TINY FIELD EMISSION ELECTRON SOURCE WITH CARBON FIBER CATHODE

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This work deals with development of field emission electron source with polyacrylic fiber cathode. For example such devices were studied in work [1]. Usage of polyacrylic fiber as cathode material brings several benefits such as ability to work in relatively low vacuum (about 10^{-6} Torr), simplicity of making an emitter, high current stability and long life time.

Field emission electron guns are usually build under triode scheme. Such construction consists of electron source (cathode), control electrode (modulator or grid) and electron receiver (anode). For such construction to work correctly both modulator and anode should have positive contribution to electric field near the cathode. Hence both these electrodes should have positive potential with respect to cathode.

Such construction has several disadvantages. First of all modulator intercepts a portion of current flowing from cathode. This problem easily solves together with second problem as we will see further.

The second problem is excessive complexity of control circuit. Cathode current can be controlled using negative voltage when modulator is grounded. Such method requires voltage inverting circuit. Second possibility is to control current with positive voltages on grid. Unfortunately this way has a problem with output stage of modulator voltage source. Due to possible current interception current can flow into modulator. Also parasitic emission from modulator can exist. Due to it in closed electron gun current can flow from modulator to anode.

Due to possibility of current flowing in both directions modulator voltage source's output stage circuit becomes excessively complex. In such scheme dangerous voltage jumps can arise. Such situation is very unpleasant because this can damage the cathode.

Considering the aforesaid we made decision to shift transfer characteristics to the region of positive voltages on cathode with respect to modulator. To control such construction one can ground modulator and control cathode current using simple transistor circuit. Another benefit of such construction is positive voltage on cathode with respect to modulator. This prevents current interception by grid and solves first problem as we mentioned earlier.

Also such connection of electron gun uses only one high voltage source. This gradually simplifies control circuit.

For electron gun to have such characteristic one should gradually increase anode influence on electric field in vicinity of cathode. Also influence of modulator on field shouldn't be lower than in classic construction because we need slope of transfer characteristic to remain high. This allows us to use cheap control transistors which can operate only in low emitter-collector voltages.

Numerical calculation model was created to determine required construction of electron gun. To simplify calculation we assume that polyacrylic fiber bundle can be approximated by cylinder with spherical cap. Such assumption enables us to use simple axissymmetrical model for calculations. Model used is shown on Fig. 1.

After it Laplace equation was solved in this geometry with different R and H and electric field in vicinity of cathode was studied. Using these results field amplification coefficients of anode and modulator was calculated. After it special calibration dependencies were created by direct current measurements in diode construction. These dependencies were used to calculate parameters of transfer characteristics such as maximum current and slope.

Special assumption used for approximate estimation of optimum parameters range. The ratio of anode voltage with respect to cathode to cathode voltage with respect to modulator assumed to be equal to ratio of anode field amplification coefficient to modulator field amplification coefficient in proximity of cathode. In turn field amplification coefficients can be considered to be linear by distance in first order of accuracy. Numerical calculations show that this assumption is correct in considered construction of electron gun.

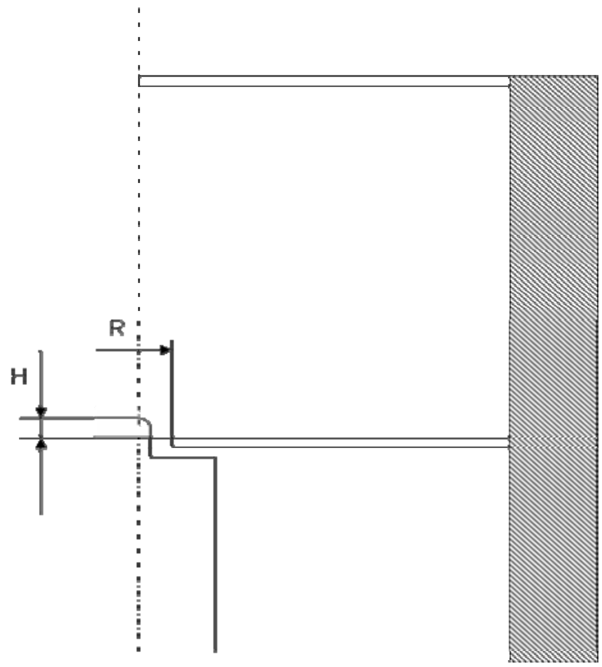

Fig. 1. Numerical model geometry.

The optimal geometric parameters have been found by this method. Finally the construction presented on Figure 2 has been proposed.

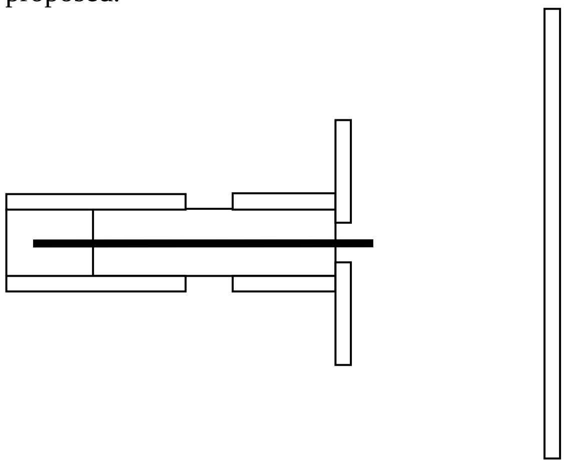

Fig. 2. Proposed electron gun construction.

Moreover such construction has not only the necessary electrical characteristics but it also has very good manufacturability due to simplicity of modulator fixation. Modulator can be positioned without any spacers. Also the gun itself consists only of 4 elements. This increases reliability of whole system.

For experimental study of construction operability a number of electron guns have been created. It has been tested in vacuum chamber and electrical parameters have been measured. These measures have shown that with 7 kV anode voltage gun closes at mean control voltage of 800 V and mean maximum current is 100 uA. A set of transfer characteristics of one electron gun is shown in Fig. 3. Characteristics have been measured with 6 kV, 7 kV and 8 kV anode voltages. Also current interception by modulator equals zero as it was expected.

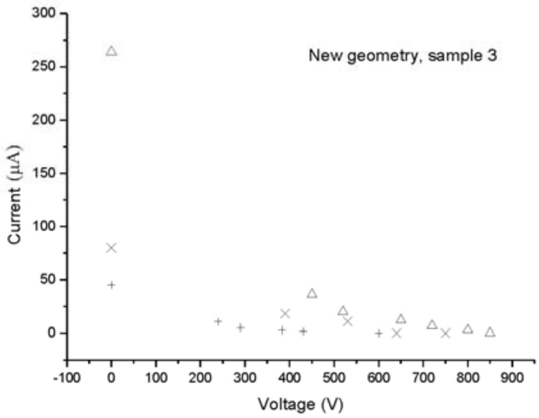

Fig. 3. Transfer characteristics measured on one of samples.

References

1. Leshukov M. Yu., Baturin A. S., Chadaev N. N., Sheshin E. P. Characterization of light sources with carbon fiber cathodes, Applied Surface Science. 2003; 215: 260–264.