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The Importance of Accurate Computation of Secondary Electron Emission for Modeling Spacecraft Charging

Sebastien Clerc

JR Dennison
Utah State University

Clint Thomson
Utah State University

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The Importance of Accurate Computation of Secondary Electron Emission for Modeling Spacecraft Charging

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Sébastien Clerc
Alcatel Space
Research Department
Cannes, La Bocca FRANCE
Phone: +33(0) 492-926-052
Fax: +33(0) 492-926-970
Sebastien.Clerc@space.alcatel.fr

J.R. Dennison
Physics Department, Utah State University
SER 250 UMC 4415
Logan, UT, USA 84322-4415

The secondary electron yield is a critical process in establishing the charge balance in spacecraft charging and the subsequent determination of the equilibrium potential. Spacecraft charging codes use a parameterized expression for the secondary electron yield $\delta(E_o)$ as a function of incident electron energy, E_o. A critical step in accurately characterizing a particular spacecraft material is establishing the most efficient and accurate way to determine the fitting parameters in terms of the measured electron yield data and physics-based theoretical models. Simple two- or three- step physics models of the electron penetration, transport and emission from a solid are typically expressed in terms of the incident electron penetration depth at normal incidence or range $R(E_o)$, and the mean free path of the secondary electron, $\lambda(E)$. We review the models for $\delta(E_o)$ derived from various forms of the range expression $R(E_o)$, including the Sternglass model based on the Bethe expression for the stopping power $R= \lambda(E_o) \sim E_o/\ln(E_o)$, several power law expressions of the form $R(E_o)=b_1E_o^{n1}$ with different n_1, and a more general empirical bi-exponential expression $R(E_o)=b_1E_o^{n1}+b_2E_o^{n2}$. Expressions are developed that relate the theoretical fitting parameters (λ, b_1, b_2, n_1 and n_2) to experimental terms (the energy E_{max} at the maximum secondary electron yield δ_{max}, the first and second crossover energies E_1 and E_2, and the asymptotic limits for $\delta(E_o \rightarrow \infty)$). In most models, the yield is the result of an integral along the path length of incident electrons. Special care must be taken in computing this integral. An improved fourth-order numerical method is presented, and its effectiveness is shown to be a significant improvement as compared to standard second-order methods. The fitting procedures and range models are applied to several measured data sets to compare their effectiveness in modeling the function $\delta(E_o)$ over the full range of incident energies, and in particular for determining crossover energies and critical temperatures.