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Measurements of Intrinsic Electron Emission Yields of High Resistivity Ceramic Materials

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Abstract

We describe a hybrid method for measuring the intrinsic—or zero-accumulated charge limit—electron emission yields of highly insulating materials with relatively large yields. The intrinsic electron yield is an essential measure of how charge will accumulate in such materials exposed to space environment fluxes and for predicting and mitigating spacecraft charging effects. There are three commonly used methods to determine the intrinsic electron yield: (i) the DC-yield method, which ratios constant incident and emission currents; (ii) the pulsed-yield method, which ratios integrated charge of short-duration, low-current pulses, thereby minimizing the amount of charge being deposited into the material during a measurement, and (iii) the yield-decay method, which extrapolates to the zero-charge limit the changes observed in the yields resulting from a series of sequential pulses with no charge neutralization between pulses. The DC-yield method produces accurate results for conductors, which do not accumulate charge or exhibit significant modification by modest beam currents; these are relatively easy to measure. For insulators it is much more challenging to accurately measure the yield due to charging effects. Pulsed-yield measurements have been extended to practical source and detector limits of $\lesssim$10 fC-cm^{-2} per pulse (*e.g.*, 5 μs 2 nA-cm^{-2} pulses), with low-energy electron flooding and UV light pulses used to help neutralize accumulated charge between pulses. Pulsed-yield methods have been shown to work for many insulating materials, but are insufficient for extreme materials with both high yields and very high resistivity. Yield-decay methods can produce results for such extreme materials, but require complex and time consuming data acquisition and analysis.

A new point-wise yield method that employs elements of both the pulse-yield and yield-decay methods has been demonstrated, and shows the potential to significantly enhance the accuracy and efficiency of intrinsic yield measurements for the most challenging of materials. Data are acquired using a storage oscilloscope of currents simultaneously reaching the sample, collector, and grids for each electron pulse (typically of 3-5 μs duration). A point-wise yield is determined at each time increment of the oscilloscope trace (typically, 4-7 ns) over the pulse duration. This analysis technique essentially provides a yield decay curve over the pulse duration, allowing this curve to be extrapolated back to the intrinsic yield. By averaging many pulses, incorporating charge neutralization between pulses, an accurate measure of the intrinsic electron yield can be determined. If neutralization is not used between pulses, subsequent yield curves show the cumulative effects on yield of the accumulated charge. The effects of the rise time shape of the beam-blanking voltage pulse, the response time of the current amplifiers and oscilloscope circuit, and the inherent properties of the sample configuration and cabling all act to complicate the point-wise analysis for such short time increments.

Yield measurements have been acquired for several insulating ceramic/glassy materials, including boron nitride, aluminum nitride, aluminum oxide and silicon dioxide. Results are presented for incident energies of $\gtrsim$20 eV to 5 keV, spanning both the first and second cross-over energies and E_{max} and both positive and negative charging regimes. These results are used to demonstrate the relative merits of the different yield methods.

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