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Yu. V. VOROB'EV

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Abstract

Full Text

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Yu. V. VOROB' EV

ON THE POSSIBILITY OF INCREASING THE RESOLVING POWER OF AN EMISSION MICROSCOPE WITH THE AID OF AN ELECTRON MIRROR

(Presented by Academician A. A. Lebedev, March 7, 1958)

The resolving power of an emission microscope, as is known, is proportional to the intensity of the electric field at the cathode of the immersion objective of the microscope. The discharge arising between the electrodes of the objective at field intensities above 10–15 kV/mm practically limits the resolving power, which in existing emission microscopes reaches several hundred angstroms. The use of small aperture diaphragms has indeed made it possible to increase the resolving power somewhat; however, it still remains approximately an order of magnitude lower than the resolving power of transmission-type electron microscopes.

In the present work we shall show that, with the aid of an electron mirror used as a filter, it is possible to increase significantly the resolving power of an emission microscope.

Let us consider an emission electron microscope in which, after the projection lens, a plane electron mirror is installed perpendicular to the axis, throwing the image onto a screen. The optical scheme of an instrument of this type is presented in Fig. 1, where k is the cathode, o the objective, n the projector, z the mirror, and e the screen.

In calculating the resolving power we shall restrict ourselves to the case of a thermocathode. Let dN be the number of electrons which, per unit time, emerge from an element of the cathode df_0 located on the axis of symmetry of the system. Let, further, the spread of these electrons in energies and in directions be equal, respectively, to $d\varepsilon$ and $d\alpha$. Then, according to the Maxwell-Boltzmann law, we have

$$dN = Ce^{-\varepsilon/V_T}\varepsilon\, d\varepsilon \sin 2\alpha\, d\alpha, \tag{1}$$

where ε is the initial energy of the electrons; α is the initial inclination of the trajectories to the axis; $V_T = \dfrac{kT}{e} = \dfrac{T}{11600^\circ}$ V; T is the cathode temperature.

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Suppose that the electron beam passing within the angle $d\alpha$ penetrates an element $df = 2\pi r\,dr$ of the image plane. Through this area, per unit time, there arrive $dN = j_z 2\pi r\,dr$ electrons; j_z is the current density.

Since electrons fall on the electron mirror after passing through the objective and the projection lens, the electron beams have a very small aperture, and therefore the intrinsic aberrations of the electron mirror may be neglected.

The radius of the circle of confusion for an emission system in the image plane of particles with zero energy has the form [1]

$$r \simeq -\frac{\varepsilon}{E}\sin 2\alpha \cdot m,$$

whence, by the law of conservation of the number of particles, we obtain

$$dj_z = C' \frac{e^{-\varepsilon/V_T}\,d\varepsilon}{\sqrt{\frac{\varepsilon^2}{E^2}m^2 - r^2}}, \qquad r \leqslant \frac{\varepsilon}{E}|m|;$$

$$dj_z = 0, \qquad r > \frac{\varepsilon}{E}|m|.$$

If a potential V_0 relative to the cathode is applied to the surface of the mirror, then only those electrons whose initial energy $\varepsilon < V_0$ will participate in the formation of the image. Therefore, on a circle of radius r in the image plane from an element df_0 on the cathode there will fall a current

Fig. 1
Fig. 1

Fig. 2
Fig. 2

$$I(r) = 2\pi \int_0^{V_0}\int_0^r dj_z\,dr\,d\varepsilon = C''\left\{1 + \left(1 + \frac{V_0}{V_T}\right)e^{-V_0/V_T} - \int_{\varphi_0/V_T}^{V_0/V_T} e^{-u}\sqrt{u^2 - \frac{\varphi_0^2}{V_T^2}}\,du\right\},$$

where

$$\varphi_0 = rE/|m|.$$

If now the resolvable segment $\Delta r(V_0)$ is taken to be the radius of the circle on which 80% of the intensity falls, the calculation gives the dependence of the resolving power on the mirror potential V_0 shown in Fig. 2.

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Curve 1 gives the ratio $\Delta r(V_0)/\Delta r_\infty$, and curve 2 the ratio $I(V_0)/I_\infty$. Here Δr_∞ and I_∞ denote, respectively, the resolvable segment and the current density on the screen in the absence of the mirror.

It follows from these graphs, for example, that at a cathode current density of the order of 1 A/cm^2 and a magnification of 30,000 the image still remains visible on the screen when $V_0 = 0.5V_T$; in this case the resolving power of the microscope increases by approximately a factor of 7.

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1. Yu. V. Vorob' ev, ZhTF, **26**, no. 10, 2269 (1956).

Note: Figure translations are in progress. See original paper for figures.

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