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Abstract

Full Text

PHYSICS

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MICRORELIEF AND SHAPE OF THE TIPS OF AN ELECTRON PROJECTOR AFTER ELECTRICAL VACUUM BREAKDOWN

Studies of metals and alloys by means of an autoemission electron microscope —an electron projector—were, until a certain time, limited to relatively refractory substances, such as tungsten, molybdenum, rhenium, metals of the platinum group, and others ([1]). In the case of metals with a melting temperature $\leq 1500^{\circ}$, the preparation of tips satisfying experimental requirements involves great technological difficulties.

Several years ago our laboratory proposed ([2,3]) a simple method for preparing electron emitters for metals and alloys with melting temperatures $\leq 1500^{\circ}$. It was shown that the method can be successfully used for qualitative investigations in an electron projector of alloys ([4]) and compounds ([5]).

In the initial publication ([2]) this method was called the "blisters" method, since in the process of electrical vacuum breakdown images were observed on the projector screen that could be interpreted as patterns arising from hillocks on the surface of the tip. This name was subsequently abandoned.

The method of preparing electron emitters in the process of an electrical breakdown between the tip and the screen was given the name of the interrupted vacuum arc method ([5]). This name better corresponds to the physical conditions of formation of hillock-subtips, in accordance with the concepts developed in work ([2]).

A major shortcoming of the method for preparing subtips is the absence of data on their dimensions and curvature and, consequently, on the magnification of the images on the projector screen. Investigations carried out with such tips proved to be qualitative, which did not always satisfy the stated requirements. It is therefore quite natural to attempt to investigate the shape of the hillock-emitter arising as a result of a retarded vacuum breakdown. Knowledge of the shape and dimensions of the new emitter makes it possible to judge the magnitude of the electric field at its surface and also, taking account of the distortion of scale, to determine the magnification on the projector screen.

The present article gives data on the nickel—beryllium alloy (1 wt.% Be) and on platinum. The starting beryllium was obtained by repeated distillation in

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Figure 1

Figure 1: Figure 1

Figure 2

Figure 2: Figure 2

vacuum at 10^{-7} mm Hg; the nickel was of 99.99% composition, and the platinum 99.86%.

The choice of an alloy and of a pure metal was motivated by the desire to determine how the shape of the hillock-emitter changes when a second component is introduced into the metal. Platinum is the metal least subject to oxidation; therefore

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Fig. 1. *a*—tip-emitter of Ni—Be, 12 500×; *b*—electron image of the same tip

Fig. 2. *a* and *b*—tip-emitters of Ni—Be after retarded vacuum breakdown, 1400×; *v* and *g*—corresponding to *a* and *b* electron images on the projector screen; *d*—Pt subtip, 1400×; *e*—electron image corresponding to subtip *d*

Fig. 3. Electron image of a subtip of Ni—Be

Fig. 4. *a*—Ni—Be tip after repeated electrical breakdowns, 1400×; electron image of the same tip

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Fig. 1

Fig. 2

Fig. 3

Fig. 4

to a minimum, the possibility of obtaining a thick oxide film on the surface of the specimen during preparation before placement in the electron microscope was eliminated. Ordinary tips of the materials mentioned were prepared by electrolytic etching and smoothed by prolonged annealing in vacuum at a temperature 100-150° below the melting temperature. The tips obtained were practically hemispherical, with radius, in the case of the nickel—beryllium alloy, $\simeq 6 \cdot 10^{-5}$ cm, and for platinum $\simeq 3 \cdot 10^{-5}$ cm.

Figure 3

Figure 3: Figure 3

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Figure 4

Figure 4: Figure 4

The initial vacuum in the bulbs was obtained in compliance with the requirements of vacuum hygiene: degassing of the glass and metal parts, gettering, etc. The initial pressure in the bulb was less than 10^{-9} mm. Vacuum electrical breakdown was produced with the aid of a special pulse installation. An inductance was provided in the high-voltage circuit of the installation, causing interruption of the vacuum arc. The installation made it possible to regulate the frequency and magnitude of the pulses. After breakdown, images of emitter protrusions were observed on the projector screen.

Such protrusions were considered good if they produced on the screen a sufficiently stable and symmetric field-emission pattern of the crystal faces. After such protrusions had been obtained, the projector bulb was opened, the tip was cut off from the shank and placed on an objective grid for study in the electron microscope.

As can be seen in Fig. 1a, the initial vertices of the "macrotip" had a smoothed, practically hemispherical shape. After breakdown, the relief of the smoothed tip undergoes substantial changes. According to ([3]), a liquid phase may form at the site of the breakdown, and its drawing-out by ponderomotive electric forces leads to the formation of a protrusion.

Because of the short duration of the breakdown action, the liquid phase, having good thermal contact with the base, cools rapidly, which leads to the formation of a protrusion giving an image of a crystal that does not differ from the image of the macrotip. Such protrusions are shown for the Ni—Be alloy in Figs. 2a, b, and for platinum in Fig. 2c.

Figs. 2c, d, and e show field-emission images of these tips on the projector screen. Sometimes, in the process of formation of an emitter protrusion, it rotates, which leads to the formation of a characteristic "helical" structure observed on the projector screen (Fig. 3).

In cases where breakdown is carried out repeatedly, the surface of the macrotips (see Fig. 4a) proved to be strongly pitted, and many spots appeared on the projector screen. After heating, these spots, as a rule, did not give crystallographically regular images (see Fig. 4b). If the dimensions of the protrusions are determined from their images obtained in a transmission electron microscope, it turns out that their radius of curvature is approximately 10 times smaller than the radius of curvature of the "macrotip." Taking this size ratio into account, and also the circumstance that the protrusions are not "high," one can use, for determining the magnification of their electron image, Rose' s formula ([6])

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$$M_l = M_0 \cdot 1.1 \left(\frac{R}{\rho_0}\right)^{1/2},$$

where M_l is the magnification of the image of the hemisphere on the projector screen; M_0 is the magnification of the substrate tip; R is the radius of the substrate tip; ρ_0 is the radius of the hemisphere on the protrusion.

If the magnification is estimated by this formula, it turns out to be 3-5 times greater than that obtained with ordinary tips.

It should be noted that the smallness of the dimensions of a protrusion determines its short lifetime upon an increase in temperature and rapid equalization of the concentration in the event that it differs from the concentration of the base. Thus, possible doubts concerning the difference in concentration of the components in the base and in the protrusion are removed.

In conclusion, it may be said that the use of substrates ensures the obtaining of quantitative research results to the same extent as when ordinary tips produced by the etching method are used.

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