Degradation of a CNT-based field emission cathode due to ion sputtering

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The rate of degradation of carbon nanotubes (CNT) comprising a field emission cathode is calculated. The sputtering of CNT material by incident ions formed through the electron impact ionization of the residual gas molecules is considered as the degradation mechanism. It has been found the abrupt dependence of the degradation rate on the applied voltage which is caused by a sharp character of the Fowler-Nordheim dependence.

The rate of degradation of a CNT was calculated using the following expression

$$\frac{dm_c}{dt} = \frac{M_c I N_M}{e} \int_{r_o}^{R} \sigma_{ion}[E_e(x)] Y[E_i(x)] dx = \frac{M_c I N_M}{e} J(U)\,, \qquad (1)$$

where M_c is the mass of the carbon atom; the axis x coincides with the direction of the electrical field so that the point $x = 0$ corresponds to the nanotube's tip; $N_e(x)$ is the electron number density; I is the emission current; $v_e(x)$ is the electron velocity; $E_e(x)$ is the electron energy that is determined by the distribution of the electrical potential $U(x)$ along the electrical field; $E_i(x)$ is the kinetic energy of an ion formed in the x and reached the emitter surface in the point $x = 0$; N_m is the number density of the residual gas molecules subjected to the electron impact ionization; $\sigma_{ion}[E_e(x)]$ is the electron impact ionization cross section for the residual gas molecules; $S(x)$ is the cross section of the cone where the electron beam is found; $Y[E_i(x)]$ is the ion sputtering coefficient. The applied voltage and the emission current are inter-connected through the Fowler-Nordheim equation with taking into account the electrical field amplification factor for a CNT of specific geometry. The results of calculation are shown on Figure.

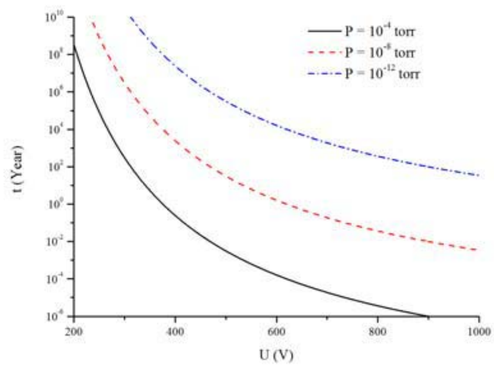

Figure. Dependences of the lifetime of a nanotube defined as $t = M_t \big/ \frac{dm}{dt}$ on the applied voltage calculated for a CNT of $d = 10$ nm in diameter and $L = 1$ μm in height on the basis of Eq. (1) at various residual gas (air) pressures. The inter-electrode distance $H = 100$ μm, the electron work function for a nanotube $\varphi = 5$ eV.