NANOSCALE IRREGULARITY EFFECTS IN THE FIELD EMISSION OF METAL SURFACES.

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Present vacuum microelectronics technology (VMET) is a field that has gained a great and sustained impulse during the last few decades. Electrons emitted from very sharp tips, as a result of an externally applied electric field, which is a consequence of a potential bias, tunnel through a potential energy barrier, resulting in an electric current. Since some applications require strong electric currents under low voltages, investigations of low work-function materials or structures are of great practical importance. The next generation of such electron emitters requires a fine tuning of several parameters such as material work-function, surface structure, field strength, and temperature, in order to warrant that most part of the emission originates from electronic energy levels in the vicinity of the potential barrier.

Some results [1,2] suggest that a substantial reduction in the emitting field can be achieved by using cathode surfaces with fractal structure of increasing self-similarity. In previous works, [3,4] some of us explored the scaling behavior of equipotential surfaces in an electric field generated by conductors with fractal geometry. The results were analyzed for models of **D+1** dimensions, with **D=1,2**.

The purpose of this work is to present a theoretical analysis of the influence of the irregular structure of cold emitted conductors on the emission properties. First, we discuss the connection between the geometrical properties of the emitter surface generated by **fBm** algorithm [5], fractal dimension $\mathbf{d_f}$, roughness **W**, and the local intensity of electric field. Our results suggest that the fractal dimension may be related to the field amplification factor, while the total emission current is determined by the roughness of the surface [5]. These results were supported by the analysis of the Fowler plots (FP), which relates the average emission current, **<J>,** with respect to the anode potential (see Fig. 1). Also, it is possible to observe the relation between the effective field amplification and the irregularities at nanometric scales by performing a comparison between the electric field intensity and local roughness distributions. We believe that these results can help to explain some differences between theoretical calculations with smooth geometries and experimental studies, which predict high values of the field amplification factor and very small values of effective emitting area.

In addition, we investigate, the case of a metallic cathode surface composed by an “array” of nanopyramidal structures*. It is possible to determine the influence, on the emission properties, of parameters like the distance anode-cathode and number of pyramids per unit of area of the underlying surface. The results demonstrate that the inter-pyramidal distance (δ), exhibits an important effect in the optimisation of the maxima field amplification factor (γ^{max}) (see Fig. 2).

*** These analyses were done in collaboration with Profs. Caio Castilho and Fernando Mota, of the Physics and Materials Surfaces´s Group of Universidade Federal da Bahia, Brazil.**

References:

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Figures:

Fig1:. Fowler-Nordheim plot, representing how the average current density depends on the anode electric potential. Circles, triangles, squares and diamonds represent the emission surfaces in descending order of roughness.

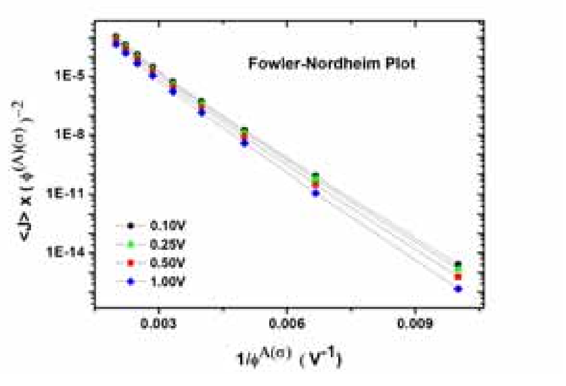

Fig2:. Maxima field amplification factor, γ^{max}, as a function of inter-pyramidal distance δ. In this case, we considerate the cathode formed by 16 pyramidal structures in a regular disposition, and the anode potential 250V. The horizontal line indicates the value of the maxima field amplification factor on top of an isolated pyramidal structure.