Investigation of the nature of low-frequency fluctuations of the field emission current using a two-dimensional distribution function

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(Submitted April 27, 1998)

A two-dimensional distribution function in the frequency range 0.03–1 Hz was used to investigate the statistical characteristics of the fluctuations of the field emission current from single crystals of tungsten and p-type silicon. In order to determine the type of nonlinearity predominating in the low-frequency noise of the emission current, calculations were made of the two-dimensional distribution function for a Gaussian random process subjected to a given type of nonlinear transformation and the profiles of the experimental two-dimensional distribution functions were compared with dependences obtained by numerical methods. It was established that fluctuations of the effective emitting surface of the cathode, the barrier transmission, the work function, and of the electric field strength near the emitter surface may act as primary sources of low-frequency noise in the field emission current.

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dimensional distribution function for a tungsten single crystal are more extended but narrower (Fig. 1b), which we attributed previously to the appearance of nonlinear effects. For the simulation we used the dependence as the most natural form of the nonlinear transformation of primary Gaussian noise for metal and semiconducting field emitters. Note that the nonlinear dependence for \( j(a,b,F,\varphi) \) is only preserved for the last three arguments, although it was important to ensure continuity of the function \( H(X(t)) \), which describes the nonlinear transformation of the fluctuation process \( X(t) \). This situation arose because in order to obtain a function with a particular profile, it was necessary to use two regions of variation of the argument and two analytic functions which determine the form of \( H(X(t)) \).

For the fluctuating parameter \( b \) the function \( H(b) \) consisted of a linear function set which changes to exponential,

\[
H(b) = \begin{cases} 
  b, & b \leq 0, \\
  \text{const} \times \left[ \exp\left( \frac{b}{\text{const}1} \right) - 1 \right], & b > 0.
\end{cases}
\]

For the nonlinear transformations \( H(F) \) of the electric field fluctuations \( F(t) \) and \( H(\varphi) \) of the work function fluctuations \( \varphi(t) \), it was necessary to use the sum of linear and exponential dependences

\[
H(F) = \begin{cases} 
  F, & F \leq 0, \\
  F + a \left( F^2 \exp\left( -\frac{\text{const}2}{F} \right) \right), & F > 0;
\end{cases}
\]

\[
H(\varphi) = \begin{cases} 
  \varphi, & \varphi \leq 0, \\
  \varphi + a \left( \exp\left( -\frac{\varphi^{3/2}}{\text{const}3} \right) \right), & \varphi > 0.
\end{cases}
\]

From the point of view of the physical mechanism for the occurrence of the fluctuations, the difference between the forms of Eqs. (3) and (4) compared with Eq. (2) may be explained by the fact that the fluctuations \( F(t) \) and \( \varphi(t) \) are local, whereas the fluctuations of the barrier transmission \( b(t) \) embrace the complete emitting surface of the cathode. Thus, the equivalent electrical circuits (3) and (4) com-