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E. S. MASHKOVA, V. A. MOLCHANOV, D. D. ODINTSOV

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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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E. S. MASHKOVA, V. A. MOLCHANOV, D. D. ODINTSOV

ANISOTROPY OF THE ION-ELECTRON EMISSION COEFFICIENT OF SINGLE CRYSTALS

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Among the particles produced when metallic surfaces are irradiated by ion beams, electrons constitute a considerable fraction ([1,2]). The coefficient of ion-electron emission of single crystals exhibits a pronounced anisotropy ([3]). In the present work we give the results of measuring the dependence of the ion-electron emission coefficient of the (100) face of a copper single crystal on the angle of incidence of the ions on the target. The same single crystals were used as in ([3]). The targets were irradiated with singly charged argon ions of energy 20 and 30 keV.

The scheme of the measuring device is shown in Fig. 1. Secondary electrons knocked out of the target were collected by a collector held at a positive potential relative to the target. Near the collector a grid was installed, serving to suppress "tertiary" electrons arising at the collector. In the course of the experiment the ion current I_0 and the current I_1, which is the sum of the ion current and the current of secondary charged particles, were measured. The ion-electron emission coefficient was determined as the ratio of the secondary current to the ion current. Since mass analysis of the secondary particles was not carried out, the obtained values of the coefficients contain a certain error. However, according to ([2]), it apparently does not exceed 10%.

Fig. 1

The measurement results are shown in Fig. 2. The corresponding dependences for polycrystalline copper M-0000 are also given there, as well as a curve constructed from the data of ([4]). It is seen that the ion-electron emission coefficient, like the coefficient of cathode sputtering of single crystals (Fig. 2 of ([3])), depends nonmonotonically on the angle of incidence of the ions on the target. When the direction of the primary-ion beam coincides with the principal crystallographic axes of the target, a sharp decrease in the number of emitted electrons is ob-

Fig. 2

Figure 2: Fig. 2

served. Qualitatively analogous dependences are also observed for nickel and zinc single crystals.

Such a character of the dependence can be explained if one uses the method applied in (5) to explain the anisotropy of the cathode sputtering coefficient of single crystals. It is known (see, for example, (6)) that, with an increase in the angle of incidence of ions on a polycrystalline target, the ion-electron emission coefficient increases inversely proportional to the cosine of this angle. We shall assume (see (4)) that the number of emitted electrons is proportional to the energy lost by the ion in collision with a target atom near its surface. The proportionality coefficient

must depend on the depth at which the collision occurred, since the deeper the electron is produced, the greater the probability of its absorption inside the target (7), and also on the angle of incidence of the ions on the crystallographic plane. Thus, the emission coefficient is

$$\gamma = \sum_i \beta_i^{(\varphi)} \sigma_i \overline{E}_i;$$

$\overline{E}_i$ is the average energy transferred by the ion to the atoms of the i-th plane; σ_i is the effective cross section for collision of the ion with an atom lying in this crystallographic plane; $\beta_i^{(\varphi)}$ is the proportionality coefficient.

Since the ion velocities in the present experiment did not exceed $4 \cdot 10^7$ cm/sec, according to Bohr (8) the loss of ion energy, in the first approximation, may be calculated from the formulas for collision of elastic spheres. By a method analogous to (5) (transition from formula (1) to (3)), we obtain the calculated relation

$$\gamma = \frac{1}{A_0 \cos^2 \varphi} \left[\beta_{1,2} \pi R^2 \frac{E_{\max}}{2} + \beta_{3,4} S_3 \overline{E}_3 + \beta_{5,6} S_5 \overline{E}_5 + ... \right].$$

Fig. 2. 1 –calculated curve for Ar^+, 30 keV; 2 –calculated curve for Ar^+, 20 keV; 3 –polycrystalline copper M-0000 Ar^+, 20 keV. *a* –experimental points for a single crystal; *b* –experimental points for polycrystalline copper M-0000. Dashed line –data from work (4)

Here A_0 is the area of the face of the crystal unit cell corresponding to one surface atom (see Fig. 3), S_i is the open area of the collision sphere, $E_{\max}$ is the maximum energy transferred by the ion to a target atom in a head-on collision, and R is the radius of the collision sphere. The radii of the collision spheres were determined from the experimental values of the emission coefficients at 48°,

Fig. 3

Figure 3: Fig. 3

and the coefficients $\beta_{i,i+1}$ from the experimental values at the points $0, \sim 13, \sim 19^\circ$. They proved to be different: $\beta_{1,2} = \beta_{3,4} = \frac{5}{3}\beta_{5,6} \sim 0.23$ keV^{-1}. All the remaining $\beta_{i,i+1}$, $i > 7$, were taken equal to zero. The calculated curves are shown in Fig. 2. It is seen that their agreement with the experimental results is satisfactory.

Fig. 3. Unit cell of a copper single crystal (atoms on the side faces are not indicated). The arrow indicates the direction of rotation of the crystal in the experiment.

This permits the conclusion that, for ion-electron emission, collisions of ions with atoms of only several first atomic planes are apparently significant, and the shape of the curve of the dependence of γ on φ agrees with the variation of the collision probability.

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Moscow State University
named after M. V. Lomonosov

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Note: Figure translations are in progress. See original paper for figures.