Problems in obtaining high emission current densities for matrix field emission cathodes based on carbon nanotubes

V.Labunov[1], B.Shulitski[1], A.Tymoshchyk[1], N.Kargin[2]
[1]*Belarusian State university of Informatics and Radioelectronics, 220013 Minsk, Belarus*
[2]*National Research Nuclear University "MEPhI" 115409 Moscow, Russia*
labunov@bsuir.by

For some important applications, particularly in the field of microwave electronics (triodes, klystrons, traveling wave tubes), using carbon nanotubes based field emission cathodes (CNT FECs), required field emission current density (J_{FE}) >of 1 A/cm^2 with the cathode working area (S_W) > of 1 cm^2. Until resently CNT FECs with such parameters are not created. In this article we analyze the problems related to the obtaining high J_{FE} value of CNT FECs.

CNT FECs were produced by CVD method by high temperature catalytic pyrolysis of the hydrocarbon mixtures of decan ($C_{10}H_{22}$) (0,15 cm^3/min) with ferrocene ($(C_5H_5)_2Fe$) in the presence of localized and pre-structured catalyst on the substrate. Dependence of the emission current density on the area of the CNT FECs matrix and the frequency of applied voltage have been investigated.

The maximum values of current density J_{FE} of 110 A/cm^2 were obtained in DC mode with a working area of the cathode $S_w = 2{,}5 \cdot 10^{-7}$ cm^2. With the increase of the FECs area the current density was sharply falling down. For example, at $S_w = 1{,}7 \cdot 10^{-4}$ cm^2 the current density J_{FE} reached the of 2.0 A/cm^2. In the AC mode with the same working area of the cathode $S_w = 1{,}7 \cdot 10^{-4}$ cm^2 the value J_{FE} reached of 70 A/cm^2, that can be associated with decreasing the load on the cathode and decreasing of the cathode bombardment by ions of residual gases. However, with the increasing of the area are seeing the same - a sharp decline in the values of the current density.

On the basis of analysis and comparison of I-V graphs, Fowler-Nordheim curves, as well as images of the emission area, obtained by using the built-in video camera (Fig. 1), an analysis of the possible reasons of the declining behawior of J-S characteristic was carried out.

It is established that in the current range 10^{-6} - 10^{-5} A change occurs of tangent slope of F-N curves. Analysis of images of real-time video shows the appearance of a glow effects in the area of field emitting cathode for currents in the same range. The glow effects in the region of cathode was noted by the authors of [1, 2], but the nature of the emission was estimated as ambiguous. In [1] glow effects are associated with the phenomenon of fluorescence, but in [2] shows that the emission is due to thermal heating (Planck thermal radiation). Based on a comparison and analysis of the I-V characteristics and real-time video of field emitters area, we find a phenomenon of migration of this thermal radiation on the emission area. Migration of termal radiation on the emission area indicate presence of cathode macro- and micro-inhomogeneities that prevent to obtain of homogen emission from whole surface of cathode and limit field emission current.

It is shown that to increase the current density of CNT FEC requires search of synthesis technology of CNT with unified height, diameter and distancing at the required surface area of the cathode matrix with low micro-and macroinhomogeneity of structure. The solution to this problem would open the way to creation of new generation of devices and field emission devices of microwave electronics on the basis of CNT FEC.

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[2] S. Purcell et all. Physical Review Letters. V. 88, number 10 (2002).

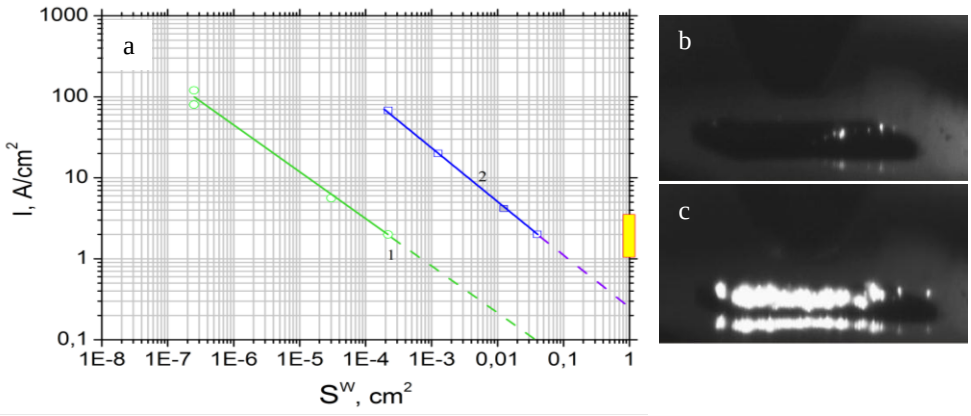

Fig. 1 (a) J – S characteristics; (b, c) image of emission areas, obtained in real time.