IMPROVED METHOD FOR MEASUREMENT OF CONTACT DIFFERENCE OF POTENTIALS WITH A VIBRATING WIRE

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The methodology of measurement of the contact difference of potentials of metallic wires while applying tension is described. The method permits evaluation of changes of surface layer properties (oxides, lacquers, and others) of metals during deformation.

The ability of rigid bodies to emit electrons does significantly depend upon the structure of the surface layers. Therefore, at the present time, various methods of investigation of the thin surface structure, utilizing emission processes [1,2], are being developed. The methods based on the measurements of the work of electron output may also be related to this group.

The properties of the surface of a rigid body change significantly under mechanical work (grinding, polishing, compression, tension, etc.). This change is related to the disturbance of solid surface films [3,4], as well as to the changes in atomic structure of purely metallic surfaces [4-7].

This article describes a method for measurement of contact difference of potentials during deformation of the sample in high vacuum.

The contact difference of potential was measured in a manner developed for the case of a dynamic capacitor consisting of two parallel wires [8].

Periodic change of capacitance of the two-wire system was obtained by vibration of a counting wire in a constant magnetic field, while passing through it an alternating current, the frequency of which (300-500 cps), corresponded to the resonant condition of the wire.

The method of measurement of the contact difference of potential by means of utilization of the wire electrodes is convenient for the study of the influence of deformation processes on the work output of the metal. This method has significant advantages over the method described by Wallis and Farnsworth [7], who, for the measurements, used a massive counting electrode and a sample in the shape of ribbon or wire. The considerable size of the electrodes made cleaning of the metallic surfaces difficult, and required complicated attachments to obtain the deformation.

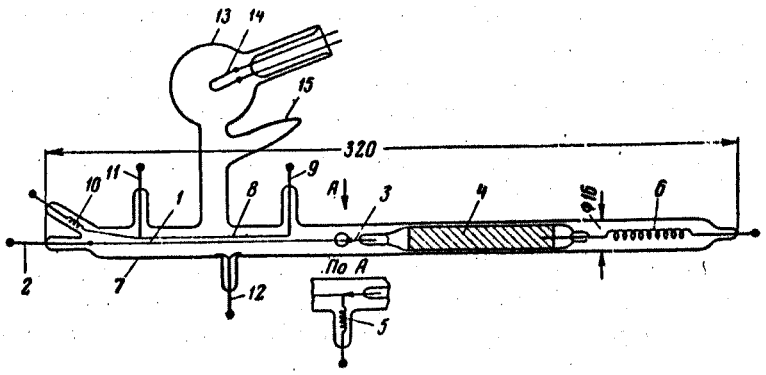

Fig. 1. Measuring tube.

A ZG-10 generator served as the source of audiofrequency current. The contact difference of the potentials was compensated by a low-resistance potentiometer. An oscillograph of type ÉO-7, connected to a

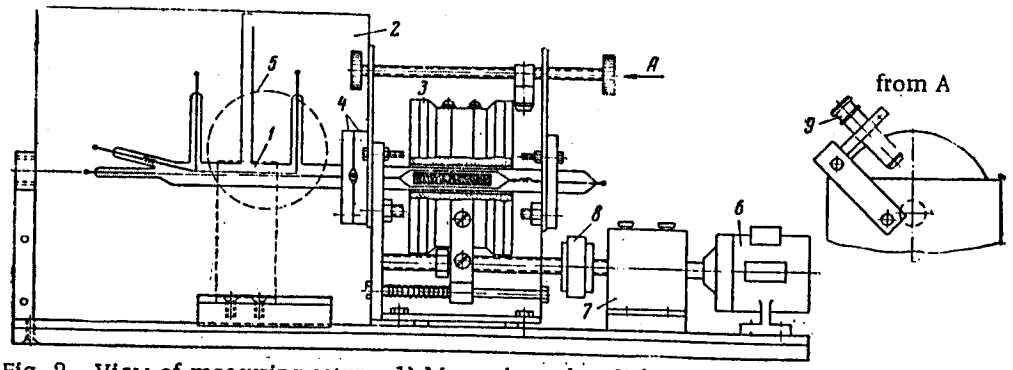

Fig. 2. View of measuring setup. 1) Measuring tube; 2) brass cover of electrical shield; 3) massive plate; 4) teflon gasket flanges; 5) winding and base of electromagnet creating field for vibration of counter electrode; 6) electric motor of drive; 7) speed box; 8) clutch; 9) microscope for reading deformation values of sample.

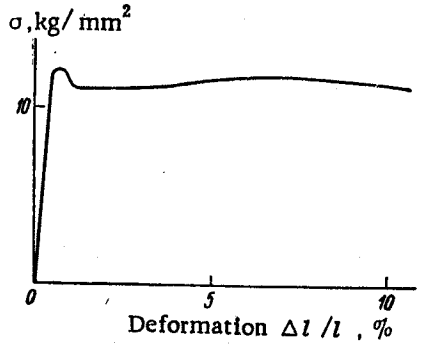

Fig. 3. Diagram of elongation of molybdenum wire.

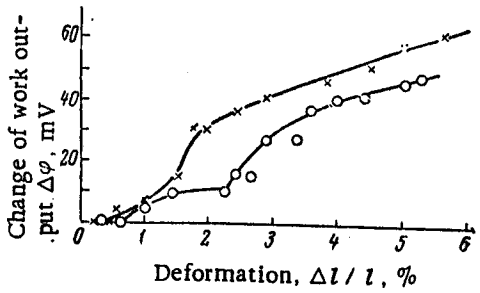

Fig. 4. Change of work output during deformation of two molybdenum samples.

wideband linear amplifier of type D, with an amplification constant of 10^5, was used as a null indicating instrument. Careful shielding and the utilization of electrical filters permitted performance of the measurements with an accuracy of ±0.005 V. In determining the contact difference of potentials during the process of sample deformation at high speed, the accuracy of measurements decreased to ±0.01 V.

The static capacitance of the two-wire system, of 50 micron wire diameter, with a length of the counting wire of 8 cm and a distance between them of 0.5-0.6 mm, is 4-6 pF. The change in capacitance for deformation of the wire sample down to its rupture point does not exceed 0.02 pF.

The view of the measuring tube is shown in Fig. 1. The wire sample 1 is on one end secured to a molybdenum lead-in 2, and on the other end to a molybdenum post 3, connected with the glass envelope of the iron core 4. The end of the wire is threaded through a special cone, put onto thin leads, and secured by tack welding. The inner contact of the end of the wire, which is necessary to supply current, was facilitated through a thin molybdenum spiral 5, which did not interfere with the displacement of the core during deformation of the wire. A tungsten spring 6 provided the inner contact of the core, necessary for grounding, and prevented sag of the wire sample. Spring tube 7 was made of molybdenum glass.

Counter wire 8 was strung between two molybdenum leads 9 by means of tungsten spring 10, which prevented sag during degassing. Support 11, with a flat face, was used for adjustment of the distance between the wires. To prevent the storage of charges on the inner walls of the tube, and for purposes of shielding, the walls were in a vacuum sprayed with a layer of tantalum, which contacted the external lead 12. A tantalum getter bulb 13 with tantalum getter 14 was connected to the tube. The tube was sealed at the point where it necked down at protrusion 15. After sealing, it was placed in a special device (Fig. 2) with a drive for displacement of a solenoid, by means of which deformation of the wire sample was caused.

During preliminary experiments, where the sample was free to move behind the core, without checking deformation, it was established that change in the relative position of the internal parts of the tube did not

influence the magnitude of the measured contact difference of potentials. In the given arrangement, the center point of the counting wire is at constant potential with respect to ground [9], and deformation does not lead to motion of the center point and does not influence the shape of the null line. With proper preparation of the tube and of the glass envelope of the core, the distance between the wires does not change for practical purposes during deformation of the wire sample and, consequently, the sensitivity of the measurements does not change during the course of the experiment.

The influence of the degree of deformation on the work output for molybdenum samples in a vacuum at $(5\text{-}2) \cdot 10^{-8}$ mm Hg was determined in the device described. The sample and the counting electrode were prepared of molybdenum wire, type MK, of 50 micron diameter. After a vacuum of $(1\text{-}2) \cdot 10^{-6}$ mm Hg was reached in the system, the wires were heated at a temperature of 1800-1900°C for the duration of 15 min. During this, a structure of large crystals was formed and in the length of the wire sample (100 mm), one to two crystals were obtained. Thus, the influence of grain boundaries on the results of the measurements was practically excluded. Wires obtained after such annealing were of a high degree of plasticity (Fig. 3).

Then a furnace was lowered over the heated section of the vacuum system and degassing of the wires, getter leads, and getter were performed at 420-450°C and a pressure of $1 \cdot 10^{-6}$ to $5 \cdot 10^{-7}$ mm Hg. After that, the tube was sealed with the getter turned on. After two hours of spraying of the getter, a vacuum of $5 \cdot 10^{-8}$ to $2 \cdot 10^{-8}$ mm Hg was reached in the tube. Since no supplementary cleaning of the surfaces prior to the measurements was performed, it could be considered that in its initial condition the metal was covered with a monolayer of atoms of the residual gases.

The contact difference of potentials during the process of deformation of the wire sample was measured in the sealed tube. The initial values of the contact difference of potentials between two molybdenum wires, measured in various tubes, varied within ±50 mV, which, apparently, is related to the properties of the adsorbed films not being identical. These values, measured on one and the same tube, are stable and do not depend upon the duration of the measurements.

From the results, curves of change of work output $\Delta\varphi$ vs. degree of deformation $\Delta l / l$ (Fig. 4) were plotted. During this it was assumed that the work output φ for the counter electrode does not change during the time of measurements. The increase of φ in the figure corresponds to the decrease of φ of the sample during deformation.

The experiments were performed on 7 samples at a speed of deformation of 1.2 mm/min and a pressure of $(5\text{-}2) \cdot 10^{-8}$ mm Hg. In all samples, an increase of the changes of work output $\Delta\varphi$ during the time of deformation of the sample was observed. The value of $\Delta\varphi$ related, for example, to 5% of deformation represents for all samples investigated 40-60 mV.

From comparison of the curves obtained with the stress-strain diagram (see Fig. 3), it follows that, in the region of elastic deformation, no noticeable effect of change of work output was observed. The same also takes place during repeated elongation of plastically deformed samples. During this, the value of the work output φ also does not change in the region of elastic deformation.

During plastic deformation the value φ initially changes slowly, and then the rate of change increases and then again decreases. It should be mentioned that these three sectors can be found on the experimental curves even in the presence of a large degree of scatter of the points (especially during the initial period of deformation).

In the case where the zone of failure is beyond the limits of the counting electrode, the value of change of work output $\Delta\varphi$ after reaching some limiting value (at 3% deformation), practically does not change any more during further deformation. In this manner, only the processes taking place on the surface of the metal during its deformation are responsible for the effect of decreasing the work output φ.

In a number of experiments it was shown that the character of change of the curve $\Delta\varphi = f(\Delta l / l)$ and the magnitude of the effect do not depend upon whether the deformation of the wire takes place continuously or in steps.

Our data coincide with the results of work of other authors, obtained by means of utilization of other methods [4-6]. The value of change of output work $\Delta\varphi$ [10-12] should characterize the degree of defectiveness of the surface layer.

The method described may also be utilized for the study of strength characteristics of various types of coatings (oxide, lacquer), the density of which may be damaged during the process of deformation of the metallic base.

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