USING FOWLER-NORDHEIM PLOT FOR THE COMPARISON OF ELECTRON EMISSION EFFICIENCY OF FIELD (FE) AND THERMAL EMISSION (TE) CATHODES

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ABSTRACT

The commonest method of characterising a cold field electron emitter is to measure its current-voltage characteristics, and the commonest method of analysing these characteristics is by means of a Fowler-Nordheim (FN) plot [1]. But for the comparison of electron emission efficiency of field emission (FE) and other electron emission mechanism, particularly with regard to thermal emission (TE), an extended use of FN plot is proposed. For this the inverse voltage (x-axis of FN plot) is extended with factor $1 = I_E/I_E$:

$$\frac{1}{U_{extr}} = \frac{1 \cdot I_E}{U_{extr} \cdot I_E} = \frac{I_E}{P_{extr}} = \frac{\boldsymbol{I_E}}{\boldsymbol{P_{el}}} \qquad [V^{-1}] \qquad (1),$$

where U_{extr} is the extraction voltage of FE, I_E is the electron emission current, and P_{el} is the electrical power required for this current I_E. The relation I_E/P_{el}, easy to measure (e.g. for TE is $P_{el} = P_{heat}$), is therefore a simple criterion reflecting the electron emission efficiency, independent of the kind of electron emission mechanism.

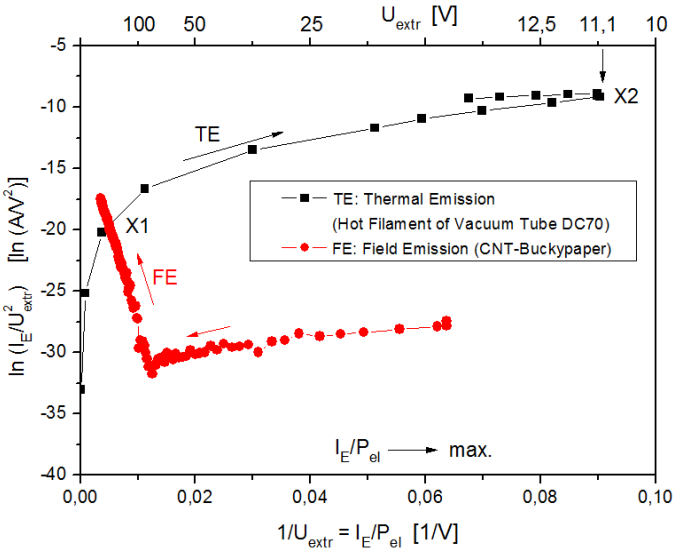

Fig. 1 FN plots of field (FE) and thermal emission (TE).

Fig. 1 shows a FN plot with the characteristics of FE and TE cathodes. The comparison is based on the calculation of a fictive extraction voltage for TE: $U^*_{extr} = P_{heat}/I_E$. Interesting results are:

- For higher emission current I_E: TE has an increasing and FE has a decreasing emission efficiency!
- The cross-over point X1 has a current of $I_{E\_X1} = 117\ \mu A$. For $I_E > I_{E\_X1}$ TE becomes more efficient.
- FE requires more voltage U_{extr} for higher emission current I_E. With higher voltage a transition to glow discharge or even vacuum micro-arcs are more likely to take action, if $I_E > 0.1 \ldots 1.0\ mA$ for GD [2].

This comparison, further and improved measurements and results, will be presented and discussed.

References

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[2] W. Knapp, "Energetic evaluation of the transition from field electron emission to plasma discharges with extended use of the Fowler-Nordheim plot". 30th IVNC 2017, July 10-14, Regensburg, Germany, TECHNICAL DIGEST, p. 35/36.