E. S., Proceedings of the VIIth International Conference on Phenomena in Ionized Gases, Belgrade, 1965, p. 129.
3) Dahl, P. and Sandager, N., *private communication.*
4) Details of our calculations will be published in Physica.