Reply to Critical Remarks of I. F. Kvartskhava[1] Concerning our Papers[2-6]

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IN Refs. 2–6, we investigated the dependence of the electrical emission on the energy E released from a metal at currents $i \sim 10^5 - 10^7$ amp/cm^2. Let us review the basic results of these experiments: *a.* The anomalous dependence $R \neq R(E)$ is not observed prior to the beginning of melting of the metal[6]. *b.* Melting begins and ends with the usual values of E and R: $E = W_n + W_{fl}$, $R(W_n) = R_{fl}^s$ $R(W_n + W_{pl}) = R_{fl}^l$.[6,7] *c.* When E reaches the value E_c, the metallic reistance suddenly disappears and the metal explodes[2,5,6,7]. Essentially, E_c increases with the increase of current *i. d.* Near the melting point of the metal, there are observed anomalies of electron emission[3,6] *e.* In lamps with wolfram cathodes, for which the anomalous emission is very high, Langmuir's law does not hold.[4].

Dependence of E_c on i and the anomalous emission could not be attributed to errors. An assumption was therefore made concerning the anomalous condition of the metal. In Ref. 5 a faulty deduction was made that at $i = 5 \times 10^5$ amp/cm^2 the metal does not become liquid at $E = W_n + W_{fl}$. As indicated by the correct interpretation of these experiments, given in Ref. 7, the error made in Ref. 5 is not connected with inaccuracies of R and E measurements.

2. It may seem from Ref. 1 that, in Refs. 2 to 6, we arrived at a conclusion concerning the anomalous dependence of R on $E \leq W_n$ and the breakdown of Ohm's law. But the absence of anomalous R and E at $E \leq W_n$ was established with an accuracy of $\sim 5\%$ in Ref. 6 (pp. 97–100, Fig. 4).

We have never observed deviations from Ohm's law; on the contrary, in Ref. 5, p. 613 and Ref. 6, p. 108, it is noted that the error which lead other experimenters to the deduction concerning the breakdown of this law, is due to inductive distortions of the oscillograms. The same error as in Ref. 1 is unjustifiably ascribed to us, (Ref. 2, p. 630). The assertion of Kvartskhava not withstanding, an induction correction was introduced in Ref. 2 and in the oscillograms Fig. 7 which is indicated on p. 634 of that work.

It should be noted that in Ref. 1 (point 1) our point of view was not formulated correctly. The correct formulation of our conclusions is presented above.

3. Kvartskhava states that our measurements of R and E are incorrect, and that the observed excess energy of the wire at resistance of i is connected with macroscopic movements of the metal and not with internal energy. However, our conclusions are confirmed by new data[7] according to which at $i \geq 5 \times 10^6$ amp/cm^2, the motion of the metal prior to the explosion is not of sufficient duration to disturb the constancy of the cross section along the wire. Therefore the high values and energy of the entire wire enable us to find R and E for $E < E_c$, which has been confirmed by measurements of R_{fl}^s, W_n and W_{fl} for Ni and W[6] and by measurement of R_{fl}^l / R_{fl}^s for Cu.[7]

If the current is switched off at a valve E even a little less than E_c, the wire does not explode and instead disintegrates into drops, the kinetic energy of which $K << E \sim W_n$.[7] Therefore neither the explosion nor the excess energy $\sim W_n$ (of the E_c dependence on i) can be explained on the basis of K. The description of the explosion mechanism in Refs. 1 and 8 (Sec. 4) is in our opinion incorrect.

4. In Ref. 1 there is an attempt to explain the anomalies observed by us of the anode current I_a by the glowing discharge. The author asserts that when discharge takes place along the wire, the relation of the "electronic" I_a to the "ionic" I_i is determined by the ratio of the ion mass to electron mass m_i/m_e and that this relation is observed in our experiments. But as the charge ignites the growth of currents I_i and I_a are limited by the properties of the external links and not by the ratio m_i / m_e (Ref. 3, p. 724). The small value of I_i / I_a measured by us in the absence of discharge* is also not determined by the ratio m_i / m_e, inasmuch as I_i / I_a changes in the course of the experiment and depends on the degassing of the electrodes (Ref. 4, Sec. 2 and Ref. 3, Sec. 3).

5. It is stated incorrectly in Ref. 1 that, at anode voltages $V_a < 1$ kv used by us, the magnetic field of the wire heating current i, should in general lock the anode current I_a as long as there is no discharge along the wire. For the evaluation of the critical anode potential, V_k in Ref. 1 was taken as $i = 10^3$ amp and $i = 10^2$ amp

and the obtained $V_k \approx 100$ *kv* and $V_k \approx 1$*kv*, i.e, $V_k > V_a$. However, in Ref.3, we measured I_a when i passed through zero and remained less than 15 amp. (Ref. 3, Fig. 13) while $V_k \leq 23\ V_k < V_a$. In experiments with $V_a \approx 6v$ condition $V_k < V_a$ is also fulfilled, inasmuch as I_a is here measured with the complete exclusion of current i Ref.4, upper curve, Fig. 3*g*). To a lesser degree this condition is observed in Ref. 6, Sec. 2, where I_a was measured at i = 17 amp, but even in this case

$$V_k < 29\ \text{V} < V_a (62\ \text{V} \leqslant V_a \leqslant 70\ \text{V}).$$

It is obvious that the condition $V_k < V_a$ was maintained during our measurements: besides the anomalous current I_a there is also observed the normal anode current which precedes it and which, according to Ref. 1, cannot take place in the absence of discharge (Ref. 4, Fig. 4, *g,h* and Fig. 6, *a–h*, where $V_k \approx 90\ V < V_a$). The absence of discharge is insured here because in normal emission Langmuirs' law holds and the $I_a = I_a\ (t)$ curve has a plateau (Ref. 4, p. 496).

Thus, the explanation proposed in Ref. 1 of the anomalous anode current as caused by the discharge, and the explanation of the E_c dependence on i by the macroscopic movement of the metal, are contrary to the results of our experiments. The data contained in Ref. 1 and 8 do not furnish a basis for renouncing the conclusions given above (*a–e*).

*During measurements of I_a and I_n the potential difference between the ends of the emitter was maintained below the discharge ignition potential.

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Investigation of the Allotropic Transformation $\alpha \rightleftarrows \beta$ Zr with the Aid of an Electronic Projector

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THE use of an electronic projector permits a visual observation of phase transformations in metals at crystal particle dimensions of the order of 10^{-4}-10^{-5} cm, with a resolving power of 100-20A. The investigation of transformations in such small crystals has independent interest, since the increased role of surface energy must have an effect at such small dimensions.

The usual Muller[1] electronic projector was used, with a zirconium point, the monocrystalline tip which was the object of investigation. The investigation of zirconium in an electronic projector makes special demands on the quality of the vacuum, since with heating, there is a strong tendency to form oxides, nitrides, and carbides of zirconium which are extremely refractory and nonvolatile, and consequently, are not removed from the surface by heating the point in vacuum.

In spite of the fact that the pressure of the residual gases in the bulb of the projector was less than 10^{-8} mm of mercury, it was not possible to obtain a picture of the autoelectronic emission of a smooth crystal similar to the well known picture of a pure tungsten point.

Crystal particles such as α-Zr (hexagonal close packed lattice), as well as β-Zr (cubic volume-centered lattice) were obtained with corrugations. It is natural to associate the corrugation and the clearly expressed faceting of the crystal with the well-known action of an electric field on the crystal during heating[2]. The faceting of the crystal by faces of the cube {001} and {122} is apparently associated with the intrusion into the surface layer of nitrogen atoms from the residual gases. The nitrogen atoms occupy the spaces between metal atoms, which in addition to smoothing the atomic unevenness, increases the durability of the surface layer.

The following steps were taken for the "purification" of the surface: 1) the layer-by-layer