ANISOTROPY OF THE REFLECTION OF ARGON IONS FROM A COPPER SINGLE CRYSTAL

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The results are given of a study of the reflection of Ar ions of ≈1.5 keV energy from a (100) surface of a copper single crystal. It was established that the regularity of the crystal lattice affected the intensity of ion reflection. The minimum reflection was observed in the directions of close atomic packing [110] and [100]; between these two directions, the ion reflection had a maximum.

WHEN a single-crystal target is bombarded with gaseous ions, some of these ions penetrate into the target and cause a chain of collisions between the atoms of the crystal lattice.[1,2] Other ions are reflected after two or three collisions with the surface atoms of the target.

The number of ions reflected from the surface of a single crystal depends on the orientation of the crystallographic axes with respect to the direction of incidence of the ion beam.[3] The total number of ions reflected from a face of a single crystal is minimal when the ion beam is incident along a direction of close atomic packing (for example, along the directions [110] and [100] for a face-centered cubic (fcc) lattice[3]). This dependence is opposite to that observed for sputtered particles.[4]

We may assume that for a fixed direction of incidence of the ion beam (for example, normal to a single-crystal surface) the density of ions reflected along certain crystallographic directions should have maxima similar in some ways to the "Wehner spots" for sputtered particles.[5]

A graphoanalytic calculation [6] for the case of the bombardment of a (100) plane of a Cu single crystal with Cu and Ar ions (for normal incidence of the ions) showed that the spatial distribution of the reflected ions should have a strong anisotropy. According to this calculation, the projections of the reflected-ion yield maxima on the (100) plane should lie symmetrically on both sides of each of the close-packing directions [110] and [100], lying in that plane, and the angular separation between them should be ≈45°; the reflection minima should correspond to the directions [110] and [100].

To check this hypothesis, we studied the angular distribution of reflected ions during the bombardment of a (100) surface of a Cu single crystal with Ar ions of ≈1.5 keV energy. The experimental arrangement is shown in Fig. 1. The principal components of the apparatus were: an ion source, a movable reflected-ion collector, and a sample holder. The glow-discharge ion source (its construction and parameters are given in von Ardenne's work [7]) produced an ion current of ≈1 mA/cm^2 density in a beam which was ≈2 mm in diameter at the sample. To measure very low reflected-ion currents, we used an electrometer amplifier (type ÉMU-4) connected in a circuit which compensated the constant ion-current component.

In carrying out these tests, the following requirements were kept in mind:

1) clean surface of the sample;

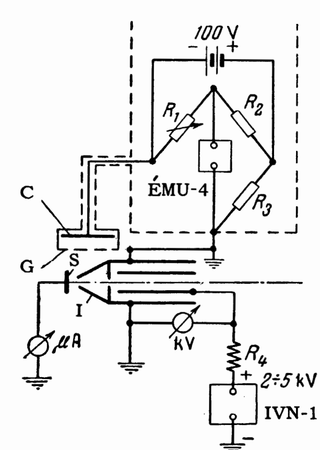

FIG. 1. Schematic diagram showing experimental apparatus: I is the ion source, C is the collector, G is the grid, and S is the sample.

2) establishment of an equipotential space between the sample and the collector;

3) rigorous coincidence of the axis of rotation of the collector with the ion beam axis;

4) need to distinguish a weak reflected-ion current against a background of interference: scattered ions and electrons from the primary beam, and currents representing secondary electron and ion emission;

5) compensation of the constant component of the current of the reflected ions.

The surface was cleaned by ion bombardment using a current of ≈ 1 mA/cm^2 in 1×10^{-5} mm Hg vacuum. Under these conditions, the rate of sputtering was higher than the rate of contamination of the sample. The same ion current density was used throughout the tests, which ensured satisfactory cleanness of the test surface. A deposit of the sputtered substance was collected on a mica screen and the resultant spot pattern was compared then with the angular distribution of the reflected ions. The remaining conditions listed above were satisfied by suitable construction of the apparatus and selection of the circuit elements.

From these measurements, we obtained a dependence of the reflected-ion current on the angle of rotation of the collector about the ion beam axis (Fig. 2), i.e., on the horizontal angle φ. The curve showed several reflected-ion current maxima separated by $\approx 45°$. A small reflection peak was also usually observed near the [100] direction.

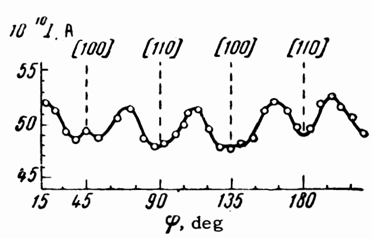

FIG. 2. Angular distribution, in a horizontal plane, of Ar ions reflected from a (100) surface of a copper single crystal; dashed lines show the directions of close packing in the (100) plane.

Comparison of this curve with the pattern of spots in the deposit formed on sputtering of the same sample surface showed that the directions of maximum yield of sputtered particles, corresponding to the crystallographic directions [110], coincided with the reflected-ion minima.

The absolute values of the changes of the reflected-ion current were of the order of 10^{-10} A on a background having a constant component of $(2-5) \times 10^{-9}$ A. The current was very low because the reflected ions were collected from a small solid angle (1.5°–2°) in order to increase the resolving power.

The results obtained are in good agreement with the conclusions of the earlier graphoanalytic calculations [6], and they can be understood by assuming that ions penetrate open channels along the close-packing directions in the fcc lattice. Along these directions, one would expect minimum reflection and, conversely, along the directions of minimum penetration we should have maximum reflection.

Thus, the regularity of the crystal lattice structure exerts a considerable influence even on such a basically surface effect as the ion reflection.

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69