

NEW DESIGN OF ELECTRON GUN FOR FIELD EMISSION LIGHT SOURCES WITH CARBON FIBERS CATHODE

Leshukov M.Yu.*, **Sheshin E.P.**

Moscow Institute of Physics and Technology, Russia
 Institutskii Per. 9, Dolgoprudny 141704, Moscow Region, Russia
 * Fax: +7 (095) 409-95-43, E-mail: mike@lafeet.mipt.ru

Introduction

An efficiency of the cathodoluminescent light source depends directly from the efficiencies of its basic components: an electron gun and luminescent covering. The diminishing of the power consumption and the increasing of the cathodoluminescent lamps efficiency are provided with application of field emission cathodes made of carbon fibers.

Such field emission cathodes require no heating, they are not inertial. These cathodes are stable against temperature fluctuations, and they possess a high density of field emission current and a high slope of current-voltage characteristics. The field emission cathodes based on carbon fibers have a sustained performance in conditions of technical vacuum ($\sim 10^{-4}$ Pa)

The purpose of the current work is the development of the effective electron-optical system for the cathodoluminescent light source with the field emission cathode based on polyacrylonitrile (PAN) carbon fibers [1].

Electron-optical system of the light source with field emission cathode

The electron-optical system of the cathodoluminescent lamp consists of electron gun and luminescent screen, which is covered by phosphor. It represents the triode construction. The base of this triode is the cathode-modulator unit (CMU) that consists of field emission cathode and extraction electrode (modulator).

The field emission cathode is made of PAN carbon fibers bundle encapsulated into the glass capillary. The diameter of the single fiber is 7 μm (the bundle contains about 300 fibers).

The anode of the lamp is supplied with positive high voltage $+U_A$. The cathode potential is grounded, and the modulator is supplied with positive control voltage. Electrons are extracted by the modulator and accelerated by the anode voltage. Phosphor glows under the influence of high-energy electrons.

The electron-optical system of a lamp should provide high operating ratio of field emission current emitted by the cathode. Earlier the prototype design of the electron gun with field emission cathode based on a bundle of carbon fibers has already been presented [2]. The first disadvantage of

that electron gun was a sufficient modulator current (10-20% of the total current from the cathode).

In other words a considerable portion of electron flow from the cathode come upon the control electrode (fig. 1a), decreasing the efficiency of

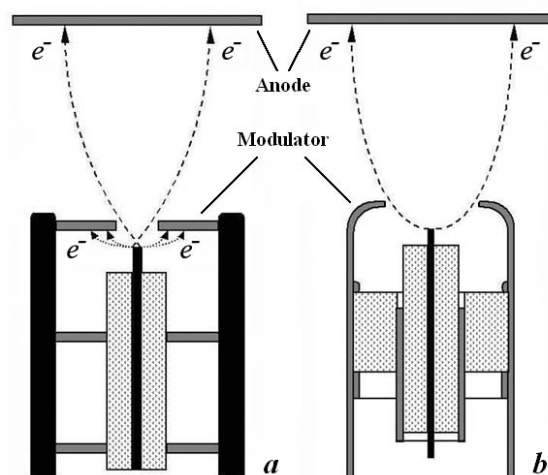


Fig. 1. Cathode-modulator unit: *a* — prototype design; *b* — new optimized design

electron projector. And the second disadvantage is that operating voltages of the control electrode were sufficiently high (in the range 1.5-2.0 kV).

In order to increase the efficiency of electron projector a modernization of the cathode-modulator unit of the lamp was carried out. The new design of electron gun was offered (fig. 1b). It possesses the higher transmission of the cathode current (the modulator current is less than 1% of total cathode current) against the prototype design of CMU, where the essential portion of electrons is certainly held up by the control electrode.

The current-voltage characteristics for the electron gun with the prototype (fig. 2a) and the new (fig. 2b) CMU design were measured. As one can see, at the anode voltage +10 kV (an operation mode for the cathodoluminescent lamps) the maximum value of the modulator voltage is 1200-1300 V (at the cathode current 100 μA).

Forming the emitting surface of the field emission cathode made of carbon fibers bundle

Creation of the advanced emitting surface of the field emission cathode is provided not only by an internal structure of carbon fibers, but also by corresponding preliminary forming of the cathode.

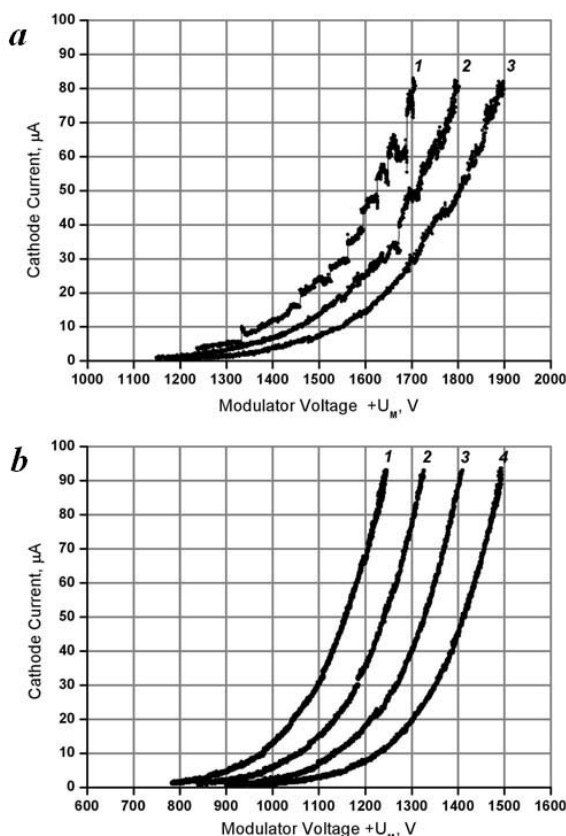


Fig. 2. The dependence of the cathode current on the voltage of control electrode for the CMU of the prototype design (a) and the new optimized design (b) at different anode voltages: 1 — $U_A = +10$ kV, 2 — $U_A = +9$ kV, 3 — $U_A = +8$ kV, 4 — $U_A = +7$ kV

It is necessary to shape the carbon fibers bundle into such geometrical form, which would provide a

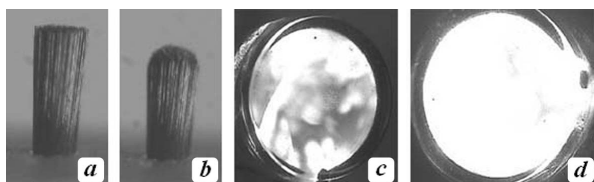


Fig. 3. The non-forming carbon fibers bundle (a) and its field emission image (c). The carbon fibers bundle etched by plasma-chemical method (b) and its field emission image (d)

maximum quantity of the emission tips in regular intervals located on its surface giving about the identical contribution to the general field emission current.

Using the plasma-chemical method [3] of etching it was possible to receive the corresponding

structure of carbon fibers bundle.

The carbon fibers bundles structures of the raw cathode and the cathode etched by the plasma-chemical method are represented in fig. 3. Their corresponding field emission images are also presented there.

At plasma-chemical etching process the carbon fibers bundle gets the rounded form: prominent fibers are absent, and peripheral — are short. At that time the uniformity of the luminescent screen radiation essentially improves.

The obtained data testify that the much greater number of fibers works, and the field emission tips after the forming process are distributed more regular on the surface of the cathode.

Conclusions

The effective electron-optical system with the field emission cathode based on PAN carbon fibers is developed. Modernization of electron gun design has allowed to decrease operating voltages of the light source essentially and to enhance the cathode current transmitting.

The decrease of operating voltages down to a level less than 1500 V specifies an opportunity of developing the control circuit with use of existing high-voltage transistors.

The uniformity of the field emission image was greatly improved by means of preliminary plasma-chemical processing of carbon fibers bundle.

Acknowledgements

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References

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