Computer Modeling of the Schottky Electron Source

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The Schottky Electron source (SE) has become the most used source in electron optical systems where high brightness and/or small energy spread are required. A computer modeling program has been developed that allows the computation of important source parameters for the SE source such as the virtual source size (d_v) and total energy distribution (TED). A commercial charge density boundary element method program (CPO3D by Electron Optics Ltd.) was used to evaluate the source geometry. This program calculated the surface charge density and the electric field $F(z)$ normal to the surface calculated which allowed trajectories of emitted electrons to be calculated along with the TED and d_v. These calculations were performed both with and without coulomb interactions included. The ratio of $I'/J=K$ was also computed, where I' is the axial current per unit solid angle and J is the axial current density. This program allowed for distinction among the three major equilibrium faceted shapes, which have been reported previously[1]. In some instances the Stage 0 end form was separated into a Stage 0-a or 0-b depending on whether the four side (110) planes intersect the rounded, central (100) plane[2]. The axial value of field factor $\beta=F/V$ (where F and V are the applied field and extraction voltage respectively) was found to follow a power law dependence on K as the emitter inscribed radius varied from 200 to 700 nm. The latter relationship holds regardless of the end form as observed in Fig. 1 and allows for the accurate conversion of experimental I' values to J.

The computed values of the axial d_v (with coulomb interactions) normalized by the intrinsic d_v(int.) (without coulomb interactions) are shown in Fig. 2 for the same emitter data set given in Fig. 1 and for I' values from 0.25 to 1.0 mA/sr. A linear relationship with J is observed for d_v/d(int.) independent of the stage end form. Similarly the values of the full width of the TED curves containing 50% of the current (FW50) normalized by the FW50(int) values versus I' are shown in Fig. 3. In this case experimental values are shown which are supported by the computed values. The data can be fit to a 2nd order polynomial with reasonable accuracy – again the relationship is not altered by the various end form stages and radii which vary from 300 to 800 nm. It is interesting to note from Figs. 2 and 3 that at $I' \approx 0.5$ mA/sr the coulomb interactions have increased d_v over its intrinsic value by 15% whereas the FW50 value has increased by 50%

Another computer program using the experimental $I'(V)$ data along with the Fig. 1 $\beta(K)$ relationship calculates the emitter work function (φ) and β values. With values of K, φ and F one can determine FW50(int) and d_v(int) which along with the empirical relationships in Figs. 2 and 3 allows d_v and FW50 values to be calculated for a given I' value. In addition, the reduced brightness (B_r)[3] can be determined from $B_r = 4I'/\pi d_v^2 = 1.44J/\pi kT$. However it should be pointed out that, in contrast to the FW50 values, d_v has a z dependence so for electron optical applications it matters where the beam defining aperture is located. In this study the measuring plane for d_v was located 3 mm downstream from the emitter.

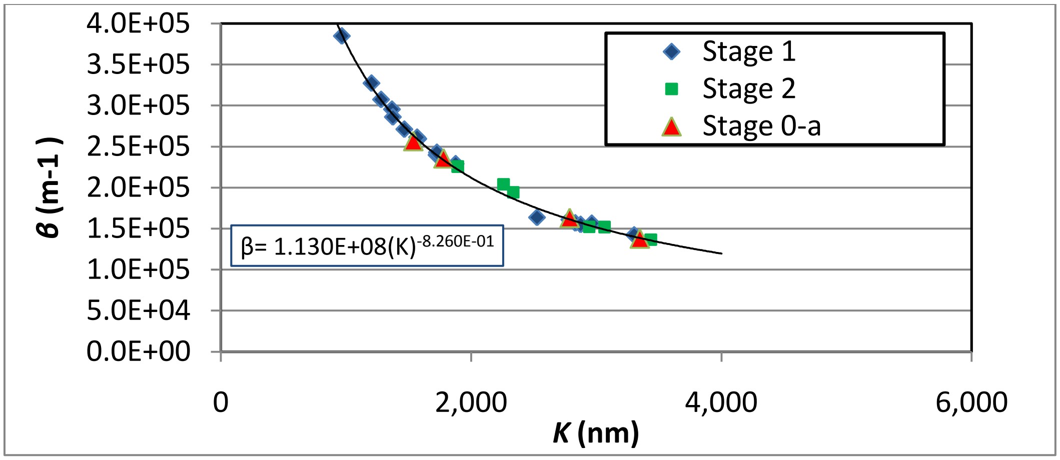

Fig. 1 The calculated axial values of β vs. K can be fitted with a power law relationship.

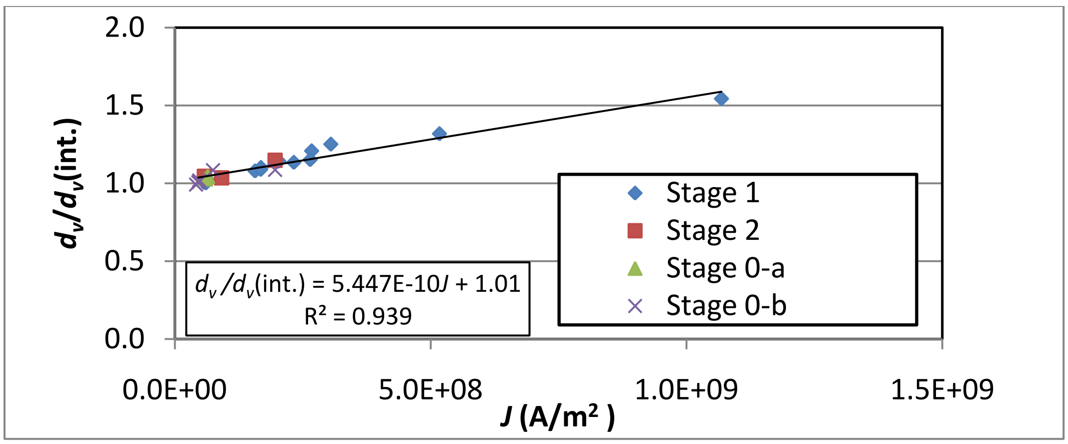

Fig. 2 The computer calculated d_v (with coulomb interactions) normalized by the intrinsic d_v(int.) (no coulomb interactions) shows a linear relationship with *J*.

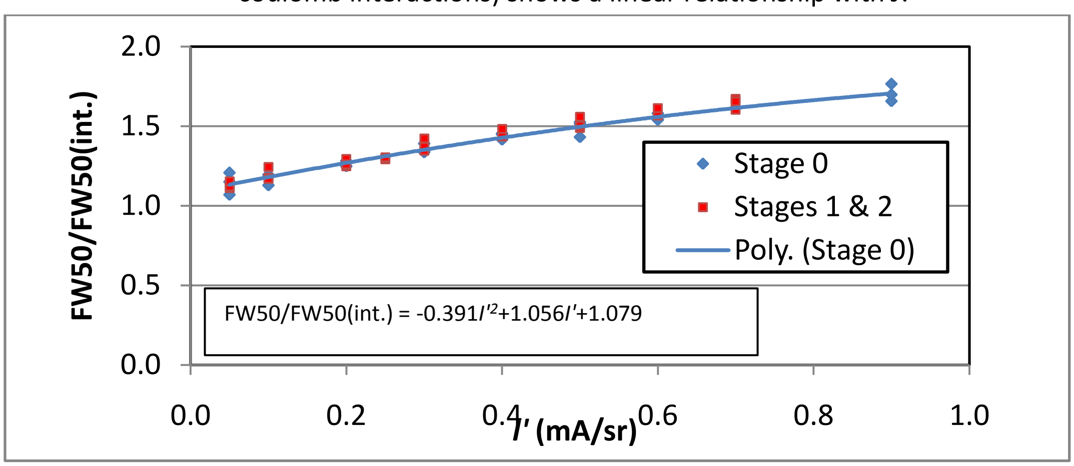

Fig. 3 The experimental *FW50* (with coulomb interactions) normalized by the intrinsic *FW50*(int.) (no coulomb interactions) can be fit with a second order polynomial dependence on *J*.

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[3] M.S. Bronsgeest, J.E. Barth, L.W. Swanson, and P. Kruit, J. Vacuum Sci. Technol. **B26,** 949 (2008).