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Simulation Of the Heat Transfer in the Nanocathode

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Abstract—The heat transfer processis simulated in a nano-sized cone-shaped cathode. A model of heat transfer is cons using the phase field system and theNottingham effect. We considerinfluence of the free boundary curvature and the Notti effect on the heat balance in the cathode.

Keywords—thermo-field emission, cathode, Nottingham effect, free boundary, phase field system, Stefan-Gibbs-Th problem

1. Introduction and Statement of the Problem

Our main goal is to simulate the heat transfer ina doped silicon nanocathode. Thecathode has the shape of a blunted cone and the following linear dimensions:

height of the cathode	10−15 μ
diameter of the cathode base	~6 μ
radius of the cathode vertex rounding	~15 nm
cathode vertex angle	~20°

Such a shape of the cathode is specified by the engineering process, see Fig.1.Such cathodes are used in the electron microscope and in other electron devices.

An obstacle for a wide use of this cathode is the instability of electron emission. This instability is in fact caused by the small size of the cathode.The cathode is heated due tothe Joule effect. The current in the cathode is very large and the Joule heat can melt the cathode.

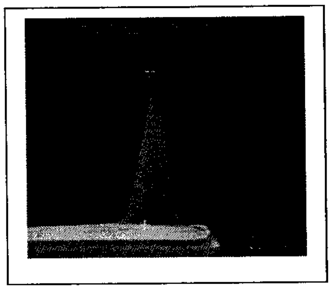

Figure 1. REM image of the silicon nanocathode.

The effect of the cathode melting is confirmed experimentally. Namely, the produced molten (liquid) layer does not contain a small region near the vertex of the cathode cone. At the sam the cathode material remains solid near the base. So observe the following sequence of layers: solid, liquid, is experimentally known that the liquid layer becom after some (unknown) time.

We present an explanation of this fact in this pap motion of the free boundary (the interface between the depends on the curvature of the free boundary Nottingham effect. Namely, the temperature dependence free boundary curvature is determined by the Gibbs-Th law [8, 9]. The Nottingham effect determines the temp of the cathode vertex under the thermoemission of elect More precisely, the Nottingham effect consists in the fo If the temperature of the cathode vertex is higher than called inverse temperature, then the vertex is cooled; temperature of the cathode vertex is lower than this temperature, then the vertex is heated.

The mathematical model of the heat transferin the fieldemission is known (see [6]),

$$\rho c(T)\frac{\partial T}{\partial t}=\nabla\left(\lambda(T)\nabla T\right)+F,\ \ \operatorname{div} j=0.$$

Here T isthetemperature, ρ isthedensity, c isthespecific isthespecific heat capacity, F is the power density of emission under the Joule and Thomson effects, and $\boldsymbol{j}$