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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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REFLECTION OF MONOENERGETIC ELECTRONS WITH ENERGIES IN THE RANGE 600–1200 keV FROM CERTAIN METALS AND GRAPHITE

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The study of the dependence of the electron reflection coefficient on the nature of the reflector and on the energy of the primary beam is of interest not only for understanding the mechanism of electron scattering by matter, but also for a whole range of problems of important practical significance.

In particular, the dosimetry of electron beams and the determination of the composition of matter by electron backscattering may serve as typical examples of problems of practical importance. Reflected electrons play an essential role in radiation-chemical processes, in particular under radiation action on catalytic processes and especially in radiation-thermal cracking of hydrocarbons and radiation polymer grafting from the gas phase.

However, comparatively few studies have been carried out on electron backscattering. Suffice it to say that at present there are data on reflection coefficients for 15 metals, and most of them refer to the energy region not above 100 keV ($^{1-7}$). The energy region 600–1200 keV has not been investigated. There are no works on a systematic study, over a wide interval of primary-electron energies, of the dependence of reflection coefficients on energy.

Fig. 1

In the present work, results are given for measurements of electron reflection coefficients with energies in the range 600–1200 keV from a number of metals and graphite.

The study of the reflection of monoenergetic electrons ($\Delta E/E < 1\%$) was carried out in the chamber shown in Fig. 1.

Fig. 2. Dependence of the reflection coefficient of monoenergetic electrons: a—of energy 600 keV on the collector potential for aluminum; b—of energy 1000 keV on the collector potential for lead

Figure 2: Fig. 2. Dependence of the reflection coefficient of monoenergetic electrons: a—of energy 600 keV on the collector potential for aluminum; b—of energy 1000 keV on the collector potential for lead

The scattering chamber has a cylindrical form. The upper and lower covers are removable. Through the lower cover, by means of a fluoroplastic seal, the sample holder is introduced into the chamber. The sample diameter is 55 mm; its thickness exceeds the thickness for complete absorption of electrons of the given energy. The chamber body is grounded.

A collector intended for collecting the electrons reflected from the sample is suspended from the upper cover on two long studs through organic-glass insulators. The aluminum collector has a cylindrical shape and is installed coaxially with the chamber body by means of a centering fluoroplastic ring. The wall thickness of the collector (5 mm) is sufficient for complete absorption of electrons of the given energy.

Between the upper cover and the collector a collimator is installed,

assembled from three aluminum diaphragms with an aperture diameter of 6.5 mm and a thickness of 2.5 mm. The height of the collimator was 60 mm. Along the axis of the upper cover an aperture 6.5 mm in diameter was also made, covered with thin (~0.005 g/cm^2) mica.

A vacuum of 10^{-4}–$5 \cdot 10^{-5}$ mm Hg was maintained in the chamber, which made it possible to eliminate the ionic current.

The electron currents from the specimen and the collector were measured with galvanometers. To separate low-energy reflected electrons, a potential in the range from −600 to +600 V could be applied to the collector.

Fig. 2. Dependence of the reflection coefficient of monoenergetic electrons: *a* —with energy 600 keV on the collector potential for aluminum; *b*—with energy 1000 keV on the collector potential for lead.

The primary current in the chamber (I_{per}), equal to the sum of the currents of the specimen (I_{obr}) and the collector (I_{kol}), was chosen to be of the order of one microampere. The reflection coefficient was determined as the ratio of the collector current to the primary current:

$$\eta = \frac{I_{\text{kol}}}{I_{\text{obr}} + I_{\text{kol}}}.$$

Carbon, aluminum, zinc, tin, and lead were used as the objects of investigation. All specimens were made from pure materials (purity not worse than 99.8%).

Fig. 3 and Fig. 4

Figure 3: Fig. 3 and Fig. 4

The surfaces of the specimens were flat and ground. No polishing of the surface was carried out. In order to study the energy distribution of the electrons of secondary electron emission, for each of the elements investigated the dependence of the reflection coefficient on the collector potential was studied.

Figure 2 presents the results obtained for Al (Fig. 2, *a*) and Pb (Fig. 2, *b*). The course of the curves for the dependence of the reflection coefficient on the collector potential is qualitatively the same for all elements and energies of the primary electrons.

As follows from the graphs, there is a large fraction of reflected electrons whose energy does not exceed 100 eV. At potentials of +300 V and −300 V, the reflection coefficient depends very little on the collector potential. Therefore, as characteristics, the reflection coefficients at collector potentials of −300 V and +300 V were chosen. The first coefficient characterizes the reflection of primary electrons; the latter, the total reflection coefficient taking into account electrons of secondary electron emission.

Data on the dependence of the indicated reflection coefficients on energy in the interval 600-1200 keV, in steps of 100 keV, are presented in the graph (Fig. 3). It is evident from the graphs that the reflection coefficient decreases with increasing energy of the primary beam for all the elements studied. A check of the reproducibility of the results showed that the maximum spread of the reflection coefficients for different experiments did not exceed 0.5%.

In each of the experiments, for all objects of study and for different energies, from 5 to 10 measurements of the reflection coefficient were made. The mean of all measurements was taken as the true value of the reflection coefficient. The maximum deviation from the mean value did not exceed $±$0.2% abs.

Fig. 3. Dependence of the reflection coefficient on electron energy in the interval 600-1200 keV for different reflectors. Collector potential: dark points +600 V, light points −600 V.

Fig. 4. Dependence of the reflection coefficient on electron energy for aluminum according to data from different authors: from 50 to 350 keV (7); from 600 to 1200 keV, our data; 1750 keV (8).

It was of definite interest to compare the data obtained by us with the results presented in work (7) for the energy range 50-350 keV. The method for measuring the reflection coefficients in these works is analogous.

As shown in the work of Trump and Van de Graaff (7), the reflection coefficient of primary electrons (without allowance for secondary electron emission) for all the elements studied at first increases, and then, in the energy region 200-350 keV, remains constant. This result, as well as data obtained with β-radiation sources, made it possible to suggest that at still higher energies the reflection coefficient should not depend on energy. However, measurements of the reflection coefficient carried out by Frank (8) at an energy of 1.75 MeV showed that at energies above 1 MeV the electron reflection coefficient decreases.

The data obtained by us indicate that already at energies in the interval 600–1200 keV the reflection coefficient of primary electrons falls approximately linearly with increasing energy of the primary electron beam.

The total reflection coefficient (with allowance for secondary electron emission) decreases continuously as the energy of the electrons of the primary beam increases, which agrees with the data of (7) for the energy region 50–350 keV, where a significant dependence of the secondary-electron-emission coefficient on the nuclear charge of the reflector was noted. With increasing nuclear charge, the secondary-emission coefficient increases.

In the energy interval 630–1200 keV, the dependence of the secondary-electron-emission coefficient on the nature of the reflector is insignificant. The secondary-electron-emission coefficients for all the elements studied lie in the interval 3–6%. Figure 4 presents the reflection coefficients.

for aluminum over a broad energy range, according to the results of the present work and ([7]) and ([8]). The data obtained by us extrapolate well to the results of studies in the region of low energies ([7]) and in the region of high energies ([8]).

To study the causes leading to a decrease in the reflection coefficient with increasing energy of the primary electrons, a more detailed investigation is being carried out—recording the angular and energy distributions of the reflected electrons at different energies of the primary electrons.

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