Soviet work on the fission of heavy nuclei by high energy particles using emulsions[25] as well as radiochemical methods[26,27].

To check on the assumptions we have made it would be desirable to perform experiments with monoenergetic neutrons. It would be interesting to to measure the fission cross section for separated isotopes – particularly those with neutron deficit, in which case fission does not require multiple emission of neutrons. The fission cross sections of some similar isotopes (for example $At^{207-209}$) must be of the order of $10^{-25}cm^2$. The combination of data on emissive fission of various isotopes at high energies may be used to determine the neutron widths and fission widths of strongly excited heavy isotopes with neutron deficits, which are not at all formed in experiments at low energies.

Translated by G. L. Gerstein
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[25] N. A. Perfilov, N. S. Ivanovna. O. V. Lozhkin, V. I. Ostroumov and V. P. Shamov, paper at the July 1955 meeting of the Academy of Sciences, USSR.

[26] A. P. Vinogradov, I. P. Alimarin, V. I. Baranov, T. V. Baranova, A. K. Lavrukhina and F. I. Pavlotskaia, paper at the July 1955 meeting of the Academy of Sciences, USSR.

[27] B. V. Kurchatov, V. N. Mekhedov, M. Ia. Kuznetsova and L. N. Kurchatova, paper at the July 1955 meeting of the Academy of Sciences, USSR.

SOVIET PHYSICS JETP VOLUME 2, NUMBER 4 JULY, 1956

Investigation of the Structure of the Surface of Films of Copper Oxide on Different Faces of a Monocrystal of Copper, and the Determination of the Contact Potential Difference between These Surfaces

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The structure of the surfaces of films of copper oxide formed on various faces of a monocrystal of copper is investigated using the method of diffraction of slow electrons. It is found that on faces (100) and (111) of a monocrystal of copper there is formed a monocrystalline film of Cu_2O with a (111) plane parallel to the base. On face (110) a monocrystalline film of Cu_2O is also formed but with a less perfect crystalline structure and with a (110) surface plane. Investigation of the contact potential difference by the method of displacement of the volt-ampere characteristic curves demonstrated that films of Cu_2O on faces (100) and (111) of a monocrystal of copper have the same work function (0.2V), and consequently, have the same crystalline orientation. The film of Cu_2O on the (110) face of copper possesses a larger work function (0.3v), and also has stronger adsorptivity of residual gases than films of Cu_2O on faces (100) and (111), which indicates a difference in the properties (orientations) of the film of Cu_2O on face Cu (110) and of films of Cu_2O on faces Cu (100) and (111).

IN order to clarify the results obtained during the investigation of secondary electron emission from the surfaces of various faces of a monocrystal of copper which were covered with films of copper oxide[1], it was necessary to determine the crystalline structure of these films and also the work function of the surface of these films. With this aim in mind, we carried out investigations of the surface structure of monocrystalline specimens by the method of diffraction of slow electrons and the contact potential difference between the surfaces of the investigated specimens.

Numerous investigations have demonstrated that after pure copper, polycrystalline or monocrystalline, is exposed to the atmosphere for a certain

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[1] N. B. Gorny, J. Exper. Theoret. Phys. USSR **26**, 79, 327 (1954).

length of time, its surface undergoes oxidation. A film of copper oxide several tens of Å in thickness[2,3] forms at atmospheric pressure and at room temperature. According to references 4 and 5, the thickness of a film of copper oxide on the surfaces of monocrystals of copper having various crystallographic directions varies. However, the data in these two references do not coincide. Various conditions of film formation (temperature, pressure of the gaseous medium, etc.) can lead to varying results with regard both to thickness of film as well as the structure of the film itself. Apparently, the very mechanism of formation of the films differs at low and high temperatures[2]. The conditions under which Gwathmey and Benton[5] carried out their oxidation processes most closely resembled ours. They found that the thickness of a layer of copper oxide decreases on the planes of a monocrystal of copper according to the following order: (100), (111), (110). The results of the work in reference 6 also agree with these results. During the investigations recently carried out by Rhodin[7] it was demonstrated that the thickness of the oxide film which formed on the (100) face of a monocrystal of copper increases rapidly at first, and then remains almost unchanged (up to 40 hours). At room temperature, the thickness of the oxide film on the (100) face attains 15Å.

A number of researchers have been occupied with the study of the structure of copper oxide films formed on the various faces of a monocrystal of copper, with the aid of the method of diffraction of fast electrons or of X-rays. However, the results of these investigations show no conformity. Pinsker and Tatarinova[8] are of the belief that, aside from a certain quantity of copper oxide in the form of a polycrystalline powder, the basic mass of Cu_2O is precisely oriented with respect to the metallic copper. Pinsker[9] indicates that, according to the degree of increase in the concentration of the oxide phase of the monocrystalline film of copper, a precise mutual orientation takes place between the Cu_2O and the copper, during the course of which three basic types of orientation are observed: on the (100) faces of the copper the copper oxide distributes itself with faces (111), (110) and (100). In references 10, 11 the authors come to the conclusion that an oxide film of monocrystalline structure forms on the (110) and (111) faces of monocrystal of copper, while a homogeneous face of Cu_2O film distributes itself parallel to the face of the copper. The (100) face of the copper is covered by (111) planes of copper oxide.

THE INVESTIGATED SPECIMENS AND THE VACUUM TUBE DEVICE

After the orientation of the copper monocrystal was determined by optical means, and the basic crystallographic directions on the monocrystal were noted[12], three discs having a diameter of approximately 10 mm and a thickness of 0.6-0.8 mm were cut from the copper; the surfaces of these discs coincided with various crystalline faces, namely: (001), (011), and (111).

After fabrication of the discs and a preparatory mechanical and electrical polishing process, they were etched with a special mixture (see reference 12) in order to make sure that the superficial layer, which was deformed during the mechanical processing, was completely removed by the electrolytic polishing process, and in order to check the crystalline orientation of the planes of the discs, according to the method described in reference 12. Then the discs were polished mechanically with a thin paste of GOI and, finally, they were polished electrolytically to a mirrorlike finish. In addition to this, a disc having exactly the same dimensions was prepared from a fragment of polycrystalline copper and polished in the same manner.

Immediately following their fabrication, the specimens were mounted in place in the tube. The tube was subjected to a lengthy process of evacuation, while the space representing the electron trap of the tube (normally filled with liquid air) was heated to room temperature for a period of time sufficient to rid it of water vapor. Subsequent de-gassing of the tube was carried out over a period of 4 days at a tube temperature of up to 450°C; the

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[2] N. Cabrera and N. F. Mott, Reports of Prog. in Phys. **12**, 174 (1949).

[3] U. R. Evans, *Metallic Corrosion Passivity and Protection*, E. Arnold, 1949.

[4] J. Bernard and J. Talbot, Comptes rend. **225**, 411 (1947).

[5] A. T. Gwathmey and A. F. Benton, J. Phys. Chem. **46**, 969 (1942).

[6] P. A. Thissen and H. Schütze, A. anorg. allgem. Chemie **233**, 35 (1937).

[7] T. N. Rhodin, J. Amer. Chem. Soc. **72**, 5102 (1950).

[8] Z. G. Pinsker, *Diffraction of Electrons*, Acad. Sci. Publishing House, 1949.

[9] A. G. Pinsker, Izv. Akad. Nau, SSSR, Ser. Fiz. **13**, 473 (1949).

[10] K. H. Moore, Ann. Physick **33**, 133 (1938).

[11] E. Menzel, A. anorg. Chemie, **256**, 49 (1948) (Annals of the All-Union Mineralogical Society).

[12] N. B. Gorny, Zap. Vses. Mineral Ob-va **80**, 245 (1951).

metal parts were subjected to a supplementary heating process by means of electron bombardment and by high frequency currents till they glowed deep red. After attainment of a high vacuum (less than 10^{-6} mm mercury) the tube was sealed off and the getters were vaporized in special compartments of the tube.

It was expedient to carry out the investigation of the structure of the surfaces and the contact potential differences in the very same tube and under the very same conditions prevailing during the investigation of secondary emission. We employed a relatively simple tube construction, which made it possible to carry out the investigation of both the secondary emission and the diffraction of the electrons as well as the contact potential difference.

In the vaccum tube which we utilized (Fig. 1) a narrow electron beam emitted from the tantalum electron gun impinged perpendicularly on a platform consisting of a tungsten disc situated at the center of the sphere represented by the vacuum tube; the platform could be turned by means of electromagnets and set to the desired position. The specimens undergoing investigation were fastened to the platform – these were monocrystals of copper with planes corresponding to faces (001), (011) and (111), and polycrystalline copper. By preliminary experiments using the method of cathode luminescence, the position of the electron spot issuing from the gun was determined relative to the light spot. The diameter of the electron spot was of the order of 1 – 1.5 mm.

INVESTIGATION OF THE SURFACE STRUCTURE OF FILMS OF Cu_2O

In investigating the surface structure of the specimens, we employed the method of diffraction of slow electrons, measuring the dependence of the current at a constant angle on the energy of a primary cluster of electrons.

A tantalum Faraday shield measuring 8 × 5 mm (Fig. 1) was used as an electron receiver during the investigation of diffraction. The current in the cylinder was measured by a vacuum tube electrometer having a sensitivity of 10^{-15} A/mm at an input resistance of 10^{10} ohms.

In order to avoid leakage losses to the glass support of the Faraday cylinder, a protective cylinder is employed which is held at the same potential as the Faraday cylinder. With the same aim in mind, the surface of the support is deliberately enlarged, and on the outside the point of issuance and the entire glass base are covered with ceresin to increase the degree of isolation. A retarding potential is applied to the outer cylinder, which prevents the possibility of entry into the receiver of any electrons which have lost energy greater than one electron volt. The actual value for the accelerating potential, which depended on the contact potentials and on the voltage drop across the cathode filament, was determined experimentally. The retarding potential at which the current in the receiver becomes equal to zero, is apparently equal to the actual value of the accelerating potential. From this, it is possible to find a correction factor, which it is necessary to apply to the reading of the voltmeter measuring the accelerating potential.

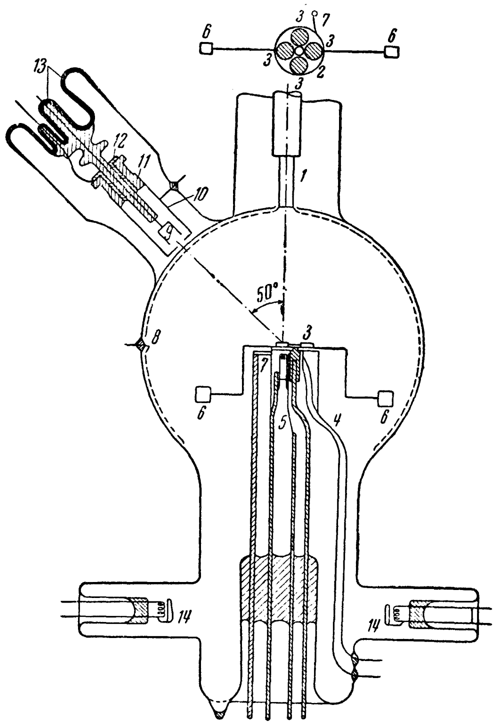

FIG. 1. Vacuum tube device. *1* – electron gun; *2* – platform; *3* - objects under investigation; *4* - thermocouple; *5* - heater filament; *6* - small iron rods imbedded in glass; *7* - locking spring; *8* - collector; *9* - Faraday cylinder; *10* - cylinder with diaphragm; *11* - quartz tube; *12* — protective cylinder; *13* - ceresin; *14* — getter.

In order to prevent distortion of the trajectory of the electrons in the tube during the measurements, the earth's magnetic field was compensated for by two Helmholtz coils having a diameter of 1 m.

The experimental data we obtained are presented in Fig. 2. The abscissa shows the energy of the incident electrons in volts; the ordinate gives the number of electrons distributed without velocity loss (or more precisely, which have lost no more than 1 v) in the Faraday cylinder. The ordinate is in arbitrary units. The measurements were carried out at room temperature and at specimen temperatures of 350 ° and 450°C. Heating was accomplished by a heater filament located inside the platform.

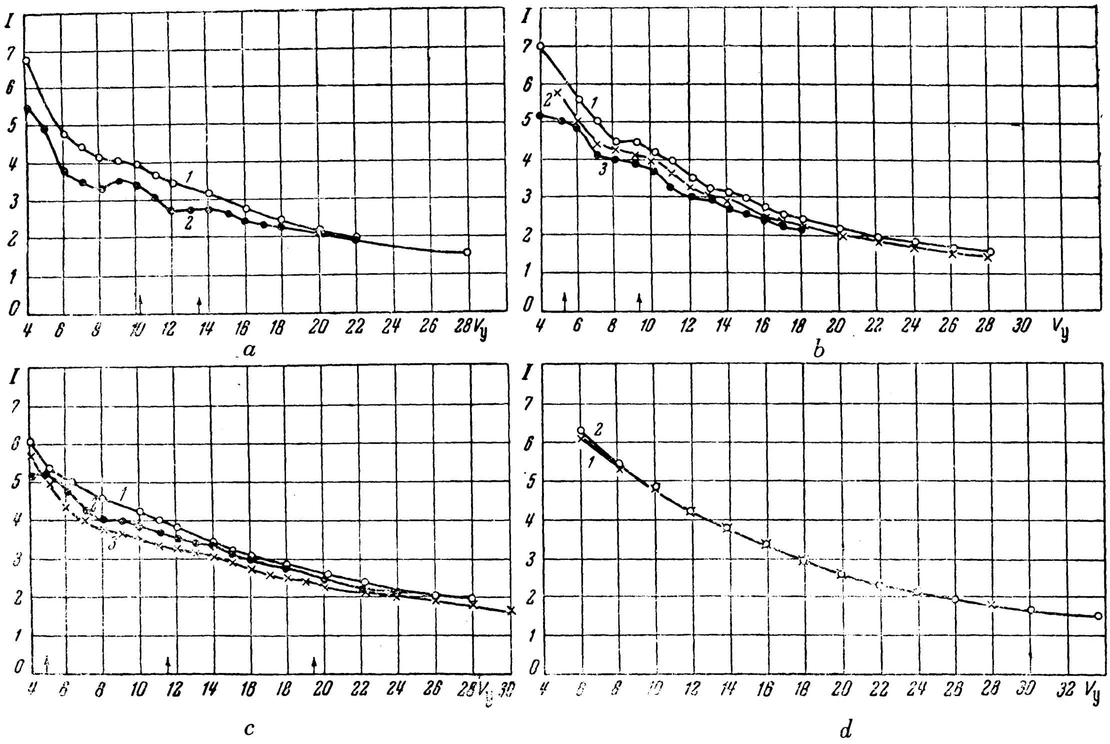

FIG. 2. Diffraction curves obtained: *a* – from the (100) plane of a monocrystal of copper (plane (111) of copper oxide); *b* – from the (111) plane of a monocrystal of copper (plane (111) of copper oxide); *c* – from the (110) plane of a monocrystal of copper (plane (110) of copper oxide); curve *2* is obtained at 450°C, curve *1* at 350°C; *d* – are curves obtained from the surface of polycrystalline copper (polycrystalline surface of copper oxide). All curves *1* are obtained at room temperature: in graphs *a*, *b*, and *d*, curves *2* are obtained at 350° and curve *3* at 450°C.

Investigations demonstrated that the magnetic field of the tungsten spiral used for heating affected the measurements, and for this reason before each reading, after the temperature of the specimens had been brought to its predetermined value and had been maintained for the predetermined length of time, the heating current was turned off.

The presence of maxima in the diffraction curves of the monocrystalline copper specimens indicates a monocrystalline structure of the surface. It is necessary to point out that the diffraction maxima obtained are weakly expressed and rather broad. This is most probably a result of the nonsymmetrical positioning of the receiver and the electron gun, as has been indicated in the investigations of Lashkarev[13], who observed an abrupt drop in the intensity of expression of the maxima upon

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[13] V. E. Lasharev, *Diffraction of Electrons*, GTTI, 1933.

changing from a symmetrical to a nonsymmetrical receiver with respect to the electron gun. In the case of the polycrystalline specimen (Fig. 2d) the scattering curve proved to be smooth and without maxima, both at room temperature and at elevated temperatures.

We attempted to compute the diffraction maxima, hypothesizing that the scattering originated in the copper lattice; however, negative results were obtained. It was then that we attributed these maxima to scattering from the monocrystalline film of copper oxide formed on the surface of the monocrystal of copper.

Copper oxide, in crystallizing, forms a volume-centered crystalline lattice with a periodicity of 4.26 Å. The values for the energy of the electrons, at which the maxima appear on the diffraction curves, conform with the following hypotheses as to the disposition of the crystalline lattice of the copper oxide on the copper lattice. On face Cu (111) there is formed a monocrystalline film of oxide with a (111) face parallel to the base, but rotated 30° about the vertical axis with respect to the copper lattice (Fig. 3a). On face Cu (001) there is formed a monocrystalline film of copper oxide with a (111) face parallel to the base, whereas the edge of the (111) face of the Cu_2O is rotated 15° about the vertical axis with respect to the edge of Cu face (001) (Fig. 3b). A (011) face of copper oxide, rotated about the vertical axis by an angle of 35° is located on Cu face (011) (Fig. 3c). The dispositions of the lattices of copper oxide on copper described above agree with the data obtained in references 6, 9, 10. This sort of accretion of copper oxide on copper is apparently connected with the magnitudes of the constants of the copper (3.6 Å) and Cu_2O (4.26 Å) lattices. The most favorable conjectures of the lattices of copper oxide and copper are obtained with the dispositions indicated above.

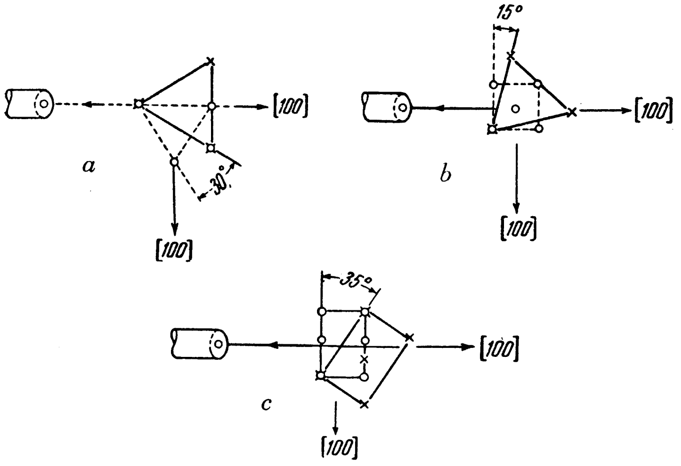

FIG. 3. Schematic of the mutual dispositions of the lattices of copper oxide and copper. The broken line represents the lattice of copper, and the solid line the lattice of Cu_2O. The primary cluster of electrons falls on the monocrystals from above. The arrows show the direction of the dispersed electrons to the Faraday cylinder. The zones of the copper lattice are shown in each drawing.

The arrows on the diffraction graphs (Fig. 2) show the potentials corresponding to the wavelengths, computed on the basis of interferential conditions, for the maxima for normal electron fall (for our specimens). The correspondence of the potentials at which the experimental maxima were obtained with the computed maxima is satisfactory.

Here it may be noted that while in the investigation of copper oxide on monocrystals of copper having (001) and (111) planes maxima were obtained even at room temperature of the specimens, and the positions of these maxima remained unchanged even at a temperature of 350°C (Figs. 2a and 2b), in the curves for copper oxide on the (110) plane of a monocrystal of copper there are no expressed maxima either at room temperature or at 350°C, and only at 450°C did a weakly expressed maximum appear. These data indicate a less perfect monocrystalline structure of the copper oxide film on the (110) face of copper than on the (111) and (100) faces of copper, apparently as a result of lesser thickness. According to the data by Pinsker, thinner layers of copper oxide have a less perfect, dispersive structure formed of tiny monocrystals[8].

We also investigated the effect of temperature on the intensity of reflection of the electrons for all specimens. Figure 4 shows the experimental results we obtained. The abscissa represents the time in minutes from the instant the heating current was switched off, at $t = 450$°C (reduction of temperature); the ordinate is the intensity of scattering of electrons (in relative units) with energy conditions unchanged. The intensity of scattering of the electrons for the two investigated surfaces – the (111) plane of copper oxide on the (100) face of the copper (Fig. 4a and also Fig. 2a) and the (111) plane of copper oxide on the (111) face of the copper (Fig. 2b) – decreases as the temperature goes up. These data coincide with the results obtained by Kalashnikov and Zamsha on a monocrystal of silver[14]. However, for the (110) plane of copper oxide on the (110) face of copper, the intensity of dispersion of the electrons at first drops, and then only upon continued reaction in temperature, increases (Fig. 4b). These data for a film of copper oxide on the (110) face of copper, and the circumstance noted above that for such a film weakly expressed maxima are observed only at a temperature of 450°C, and at lower temperatures (350°C and room temperature) they are not expressed in the diffraction curves, can be explained by the more powerful adsorption of residual gases on the oxide film formed on the (110) face of the copper as a result of its imperfect structure. This has been confirmed by a recently published research paper[15].

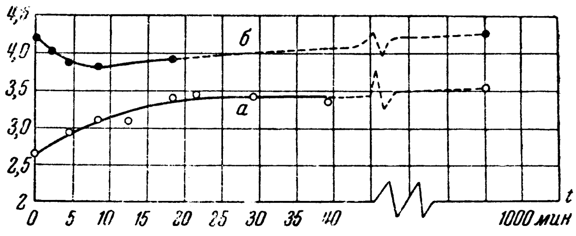

FIG. 4. Effect of change in temperature on the intensity of reflection: *a* - from the (111) plane of copper oxide; *b* - from the (110) plane of copper oxide.

INVESTIGATION OF THE CONTACT POTENTIAL DIFFERENCE

In order to check the correctness of our conclusions that a monocrystalline film of copper oxide having the same orientation with respect to the (111) plane and parallel to the base accumulates on the (001) and (111) faces of monocrystals of copper, we carried out measurements of the contact potential difference by the method of displacement of the volt-ampere characteristic curve[16,17].

A series of investigations[18-20] have shown that the work function differs for various faces of a monocrystal of one and the same metal. If the contact potential difference between the two monocrystalline planes of the very same substance is equal to zero, i.e., if these planes possess the same work function, then with a high degree of

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[14] S. G. Kalashnikov and O. I. Zamsha, J. Exper. Theoret. Phys. USSR **9**, 1408 (1939).

[15] T. N. Rhodin, J. Amer. Chem. Soc. **72**, 5691 (1950).

[16] B. M. Tsaryev, *The contact potential difference*, GITTL, Moscow, 1949.

[17] P. A. Anderson, Phys. Rev. **47**, 958 (1935).

[18] S. T. Martin, Phys. Rev. **56**, 947 (1939).

[19] M. H. Nichols, Phys. Rev. **57**, 297 (1940).

[20] P. A. Anderson, Phys. Rev. **59**, 1034 (1941).

probability one may conclude that these planes represent the same crystalline faces.

The contact potential difference between the investigated specimens was measured in the very same vacuum tube device which was used in investigating the diffraction of the electrons. An extremely important requirement for these measurements was the specification that the primary current be maintained constant (within limits of 0.5%).

This was accomplished by connecting a constant resistance into the heating circuit, and regulation of the heating current was accomplished (extremely smoothly) by means of two potentiometrically connected, plug-in type resistance boxes. The magnitude of the primary current could be judged from the readings of the microammeter. During these experiments, compensation for the earth's magnetic field was performed by two Helmholtz coils.

Figure 5 shows the experimentally determined curves for the investigated specimens. The values of the current across the individual specimens are graphed along the ordinate in relative units, while the difference between the unvarying accelerating potential and the varying retarding potential $V_y - V_z$ is graphed along the abscissa. The potentials were measured with an accuracy of ± 0.02 v. The displacement of the volt-ampere curves in the steep portion determines the contact potential difference between the corresponding specimens.

At room temperature (Fig. 5a) the contact potential difference between all the specimens is almost equal to zero, and consequently, the work function, too, is almost the same for all the investigated planes at room temperature. Upon increasing the temperature to 350°the work functions of the monocrystalline planes changed – they increased (Fig. 5b) with respect to the polycrystalline surface and with respect to the work function for these planes at room temperature, and in this instance to the greatest degree for plane (110). At a still higher temperature (450°C) (Fig. 5c) the work function of plane (110) grew even greater, exceeding the work function of the polycrystalline surface by $\Delta\varphi = 0.5$ v. As for the work functions of both planes of the films of copper oxide formed on the (001) and (111) faces of copper, at room temperature they were the same; upon raising the temperature to 350°C they changed equally with respect to the work function of the polycrystalline surface (by $\Delta\varphi = 0.2$v); and upon raising the temperature to 450°C their work functions remained unchanged and almost equal for both of the planes. Upon raising the temperature to 500°C, the disposition of the volt-ampere curves for all the investigated specimens remained the same as at 450°C.

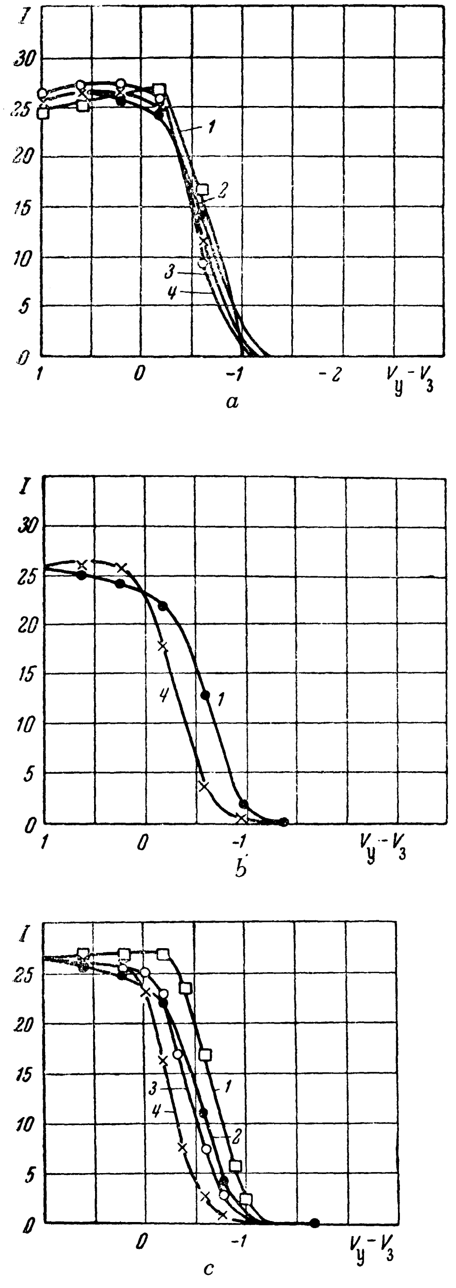

FIG. 5. Volt-ampere characteristic curves, obtained: *a* – at room temperature of the specimens; *b* - at a temperature of the specimens equal to 350°C; *c* - at a temperature of the specimens equal to 450°C. Curves *1* for films of Cu_2O on polycrystalline copper; *2* – for films of Cu_2O on the (111) face of copper; *3* – for films of Cu_2O on the (100) face of copper and *4* – for films of Cu_2O on the (110) face of copper.

EVALUATION OF THE RESULTS

On the basis of our experimental data, we can draw the following conclusions. The value of the contact potential differences among all the specimens, which is almost equal to zero at room temperature, indicates that at that temperature all the specimens are covered with adsorbed molecules of residual gas. Upon increasing the temperature to 350°C the oxide film on the polycrystalline copper and the oxide films on the (100) and (111) faces of the copper monocrystal clear themselves of adsorbed molecules of gas. The surface of the oxide film on the (110) copper face was cleared of molecules of residual gas only at 450°C, which is indicated by the change in its work function during increase in temperature right up to 450°C (Fig. 5), and also by the appearance of diffraction maxima only at this temperature (Fig. 2c). The course of change in intensity of scattering with decrease in temperature (Fig. 2c) also indicates more powerful adsorption of the molecules of the residual gases on the oxide film*, formed on the (110) face of the copper as a result of the less perfect crystalline structure of this film as compared to the films formed on copper faces (100) and (111). The less perfect crystalline structure, as we have already mentioned, apparently is connected with the lesser thickness of the film on the (110) face of the copper.

The equal values for the work function of the two copper oxide films, formed on faces (100) and (111) of the monocrystal of copper, confirm our conclusion (based on our investigations of the diffraction of electrons) as to the formation of similarly oriented films of copper oxide (with a (111) plane parallel to the base) on these Cu faces. The work function of films of Cu_2O on the (110) face of Cu differs from the work function for films of Cu_2O on the (100) and (111) faces of copper, which indicates a different crystalline orientation of this film, in conformity with the results obtained in the investigations of their structure by the method of electron diffraction.

In connection with the results obtained, we would like to make the following two remarks: 1) These results are in conformity with general considerations, which consist of the fact that a crystalline face in which the superficial atoms are more densely packed (as is the case with volume-centered cubic lattice (110)[21] should have a greater work function than a face with less dense concentration of the surface atoms (111). 2) At the same time that the work function for the (111) plane of the copper oxide remains unchanged (with change in temperature from 350°C to 450°C), the diffraction curve for the same plane (Fig. 3b) changes with change in temperature over the same range. This apparently confirms the conclusions of Farnsworth[22] with regard to the fact that only the upper atomic layer affects the diffraction, while the work function depends on a deeper layer.

The vacuum tube device described in this article (Fig. 1) was also utilized in the investigation of secondary emission from the examined surfaces of the monocrystalline specimens of copper[1]. The data obtained in the present work made it possible to explain the following peculiarities of the secondary emission for the investigated monocrystalline surfaces (for a more detailed account see reference 1).

For the monocrystalline specimens of copper with superficial planes (100) and (111), the same values for the coefficient of secondary emission δ and the same course of the curves $\delta = f(V_p)$ were obtained. Here V_p is the energy of the primary electrons. This agreement is attributed to the fact that the same monocrystalline films of copper oxide with (111) surface planes form on the monocrystalline (100) and (111) surface planes of copper.

The relative variation in δ with change in temperature from 20° to 500°C for the (111) plane of copper oxide are less than the relative variations in δ with change in temperature within the same limits for the (110) plane of copper oxide. This result points to the presence of greater contamination by molecules of residual gas at room temperature on the (110) plane of the copper oxide than on the (111) plane. The data obtained in this work with regard to the fact that a monocrystalline film of copper oxide on the (110) face of copper possesses a less perfect crystalline

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[*] This conclusion is verified by Rhodin[15], who discusses investigations of the heat of adsorption of nitrogen on polycrystalline copper and on the faces of a monocrystal of copper covered with a film of copper oxide; the investigations employed the method of measuring the adsorption with the aid of vacuum-type microbalance scales for several values of temperature. The investigations demonstrated that the heat of adsorption differs for various surfaces and increases according to the following order: pollycrystalline surface ~ 2500 cal/mol; (111) face ~ 3300 cal/mol; (100) face ~ 3500 cal/mol; and (110) face ~ 4000 cal/mol.

[21] K. Khering and M. Nikol's, *Thermoelectronic Emission*, IIL, 1950.

[22] H. E. Farnsworth, Phys. Rev. **81**, 652 (1951).

structure, and consequently, also greater capability of adsorption than a monocrystalline film of copper oxide with a (111) surface plane, conforms with the result given above.

The coefficient of secondary emission δ for the monocrystalline specimen with a (110) surface plane at a temperature of 500°C has a somewhat lesser value than for the two other monocrystalline specimens of copper oxide with a (111) surface plane at the same temperature. This may result from the fact that the work function of the (110) plane of copper oxide is greater than the work function of the (111) plane of copper oxide.

It may be noted that the juxtaposition of the results of the investigation of the structure of the surface of monocrystalline films of copper oxide and the contact potential difference between them, with the results of the investigation of secondary emission for these films, proved to be extremely useful in the explanation of these results.

Translated by A. Certner
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