Effect of nano-irregularities in the work function and field emission properties of metallic surfaces.

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An important property that significantly affects the emitting properties of a metal film is the work function (WF). This concept is related to the total energy variation of the metal sample when an electron in the Fermi level is completely removed. Accordingly, the WF can be determined as the electronic energy difference between the associated initial and final state, this one being the condition after complete removal of the electron previously at the Fermi level. The WF is strongly affected by the conditions of the metal surface [1]. These conditions include the presence of contaminants (in quantities lower than one monolayer), the occurrence of oxidation and other chemical reactions, unequal distribution of adsorbates, crystallographic orientation, etc

As a matter of fact, the micro-geometry of the surfaces of practical electron emitters is far from being smooth. Even in the best cases, when the use of crystalline materials results in a smoother surface, it is important to keep in mind that the surface results from a combination of several facets, leading to an irregular surface in a micrometric scale. In a previous paper [2], in a tentative of reproducing geometrical defects associated to real metallic surfaces by computational simulation, it was studied how the surface roughness and fractal dimension affect their emitting properties. The results lead to the conclusion that, while the roughness exhibits a significant influence in the electronic current density, the fractal dimension would be related to the electric field amplification factor – an information which is embedded in the Fowler-Nordheim (FN) plots.

The aim of this work is to analyze how the nano-irregular geometry of the surface of a metallic profile affects the corresponding WF and, as result of this, the effect on the emitting properties. In doing this, it was considered a simplified model of rectangular fractures, using a classical formalism for the WF determination. Within this formalism, the WF of a solid is defined as the minimum energy required for removing an electron at the surface of the solid, with an initial energy equal to the one of the Fermi level, till a point situated far away form the solid. By using the classical method of images, it was possible to determine how the WF is related to the fracture size. It were also analyzed the properties of the emission current density when the solid is under the influence of an applied external electric field. In order to compute the electronic current density, it was used the model recently proposed by Forbes [3,4] where it was considered a reasonable approximation for the elliptical functions which characterize the potential barrier to which the electron is subjected.

References:

[1] N. A. Burnhama, R. J. Colton, H. M. Pollock, Phys:. Rev. Lett., **69**, 144 (1992) .
[2] T. A. de Assis, F. Borondo, R. M. Benito, R. F. S. Andrade, Phys.: Rev. B, **78**, 235427 (2008).
[3] R. G. Forbes, Appl. Phys. Lett., **89**, 113122 (2006).
[4] R. G. Forbes, J. H. B. Deane, Proc. R. Soc. Lond. A, **463**, 2907 (2007).