EDGE FIELD EMITTER MADE OF CARBON FOIL

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Introduction

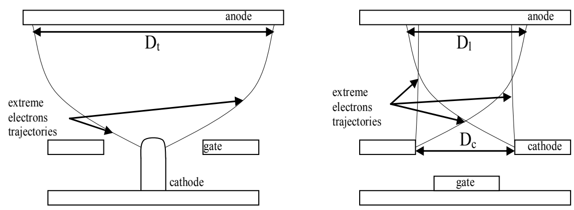
Field emission is caused by the high density of electric field near the surface of a conductor (~10^7 V/cm). Such a high value of the electric field density can not be effectively realized by controlling only electrodes potentials. Form-factor, i.e. geometrical parameters of the electron-optical system and the cathode as the part of the one, plays main role in the improvement of the field emitter operation. There are various approaches to the construction of the field emission device electron-optical system: Spindt-technology, thin-film emitters, surface emission device (SED) technology and so on.

Lateral edge field emitter is investigated in the work. In this construction field emission surface of the cathode is perpendicular to gate and anode plates of the device. The advantages of the system are emission surface area per cathode substrate area increase in comparison with Spindt systems, protection of the emission surface from the residual gases ions bombardment, inter electrode capacity decrease and economical methods of manufacturing [1]. Lateral edge emitter systems have already shown their advantages in various realizations. However, all of them meet a serious problem on the way of commercialization. Thin-film cathodes used in the constructions are not robust enough to the degradation processes. That makes the device life-time too short.

Carbon foil

After successful application of carbon foil cathodes in the classical construction of the electron-optical system [2] we propose to use the foil as lateral edge field emitter in the construction of planar electron source. This approach has such advantages as possibility to create an array of emission centers being parts of one common foil, the final device dimensions decrease, inter electrode spacing miniaturization and high precision, significant increase of the cathode emission surface area and consequently maximal operating currents of the device. For a micro tip emitter $S_t \sim r^2$, for lateral $S_l \sim D_c * h$, where r — radius of the tip curvature, D_c and h — diameter and thickness of the lateral cathode respectively. Due to the fact that $D_c >> r$ and $h \sim r$ one can estimate $S_l >> S_t$.

Emitting surface is formed of graphite layers protruding from the foil edge. Laser treatment is used to improve the morphology of the emitting surface. Under the action of fast heating during the laser beam pulse the structure of the emitting surface modifies. In the case of lateral cathode the laser treatment is used to create cathode holes in the carbon foil and simultaneously to form improved emitting surface at the edge of the cathode. Varying the power and diameter of the laser beam one can create cathode holes of definite form and morphology.



a *b*

Fig. 1. Classical (*a*) and lateral (*b*) constructions of the electron-optical system. D_t and D_l — diameters of electron beams in case of tip and lateral emitter respectively, D_c — diameter of the cathode hole in the lateral construction.

Self-focusing mechanism in case of ring shaped cathode

Mechanism of the electron beam diameter decrease is shown in Fig. 1. As one can see in the picture the value of the beam diameter decrease is the cathode hole diameter: $D_l \sim D_t - D_c$. The reason of the effect is that the emitting area is shifted from the axis of the electron beam and there is a part of emitted electrons trajectories, where electrons get closer to the axis. That decreases the final diameter of the electron beam.

Numerical simulation in "FOCUS" system was held to compare electron beams in case of classical and lateral cathode field emitter electron-optical systems. The simulation approved assumptions stated earlier.

Experiment

Cathodes were tested in triode structure. The cathode layer was separated from the gate electrode with an insulator of controlled thickness having wells at the cathode holes regions. Gate electrode was formed of the indium tin oxide layer on the glass substrate. Luminous anode was placed in the distance of 3 mm from the gate plate. During the experiment the pressure in the system was held on the level of 10^{-6} torr. Field emission image of a four hole-cathodes sample is represented in fig. 2. There was not a ballasting resistive layer in the construction of the cathode. However, tests revealed that due to the self ballasting of the cathode material and similarity of the cathodes emission characteristics each of the four cathodes took part in the emission process.

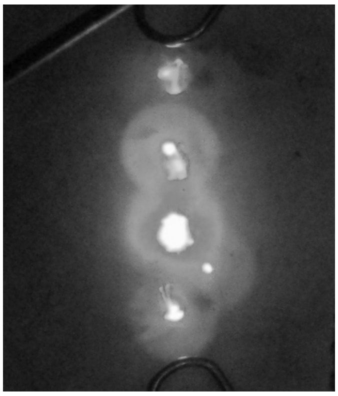


Fig. 2. Field emission image of the lateral cathode with four holes. U_a=2500 V, U_g=500 V, I_c=15 μA.

Emission current in the represented construction was well controlled by the gate voltage: $\Delta I_c[\Delta U_g=500\ V]=15\ \mu A$ (U_a=2500 V).

Luminous rings around the field emission image visible in the fig. 2 are caused by the secondary emission initiated by the field emission electrons bombarding the anode surface. The effect was described in the work [3]. In case the luminous area corresponding to separate cathode should be well localized (field emission display application) the effect can be neutralized with the application of protecting grid to the anode or using materials with low secondary emission factor. However this effect can give higher uniformity of the surface luminescence when light source of large luminous area is created.

Conclusions

Using a carbon foil as the lateral field emission cathode material provided for higher emission area, lower current load on separate emission center, lower device dimensions and separate cathode field emission image size. Proposed construction can be used for creation of flat panel display, broad area light source and other electro vacuum devices with powerful non-inertial electrons source.

References

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