A Rapid Photoemission Model for Beam Optics Codes

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Photocathodes for future Vacuum Electronic (VE) applications such as x-ray Free Electron Lasers (xFEL's) and particle accelerators must satisfy metrics related to performance addressing [1, 2]: (*i*) the mean transverse energy of the beam, (*ii*) the effects of surface roughness, (*iii*) the nature and dependencies (*e.g.*, temperature) of scattering processes, (*iv*) the impact of non-uniform coverage of coatings, (*v*) the dependence on temperature, (*vi*) how degradation and damage due to dark current, desorption, and back-ion bombardment occur, and (*vii*) the dependence on the composition (*aka* stoichiometry [3]) of the photoemissive material. Beam optics codes used to design VE devices launch macroparticles from millions of surface elements for millions of time steps, and so prioritize algorithmic simplicity and rapidity of execution [4]. We present a high speed and flexible algorithm that gives QE based on the parameterization of the dielectric function $\hat{K}(\omega)$ using Lorentz-Drude-Resonant (metal, m) and Adachi-Drude-Resonant (semiconductor, s) schemes, and show how Nordheim's alloy scattering rule and Drude's model of conductivity allow composition to affect estimates of (E_g, E_a, r_e) for band gap, electron affinity effective electron mass that appear in the QE formulae [2, 4]

$$QE_m \approx [1 - R(\omega)] F_\lambda[x_m, p] \; h_m \left[\frac{\hbar\omega}{\phi}, \frac{\mu}{\phi}\right]; QE_s \approx \left[\frac{1 - R(\omega)}{1 + p}\right] \; h_s \left[\sqrt{\frac{\hbar\omega - E_g - E_a}{E_a}}\right] \tag{1}$$

where the optical functions from which $R(\omega)$, $\delta(\omega)$ are found is

$$\hat{K}(\omega) = 1 - \sum_{j=0}^{N_b} \frac{f_j \omega_p^2}{\omega^2 - \omega_j^2 + i\omega\Gamma_j} \quad \hat{K}_a(\omega; = 1 + \frac{\mathcal{A}}{\hat{h}^4}\left(2 - \sqrt{1 - \hat{h}} - \sqrt{1 + \hat{h}}\right) \tag{2}$$

where the Drude term is such that $\omega_0 = 0$, $p = \delta(\omega)/\ell(\tilde{E})$ is the ratio of penetration depth to mean free path, $(f_j, \omega_j, \Gamma_j)$ are the weighting factor, the resonance frequency, and the broadening factor the j^{th} Lorentzian with $j \in (0, \cdots, N_b)$. For semiconductors, $\hat{K}_a$ is added, $\hat{h} = (\hbar\omega + i\epsilon)/E_g$ as $\epsilon \to 0$, and changes in composition affect $(E_g, \hat{K}, E_a, r_e)$ [5]: for substitutional binary alloys $A_{1-x}B_x$, the $P(x) = xP_A + (1 - x)P_B - bx(1 - x)$ for parameter P. It is therefore expected that composition will change these most important factors on which QE depends. We demonstrate the model's speed and performance as applied to measured QE from copper and Cs_3Sb and consequences of stoichiometric variation of the later.

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