Off Axis Modeling and Measurement of Emission Parameters for the Schottky Emitter

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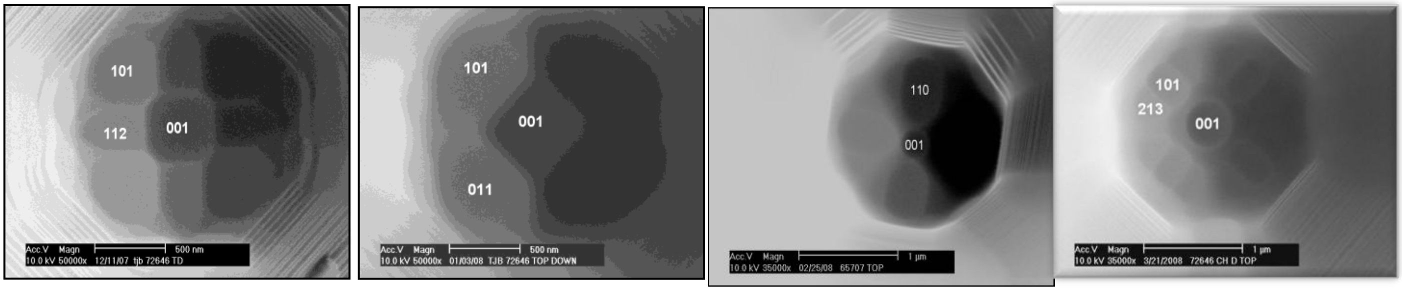
An investigation has been carried out involving both computer modeling and experimental data of off axis emission parameters for a Schottky emitter (SE). A computer based emitter modeling program (EMP) has been developed that measures critical emission parameters for the SE such as the field factor $\beta = F/V$ (where F is the applied electric field), reduced brightness (B_r), energy spread (ΔE50) (full width of the distribution containing 50% of the current) and current density (J). In this investigation we apply the EMP to experimental I'(V) (where I' is the measured angular intensity) to obtain experimental values of β and work function (φ) for various values of the off axis angle (θ). The EMP is able to simulate the various geometric end forms of the SE that have been identified earlier[1] and shown in Fig. 1. The use of the EMP extends an earlier study[2] of off axis measurements by providing an empirical relationship of the form $\beta=A(\theta)K^{-n(\theta)}$ where $K = (I'/J)^{1/2}$. Fig. 2 gives the β and K variations with θ obtained from the EMP when applied to SE emitters with various end forms and values of β. From the Fig. 2 results one is able to provide values for A(θ) and n(θ) which are found to be independent of the emitter end form for $0^o \leq \theta \leq 4^o$. The value of β, as observed in Fig. 2, increases with θ and thereby acts to increase both J and I' for a given V_e. However, since K decreases with θ the effective increase in I' is ameliorated due to the fact that $I' = K^2 J$.

As described earlier[1] with the empirical relationship $\beta=A(\theta)K^{-n(\theta)}$ one can apply a curve fitting program to the I'(V) data and thereby obtain experimental values for both β(θ) and φ(θ). The experimental β(θ) and K(θ) relationship generally follows the modeling trends shown in Fig. 2. The experimental values obtained for φ(θ), shown in Fig. 3, indicate a relatively constant value of φ as the off axis angle is increased.

Knowing values of β, φ and K, one is able to calculate from SE theory the intrinsic values for B_r(int.) and ΔE50(int.) . Fig. 4 shows the variation of B_r(int.) with experimental values of ΔE50 for a Stage 2 emitter. Data for other end forms gave similar results. The EMP program also allows for the calculation of B_r which includes the mutual coulomb interactions. The on axis B_r vs. ΔE50 relationship is useful for electron optical calculations and has been reported earlier[1]. The off axis values will be presented in this study.

[1] L.W. Swanson G.A. Schwind, S.M. Kellogg and K. Lui, J. Vac. Sci. Technol. **B 30**, 06F603-1 (2012)
[2] K. Liu, G.A. Schwind and L.W. Swanson, J. Vac. Sci. Technol. **B 27**, 2547 (2009)



Stage 1 Stage 2 Stage 0-a Stage 0-b

Fig. 1 Top down photos of the various end form stages for the Schottky emitter. Major crystal facets are noted.

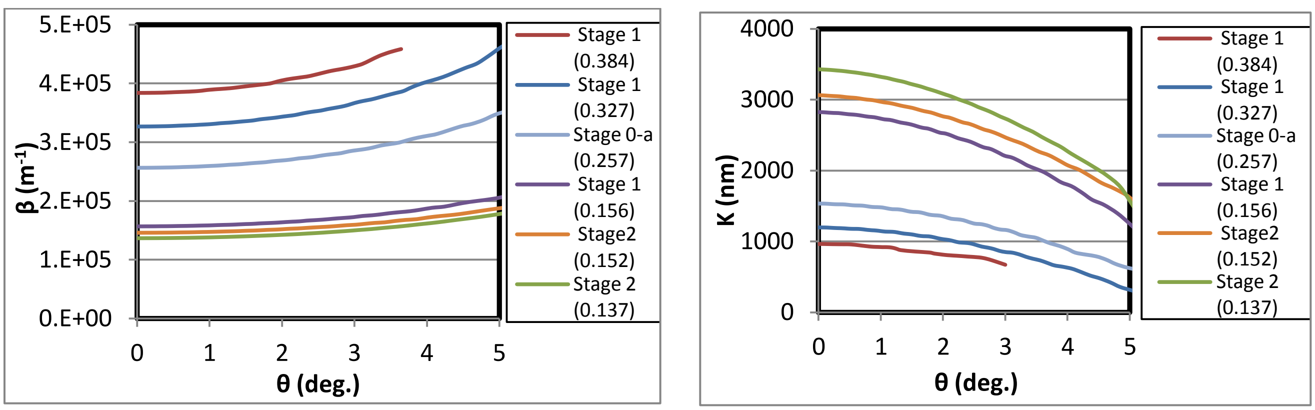


Fig. 2 Computer generated plots of β and K vs. off axis angle θ for various end form stages obtained from the EMP. Corresponding on axis values of the EMP generated values of β (μm^{-1}) are indicated in parenthesis.

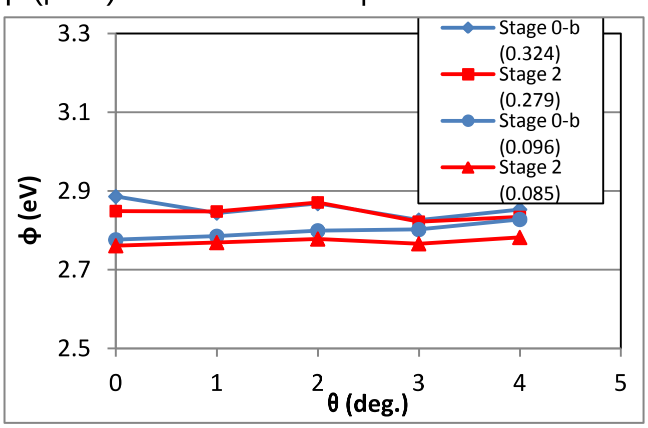


Fig. 3 Plot shows the experimental work function vs. off axis angle for the indicated end form stages and on axis values of β in μm^{-1} (in parenthesis).

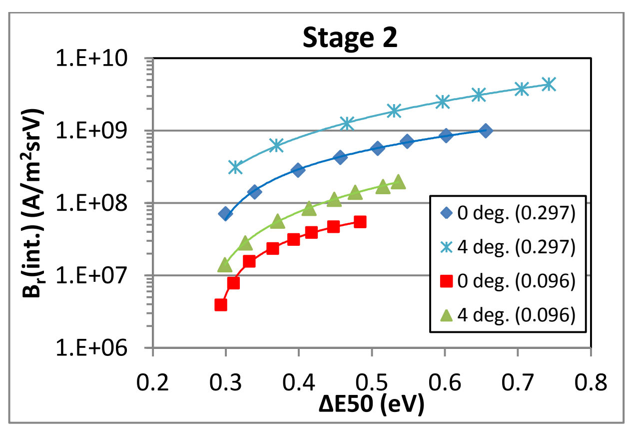


Fig.4 Plot shows the intrinsic brightness vs. the experimental energy spread for the indicated values of θ and on axis values of β in μm^{-1} (in parenthesis).