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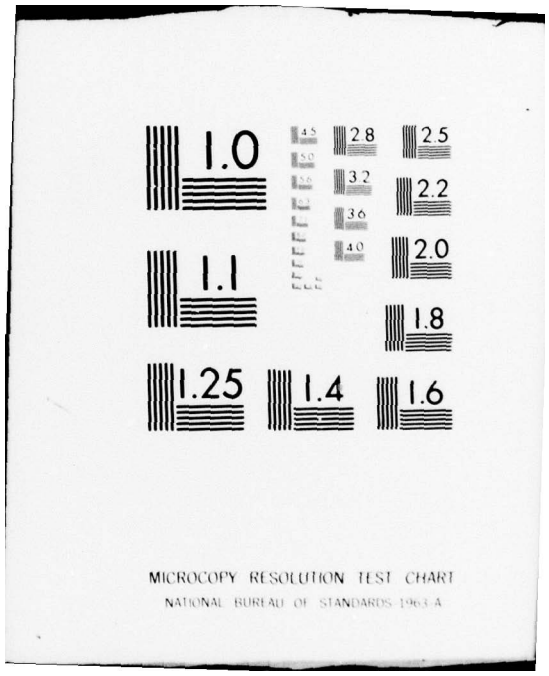
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A STUDY OF THE EMISSION CHARACTERISTICS AND EVAPORATION HEATS OF THE DIRECT-HEATED CATHODES WITH A NEW EMISSION COATING

By

E. T. Kucherenko and L. M. Makocevs'ka

EDITED TRANSLATION

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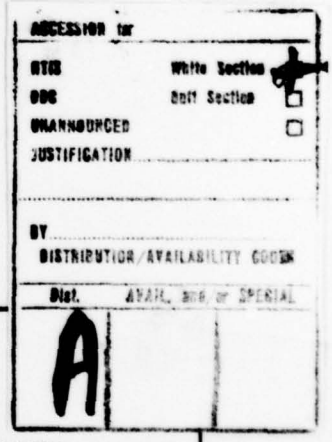

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A STUDY OF THE EMISSION CHARACTERISTICS AND EVAPORATION HEATS OF THE DIRECT-HEATED CATHODES WITH A NEW EMISSION COATING

E. T. Kucherenko and L. M. Makocevs'ka

The increased stability of the metalloporous cathodes studied by us earlier, which were prepared on the basis of the complex compounds of the barium and scandium oxides, up to an ionic bombardment and chemical toxicity made it possible to use this active substance in the direct-heated bispiral cathodes, which are being used extensively, for example, in fluorescent lights and certain types of He–Ne lasers.

In conrast to the oxide cathodes of the same type, these cathodes have a stable emission under reduced temperature conditions, have considerably less sputtering under the discharge conditions, and introduce significantly less admixtures during thermal vaporization of the active cathode layer.

This work was devoted to the study of the emission characteristics and the vaporization heats of the direct-heated cathodes based on the $3BaO \cdot 2Sc_2O_3$ compound. Conditionally, we will refer to these cathodes as the scandium cathodes.

Principle of the experimental procedure. One of the parameters characterizing an efficient thermionic cathode is the vaporization rate of the active substance, The vaporization process should be associated with the activation energy Q for the evaporation of an atom or a molecule. (Sometimes the quantity Q is called the

"evaporation heat"). The change in the evaporation rate M as a function of temperature can be expressed by an exponential law

$$M = A e^{-Q/kT} \qquad (1)$$

where T - cathode temperature, °K, k - Boltzmann constant, A - constant value.

We used a simple procedure which represents a variation of the test filament method [4].

With the heating of the cathode the atoms and moleculaes of the active substance begin to evaporate from its surface. If the test filament is in close proximity, the evaporation products will precipitate onto it, changing the value of its work function ϕ_0. At insignificant thicknesses of the coating the expected change in the work function $\Delta\phi$ of the test filament should be linearly connected with the number of atoms n adsorbed on it. In turn, n is directly proportional to the number of atoms N of the active substance which evaporate from the cathode being studied.

Thus, by controlling the change in the work function during heating, it is possible to obtain an experimental dependence $\Delta\phi=f(t)$, which will characterize the evaporation process, i. e., $N=f(t)$. After dividing N by the deposition time t we will obtain the number of atoms of the active substance M which evaporates in unit of time. Hence it follows that the evaporation rate can be reduced (with low levels of coating) to the value of the work function of the test filament per unit of time, i. e.,

$$M \sim \Phi. \qquad (2)$$

Thus, the problem of determining the temperature dependence of the evaporation rate can also be reduced to the determination of a change in the work function of the test-filament material during the period when the evaporation products are deposited onto it from the cathode under the investigation, and the evaporation heat Q can be estimated by the experimental dependences

$$\ln \Phi = \ln B - \frac{Q}{kT}. \qquad (3)$$

Results of the experiment. The most convenient and simple method for determining the change in the work function of the test filament is the method in which the contact potential difference is controlled, realized according to the shift in the initial segments of the volt-ampere (v.-a.) characteristics [5], when the test filament is the anode. In this case the temperature of the cathode must be relatively low in order to terminate the evaporation, while the cathode heating current must be constant in order not to distort the v.-a. characteristics.

However, in view of the fact that the emission capacity of the bispiral cathodes that we studied could vary little with time, in our experiments, we maintained the emission current of the cathode constant and not the heating current.

The schematic arrangement of the electrodes of the apparatus and the electrical measurement circuit are shown in Fig. 1. Test tungsten filament 1 and the studied cathode 2 were separated by a sliding door 3 and a longitudinal slit was made in anode 4 next to filament 1 for the evaporation products to come out. The vacuum in the unsoldered tube was at $\sim 10^{-8}$ mm Hg.

To reduce the effect of the nonequipotentiality of a relatively long direc-heated cathode on the form of the v.-a. characteristics, the anode of the tube had protecting rings and a symmetrizing resistance R_c was included in the measurement circuit in parallel to the cathode.

The order of measurements was as follows. First, a heating current was selected for the cathode at which no evaporation was observed and the saturation current in the anode post [translator's note: post is a translation of the word "kol" - this word is not found in the available dictionaries; another possible meaning is pole] (50–70 μA) was established by means of the potentiometer R_1. Under these conditions the current to the test filament did not exceed 10^{-9} A. The absence of evaporation was determined by the fact that the v.-a. characteristics in the unheated conditions (in the post of the test filament) remained virtually stationary throughout the measurement period. The necessary cathode temperature was established by closing door 3; after this the door was opened

and the deposition was accomplished from the object being studied onto the test filament. After the deposition the cathode temperature was reduced to the previous level and the initial segment of the v.-a. characteristic was plotted again. The value of change in the work function $\Delta\phi$ as a function of time was estimated using the parallel shift of these characteristics.

Figure 2 shows a typical series of the initial segments of the characteristics plotted at the cathode temperature of T=1530°K. Curve 1 corresponds to the tungsten filament cleaned by thermal heating, the other curves were plotted after the deposition after 5, 10, and 15 s respectively. As was to be expected, the deposition of active (electropositive) substances onto the pure tungsten filament caused a shift to the left, which corresponds to the decrease in the work function of the filament [5].

Using the data similar to those presented in Fig. 2, we constructed the experimental curves of change in the work function of the test filament as a function of the deposition time, shown in Fig. 3, for the various cathode temperatures (curve 1 - T=1430°K; curve 2 - T=1450°K; curve 3 - T=1470°K; curve 4 - T=1490°K; curve 5 - T=1510°K; and curve 6 - T=1530°K). It is evident from this figure that the initial segments of the curves for all temperatures studied are virtually rectilinear and can be used to estimate the evaporation rate and the parameter Q using the method above.

As was shown by our studies, the emission of the direct-heated scandium cathodes after the usual activation procedure was not constant and varied somewhat. On the other hand, the emissive activity of effcetive emitters, as seen from [6], depends on the state of their surface. Thus, when one speaks of equating the characteristics of the various types of cathodes using such parameters as the evaporation rate, it is important to associate them with the emission yield of the objects studied or with their work function. In our experiments we limited ourselves to controlling the work function whose change was estimated using the method of the Richardson's curves [6] under the unheated conditions.

Figure 4 shows the results of the evaporation rates obtained by us for the direct-heated scandium cathode. In this case curve 1

describes the cathode immediately after the activation is compeleted, curve 2 - after 10 h of operation in a vacuum, and curve 3 - after 20 h. As seen from Fig. 4, in the initial period of operation of the cathode under study one can observe a clearly expressed increase in the evaporation-heat value Q from 4.5 eV to 5.9 eV. With subsequent conditioning of the cathode there is virtually no change in the value of parameter Q.

A simultaneous estimation of the work-function value has shown (Fig. 5) that, in the process of thermal conditioning of well activated scandium cathodes, the latter remains virtually unchanged and stabilizes at the level of 1.3–1.4 eV.

Comparative studies of similar oxide cathodes have shown that they also have a decrease in the evaporation rate in the initial period of their operation. However, in this case, the equilibrium value of the evaporation heat Q is considerably lower and is estimated at ~3–3.5 eV (see curve 4, Fig. 4), while the work function ϕ_0, as a rule, varies between 1.1–1.5 eV.

We should also note that the direct-heated oxide cathodes are less stable from the standpoint of emission.

The results of this study concerning a decrease in the evaporation of the scandium and oxide cathodes stimulate an interest from the standpoint of reducing the level of environmental pollution in the cases when they are used in the gas-discharging devices (fluorescent lamps, gas lasers, etc.). With this mind, it is possible to recommend an additional thermal conditioning of the cathodes at an evacuation station (before they are chsrged with gas) for a period of 5–10 h. Furthermore, the comparison made above gives one grounds to give preference to the scandium cathode, which has a significantly lower evaporation rate and about the same emission parameters as the direct-heated oxide cathode.

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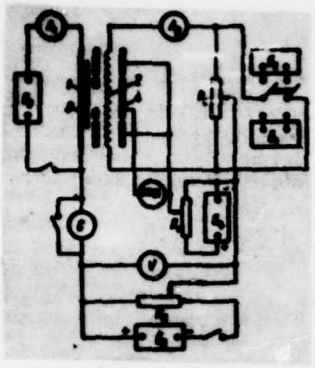

Fig. 1.

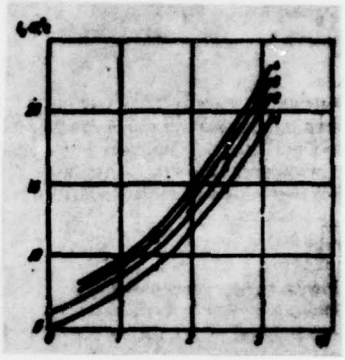

Fig. 2.

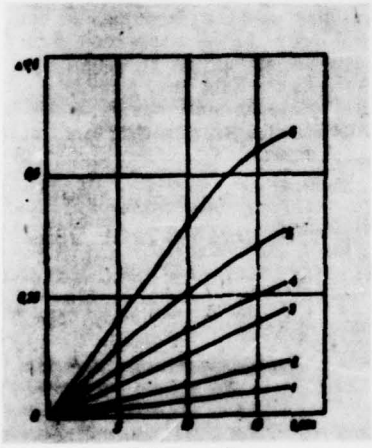

Fig. 3.

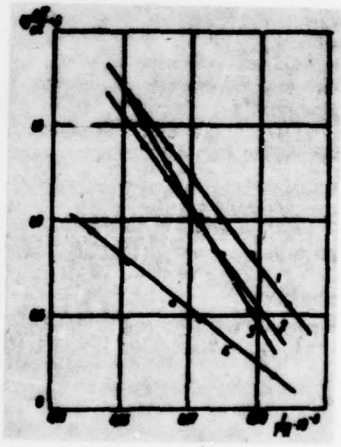

Fig. 4.

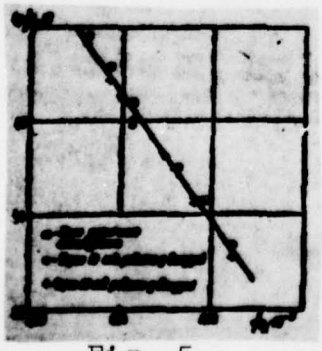

Fig. 5.

KEY: - After thermal activation

o - After 10 h of operation in vacuum

+ - After 20 h " " " "

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