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Absolute Electron Emission Calibration: Round Robin Tests of Au and Polyimide

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Absolute Electron Emission Calibration: Round Robin Tests of Au and Graphite

Introduction

Accurate determination of the absolute electron yields of conducting and insulating materials is essential for models of spacecraft charging and related processes involving charge accumulation and emission due to electron beam and plasma interactions. Measurements of absolute properties are critical to understanding calibration, experimental methods, and uncertainties.

This study presents a round robin comparison of these absolute yields measurements performed in four international laboratories. The primary objectives were to determine the consistency and uncertainties of such tests, and to investigate the effects of the similarities and differences of the diverse facilities. Apparatus using various low-fluence pulsed electron beam sources and methods to minimize charge accumulation have been developed and employed at these facilities.

Measurements were made for identical samples with reproducible sample preparation of three standard materials:
• the elemental conductor Au (0.5 mm thick 60 purity Au foil)
• the elemental semiconducting HOPG (200 µm thick Kaption-HK)
• the polymeric insulator polyimide (25 µm thick Kapton-HK).

Absolute electron yield measurements for various materials are necessary to determine absolute charging levels and hence to predict possible electrostatic breakdown and injection of charges into plasmas. They have direct application to spacecraft charging, high voltage direct current (HVDC) power and transmission lines, ion thrusters, plasma deposition, multipactor, semiconductor metal oxide interfaces, and nanoelectronics.

Descriptions of Facilities and Methods

CSIC SEY Facility

The CSIC SEY Facility of the Surface Electrostatics and Nanotechnologies Group of ICMAS-CSIC (Spain) is the surface characterization by using spectroscopic techniques and low-secondary electron surfaces to exist Mullard UHV facilities and experimental systems.

Equipped with:
• Four interconnected UHV chambers (170°C)
• Shimadzu 9900ESX electron analyzer
• VUV source (pulsed/continuous)
• Kevex source (high current)
• g-ray source (electron spectroscopy and俄)
• Particle in vacuum (<10⁻⁹ Torr)
• Sample Manipulator
• UV/visible monochromated light source
• XPS and photoelectron spectroscopy
• Temperature range: 4K - 800°C

LaSEINE TEEY Facility

The Laboratory of Spacecraft-Engineering Interaction (LaSEINE) at Kyoto Institute of Technology has studied spacecraft charging and discharging.

We have developed the Total Electron Emission Yield (TEEY) measurement facility for solar arrays. We have measured the yield of Au and graphite using the measured TEEY after saturation with ionizing radiation, atomic probes, and Ar plasma.

Measurements capabilities include:
• Vacuum analysis chamber below 10⁻¹⁰ Pa.
• Electron yield: 300-500 eV.
• Total electron emission yield measurement method:
  • Sample holder and collector are biased.
  • The electron emission current can be measured.
  • Sample current and collector current are measured for calculating TEEY.
  • For the electron yield, the measurement is performed after a one shot of pulsed electron beam in order to prevent charging effect on the sample surface.

ONERA DEESSE Facility

The ONERA DEESSE (Département d’Etude des Environnements Spatiaux et de la Surface) facility at ONERA is a 14-meter vacuum chamber.

The Space Environment Department of ONERA (DEESSE) works on many projects closely related to space application dealing with aerosols/ions/molecules/fields in space environments.

Measurements capabilities include:
• Vacuum Analysis chamber 181-10⁻¹⁰ Pa.
• Electron Energy Barkhaw Physical 1-2 keV.
• Secondary electron source, pulsed.
• Energy Distribution measured by energy analyzer.
• Sample Rotation 100°-800° to study charging.
• Surface Analysis Auger Electron Spectroscopy.
• Primary electron source (60°-80°, KEVAC source).
• KeVox source (KEVAC source).
• Kelvin surface potential probe.

Measurements of sample holder from ambient to 600°C.

USU SEEM Facility

The United States Naval Research Facility (SEEM) in Space Environment Effects (ISEE) performs tests of electronic and electric transport properties of both conducting and insulating materials, emphasizing studies of electron emission, conductive charging, and damage.

We have studied how the variation in temperature, accumulated charge, exposure time, contamination, surface modification, radiation dose, and radiation dose affect these electrical properties on diverse materials, and have related changes in structure, mechanical, thermal and optical properties of chosen systems.

Measurements capabilities include:
• Total Electron Emission Yield of Ion SEEM Electron Emission using 300-500 eV high energy, continuous and pulsed beams with 1000 electron applicator.
• Electron Emission Spectra: varied energy 0.5-1 keV and 50-1 keV/10⁶ L3/3-AU.
• Introduction Electron Emission spectra and yields for various contaminants and energy.
• Electron Energy Distribution, and for a 0.5 keV (1200 cm² H₂O, 10⁶ L3/3-AU).
• Surface Voltage endureance measurements: 0-100 vs with 3.3 time resolution.
• Temperature variations from 900K to 450 K.

Measurements were made of the absolute total electron yields at normal incidence over the full range of incident energies accessible with each group's instrumentation (a full range of 5 eV to 5 keV). Figures show linear plots with low energy detail insets (left) and log-log plots of scaled yields (f/E max) versus scaled energy (f/E max).

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CSIC, Instituto de Ciencia de Materiales de Madrid

References


Round Robin Tests Results

Summary of results:
• Shape of normalized curves are very consistent.
• Highly sensitive to surface contamination [24].
• Very good agreement of absolute yield for E max but less agreement for E in.
• HOPG agreement between facilities is the best: 5% for E max and 10% for energies.
• HOPG has the advantage that clean smooth surfaces are easy to prepare with tape cleaning.
• Au samples exhibit differing degrees of contamination as evidenced by surface analysis techniques exhibiting 2.97% (gold line) and 20% (gold contamination).[24]

Topics of future Round Robin analysis:
• Charge sensitive measurements of dielectrics. Polycrystalline (Kaption-HK) results.
• Energy discriminated measurements: Secondary/Backscattered results and emission spectra.
• Surface sensitivity: surface cleanliness tests, effects of contamination and Ar sputtering.
• Discussions of the relative strengths and weaknesses of our various methods.