A REFORMULATED GENERAL THERMAL-FIELD-PHOTOEMISSION THEORY AND APPLICATION TO CHARACTERIZATION OF COMPOUND EMITTERS

Kevin L. Jensen

Code 6362, U. S. Naval Research Laboratory, Washington, DC 20375 USA

The canonical equations of field, thermal, and photoemission (the Fowler - Nordheim, Richardson - Laue - Dushman, and Fowler - DuBridge equations, respectively, and referred to as FN, RLD, and FD) of electron emission[1] are obtainable from a master equation of the form

$$J(F,T) = A_{RLD}T^2 N\left[\frac{\beta_T}{\beta_F}, \theta(E_m) + \beta_F\ (E_m - \mu)\right];\ \ N(n,s) = n\int_{-\infty}^{\infty}\frac{\ln\left(1+e^{n(z-s)}\right)}{1+e^z}dz \quad (1)$$

where (μ, Φ) are the chemical potential and work function, $F = q|\mathcal{E}|$ is the field factor, T is temperature, and the Gamow factor $\theta(E)$ governing tunneling is linearized in the original (oGTF) approach [2] about either $E_m = \mu$ (FN-like) or $E_m = \mu + \Phi - \sqrt{4QF}$ (RLD-like) where $Q = 0.36$ eV nm. Photoemission corresponds to energy being augmented by the photon energy $\hbar\omega$, and therefore corresponds to $s < 0$, where $n(F,T) \equiv \beta_T/\beta_F(E_m)$ and $s(F,T) \equiv \theta(E_m) + \beta_F(E_m)(E_m - \mu)$. In the TF regime, where $n \approx 1$, the oGTF approach is known to overestimate the current density and result in dimples in $J(F,T)$ as the TF regime is entered and exited as F increases for a given temperature [3].

A recently developed reformulated (rGTF) approach [4, 5] corrects oGTF by evaluating the $n(F,T)$ and $s(F,T)$ factors associated with $\theta(E)$ by exactly determining E_m and evaluating $\theta(E_m)$ and $\beta_F(E_m)$ using the shape factor methods [6] in a computationally rapid manner no longer reliant on the Schottky-Nordheim factors $v(y)$ and $t(y)$. It is expressly designed to be useful for beam optics codes or describing emission from mesoscale structures with microscale protrusions that complicate characterization measurements and predictions of performance from compound emitters. The rapid and accurate method of evaluating $J_{GTF}(F,T)$ is made possible by introducing a correction factor comprised of Lorentzians that modify the linear approximation. The rGTF approach is applied to an analytical compound emitter constructed from point dipoles, having a large base on which a small protrusion exists at the apex [5]. How thermal, field, and thermal-field emission simultaneously contribute to the total current emitted from the compound structure is shown. It is demonstrated how thermal effects compromise area and field enhancement estimations from field emission data, and field effects compromise area and work function estimations from thermal emission data in ways that the canonical equations cannot account for.

References

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