USING FOWLER-NORDHEIM OR MURPHY-GOOD PLOTS TO MEASURE CHARACTERISTIC VALUES OF FIELD AND SCALED FIELD

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ABSTRACT

An *ideal* field electron emission (FE) device/system has its measured current-voltage [$I_m(V_m)$] characteristics determined only by unchanging system geometry, unchanging emitter surface composition, and the electron emission process. Being "ideal" requires that there be no "complications", such as significant voltage drops along the emitter. Many devices are not ideal.

In modern FE theory, based on the Schottky-Nordheim (SN) ("planar image-rounded") tunnelling barrier, the *scaled field f* is related to the local barrier field F by the equation

$$f \equiv F/F_R \equiv (e^3/4\pi\varepsilon_0)\phi^{-2}F ,$$

where e is the elementary charge, ϕ is the relevant local work function, and F_R is the "reference barrier field" need to pull the top of the SN barrier down to the Fermi level. This parameter f is useful both for discussing experimental results and for simulating emission currents.

This Poster aims to remind people of two things. First, that there exists an "orthodoxy test" [1] that can be applied to $I_m(V_m)$ data, to find out whether the device is ideal. Second, that (for an ideal FE device/system) one can use a Fowler-Nordheim plot or a Murphy-Good plot [2] to "*measure*" the values of characteristic (apex) field F_C and/or scaled-field (f_C) at which the device is operating. Tungsten emitters (with assumed ϕ= 4.50 eV) often operate in the range $0.2<f_C<0.3$ (though sometimes higher), which corresponds to a barrier-field range 2.8 V/nm$<F_C<$ 4.2 V/nm.

This "measurement" assumes SN barrier theory, but has been validated, with a consistency probably of order 20% to 30%, in 1950s work [3]. An FE operating field has recently been measured by a totally independent experimental electron microscope method [4], and yields the result 2.92 V/nm. This also is consistent with the "measurement" method described here.

Some carbon field emitters exhibit "low-macroscopic-field" (LMF) emission. Special explanations have been offered (e.g., resonance tunnelling). However, some relevant papers (e.g. [5]) report FN plots. Using these to measure local barrier fields suggests that, in fact, these fields are in the normal range (a few V/nm). Thus, an alternative explanation of this LMF emission may be that carbon nanostructures can exhibit anomalously high field enhancement factors. In the context of vacuum breakdown, this is an interesting hypothesis.

References

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