Structure of energy spectrum of Na^+ ions scattered by a polycrystalline silver surface

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Results are reported of measurements of energy distributions of low-energy Na^+ ions ($E_0 \lesssim 1$ keV) reflected from a polycrystalline Ag surface. The distribution contains, besides a single-scattering peak, also a peak that can be attributed to double scattering. This peak has heretofore not been observed in experiments on scattering by polycrystalline targets.

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An investigation of the reflection of low-energy ions ($E_0 \lesssim 1$ keV) from a surface is presently a subject of great interest both from the fundamental point of view and from the viewpoint of the use of this phenomenon for analytic purposes, namely the analysis of the composition and structure of the surface of a solid.

Principal attention has been paid in the investigations up to now to the scat-

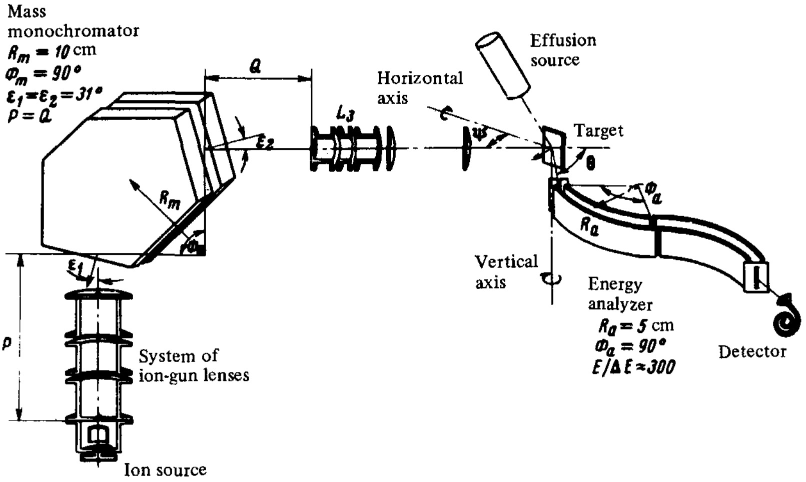

FIG. 1. Experimental setup for the investigation of the scattering of low-energy ions by the surface of a solid.

tering of inert-gas ions by various polycrystalline and single-crystal targets.[1] Data on the scattering of alkali-metal ions are much scantier, primarily because of the experimental difficulties in maintaining the surface "atomically" pure during the course of the measurements. Measurements of the energy distribution functions of the scattered ions confirm in the main the applicability of the binary model down to rather low energies of the incident ion ($E_0 \sim 5$ eV). The form of the energy distribution, as shown by experiments, is very sensi-

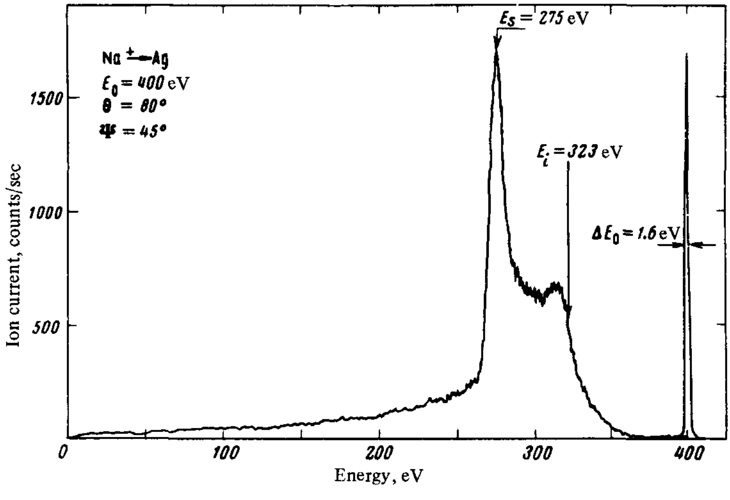

FIG. 2. Energy spectrum of Na^+ ions reflected from the surface of a polycrystalline Ag target. The figure shows the energy width of the primary beam of energy $E_0 = 400$ eV.

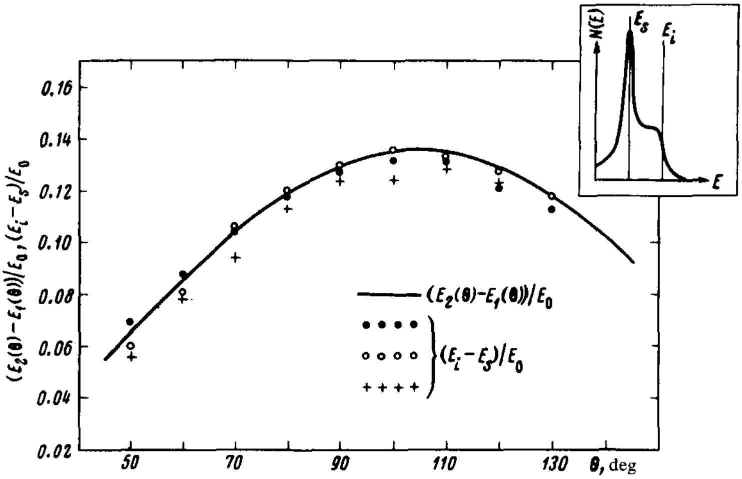

FIG. 3. Comparison of the differences between the relative energies (2) and the experimental values of $(E_i - E_s)/E_0$ for $E_0 = 400$ eV (dark circles), $E = 1200$ eV (light circles), and $E = 3200$ eV (crosses).

tive to the composition and to the structure of the investigated surface. For pure polycrystalline surfaces one obtains a clearly pronounced peak corresponding to the single elastic scattering. In the case of a single-crystal target, there exists also a second peak which is the consequence of double scattering of the incident ion by atoms of the single-crystal surface. The results of our measurements show that the second peak observed so far in the energy distribution of the scattered particles only for single-crystal surfaces can exist also for a polycrystalline target.

In our experiment (the experimental setup is shown in Fig. 1) we measured the energy distribution functions of Na^+ ions scattered by a polycrystalline Ag surface in the energy interval $0.2 < E_0 < 3.2$ keV and for scattering angles $45° < \theta < 135°$. To ensure conditions of "atomically" pure surface during the course of the measurements, the purity of the surface film was maintained constant by deposition of silver atoms with the aid of an effusion source, the flux of which was approximately 10^{14} atoms/cm^{2}sec. At the same time, the pressure in the system was of the order of 2×10^{-9} mm Hg.

A typical energy spectrum of the Na^+ ions for $E_0 = 400$ eV is shown in Fig. 2. In the analysis of the obtained spectra we investigated the position of the single-scattering peak, the position of the second peak, and the position of the inflection point on the high-energy distribution hump. The position of the single-scattering peak is in good agreement with calculation on the basis of the equation (for $n = 1$)

$$\frac{E_n(\theta)}{E_0} = \frac{1}{(1+A)^{2n}} \left[\cos\frac{\theta}{n} + \sqrt{A^2 - \sin^2\frac{\theta}{n}} \right]^{2n}, \qquad A = \frac{M_2}{M_1} \tag{1}$$

where M_1 and M_2 are the masses of the incident ion and ion and atom of the target, while θ is the scattering angle in the lab system. We were unable to relate the position of the second peak in simple fashion with the double-scattering model However, analysis shows that the position of the inflection point on the high-energy hump of the distribution ($E = E_i$) corresponds to the maximum energy ($n = 2$) that the scattered particle can possess in double scattering through an angle θ.

The results of this analysis are shown in Fig. 3, where a comparison is made between the quantities

$$\frac{\Delta E(\theta)}{E_o} = \frac{E_2(\theta)}{E_o} - \frac{E_1(\theta)}{E_o} \tag{2}$$

and the experimentally determined difference of the relative energies E_i of the inflection point and E_s of the single-scattering peak.

The reason why the contribution of the double scattering is clearly prominent in the distribution function in the case of Na^+ reflection but not in the case of inert-gas ions[2], is that the probability of neutralization of the ions near the surface of the metal is much larger in the case of inert gases, than for alkali-metal ions.

[1] E. P. Th. M. Suurmeijer and A. L. Boers, Surf. Sci. **43**, 309 (1973).

[2] W. Heiland and E. Taglauer, Nucl. Instrum. Methods **132**, 535 (1976).