PHYSICS

Academician of the Academy of Sciences of the Uzbek SSR U. A. ARIFOV, R. R. RAKHIMOV, and Kh. DZHURAKULOV

1962

SovietRxiv

Abstract

Full Text

PHYSICS

Academician of the Academy of Sciences of the Uzbek SSR U. A. ARIFOV, R. R. RAKHIMOV, and Kh. DZHURAKULOV

SECONDARY EMISSION DURING BOMBARDMENT OF MOLYBDENUM BY NEUTRAL ARGON ATOMS AND IONS

In works ([1], [2]) it was shown that, when metals are bombarded by ions of inert gases with energies up to 1 keV, mainly potential ejection of electrons occurs. When the ion energy E_0 was increased to 10 keV, ([2]) an almost linear increase in the secondary electron-emission coefficient γ was observed. On the basis of the equality of the slopes of the dependence curves $\gamma(E_0)$ with respect to the E_0 axis for pairs of ions with close masses Ne—Na, Ar—K, and Kr—Rb, the increase in emission for inert-gas ions was explained by kinetic ejection of electrons. To determine the degree of additivity of potential and kinetic electron emission, a comparative study of ion-electron emission under the action of neutral atoms and ions of the same gas is more appropriate. Below are presented the results of a study of electron emission from molybdenum under the action of neutral argon atoms and ions in the energy range 0.2–2.0 keV.

The experiments were carried out in a glass vacuum apparatus consisting of an ion source, a region for forming a narrow ion beam, a charge-exchange chamber, and a measuring section. The four sections of the apparatus were separated by metal diaphragms sealed into the glass in the form of narrow channels and were evacuated by separate glass mercury pumps. This ensured such a pressure difference between the sections that the admission of gas into the charge-exchange chamber did not lead to a noticeable change in the operating regime of the ion source and, consequently, in the intensity of the primary ion beam at the entrance to the charge-exchange chamber. The latter condition, as will be seen below, was necessary for determining the intensity of neutral atoms on the target.

A narrow ion beam with a specified energy was formed by means of a cylindrical condenser and two single electrostatic lenses and was directed along the axis of a nickel cylinder 100 mm long, which served as the charge-exchange chamber. The measuring part of the apparatus consisted of a guard cylinder, a spherical collector ($d = 50$ mm), and a target made of molybdenum foil ($0.015 \times 5 \times 30$ mm), mounted on thick molybdenum leads. The target was heated to the required temperature by passing current directly through it.

Measurements were carried out both by the oscillographic method of double

Fig. 1

Figure 1: Fig. 1

modulation (^{3}) and by the galvanometric method—with the aid of an EMU-3 tube electrometer.

The beam of neutral atoms was obtained by the method of resonant charge exchange of ions in their own gas, with subsequent deflection of the ions that had not undergone charge exchange by means of a plane condenser. The intensity of neutral atoms in the beam was determined as the difference between the intensity of the ion beam on the target before and after admitting gas into the charge-exchange chamber. The validity of this method is based on the fact that, up to certain pressures, gas type, and chamber geometry, the main process accompanying the passage of an ion beam through a gas is charge exchange (^{4}). The vacuum with respect to residual gases in all sections of the apparatus, after the corresponding degassing procedures for the entire apparatus as a whole, was not worse than $1 \cdot 10^{-7}$ mm Hg.

During the measurements of secondary emission, considerable attention was paid to the cleanliness of the bombarded surface. For this purpose the target was subjected to prolonged heat treatment at temperatures of 2100–2200° K, and all measurements were carried out at a target temperature of 1100° K, following brief heating at 2200° K.

Fig. 1

Figure 1 presents series of oscillograms of the volt-ampere characteristics of secondary emission under bombardment of molybdenum by neutral atoms (1, 2, 3) and argon ions ($1'$, $2'$, and $3'$) at energies of 500 eV (a), 1100 eV (b), and 1800 eV (c). The oscillograms shown were recorded at equal intensities of the beams of atoms and Ar ions bombarding the target. The current pulses of the primary ions in Fig. 1 are denoted by the letter I^+. Comparison of oscillograms 1 and $1'$ shows that, at an energy of 500 eV, the value of γ for Ar^0 is very small, whereas γ for Ar^+ is close to 10–12%. Consequently, in the low-energy region, in the case of bombardment of molybdenum by Ar ions, potential emission of electrons takes place, while under bombardment of the target by neutral Ar atoms, potential emission of electrons is absent. As the energy of the Ar atoms bombarding the target is increased, beginning at approximately 1100 eV (oscillogram 2), electron emission becomes noticeable and increases with a further increase in energy. In the case of bombardment of the target by Ar ions, a noticeable increase in electron emission is also observed (oscillograms from $1'$ to $3'$) with increasing energy of the bombarding ions. Examination of the left-hand part of the presented volt-ampere characteristics indicates the absence of secondary or reflected ions both in the case of bombardment of molybdenum by ions and in the case of bombardment by neutral Ar atoms. The data shown in the oscillograms for secondary electron emission under bombardment of the target

Fig. 2

Figure 2: Fig. 2

by atoms and ions were refined by using beams of ions and atoms of considerably higher intensity than in the oscillogram of Fig. 1, and by measurements with an electrometer having considerably higher sensitivity.

Fig. 2

Figure 2 presents curves of the dependence of the coefficient γ on the energy of Ar ions and atoms, measured in the energy region 0.2–2.0 keV by the galvanometric method. Comparison of the curves shows that, in the energy region below 800 eV, the value of γ for neutral atoms is small, while for ions it is equal to 8–9%.

It should be noted that the value of γ for Ar ions up to energies of 800 eV differs by 3-4% from the data obtained earlier (^{1,2}). Apparently, this is due to the fact that,

that, when the galvanometric method was used for the measurements, the target had time to become noticeably contaminated by adsorption of residual-gas atoms during the interval from the flash to the moment of measurement.

When the energy is increased to 2000 eV, in both cases there is an almost linear increase of γ. It is not difficult to see that the slope of the curves $\gamma(E_0)$ to the E_0 axis for Ar^0 and Ar^+ is almost the same. Hence one may conclude that the increasing part of the curve $\gamma(E_0)$ for Ar^+ ions is due to secondary electrons knocked out at the expense of the kinetic energy of the incident particle.

Institute of Nuclear Physics
Academy of Sciences of the Uzbek SSR

Received
17 VI 1961

References

1. H. D. Hagstrum, *Phys. Rev.*, **104**, 672 (1956).

2. U. A. Arifov, R. R. Rakhimov, *Izv. AN SSSR, ser. fiz.*, **24**, 657 (1960).

3. U. A. Arifov, A. Kh. Ayukhanov, S. V. Starodubtsev, *ZhETF*, **26**, 714 (1954).

4. L. A. Sena, *ZhETF*, **16**, 734 (1946).

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

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.