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Jennifer Albretsen

Ryan Hoffmann
Utah State University

JR Dennison
Utah State University

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Investigating the Photoyield of Spacecraft Materials
Jennifer Albretsen, Ryan Hoffman, J.R. Dennison
Utah State University Physics Department

Photoemission spectra were measured for conducting, semiconducting, and insulating materials used in NASA’s James Webb Space Telescope and Solar Probe missions to determine the contribution of photoemissions to overall spacecraft charging.

BACKGROUND: PHOTO-INDUCED SPACECRAFT CHARGING

The photoelectric effect is an important contributor to spacecraft charging.

- When photons of energy greater than the work function or electron affinity (threshold energy) of a material interact with an embedded electron, the photoelectric effect, or photoelectron emission occurs.
- Photoemissions contribute to charging of conductors, semiconductors, and insulators used in the James Webb Space Telescope and Solar Probe Mission studies. (See figures 2 and 3)

EXPERIMENTAL METHODS

1. Validation of Instrumentation Upgrade
   - Before the four spacecraft materials were measured, photoemission spectra were taken on gold (Au). A work function of about 4.65 eV was determined from these data. This corresponds to the accepted value for the work function of gold (4.4–4.8 eV), verifying the validity of the upgraded measurement system. (See Fig. 7)

2. Photoelectrons as Monochromator Intensity Gauge
   - A photodiode spectrum was taken each day and corrected for the known photodiode detector quantum efficiency. The resulting spectra corresponds to the light intensity from the monochromator at each photon energy. A transmission threshold of ~6.75 eV is observed. (See Fig. 7)

3. Purging Monochromator Box
   - Purging monochromator box with nitrogen (N₂) gas reduces UV light absorption by H₂O and O₂ gas. This enhances the transmission spectrum of the monochromator. (See Fig. 8)

4. Measuring Photoemission Spectra
   - Spectra were taken for four spacecraft materials with energies ranging from ~2 eV to 6.75 eV, the monochromator threshold. Measurements taken in ultra high vacuum, ~10⁻⁹ torr. (See Fig. 6)

RESULTS

Of the four spacecraft materials studied, only the silicon alloy on Kapton E substrate produced a detectable photo-induced current.

- Polycrystalline Nitride (PNB): An insulator used in the Solar Probe Mission study. White light illumination, high emittance ceramic for use as possible coating on solar probe. ~3 mm thick. No photo-induced current detected. (See Fig. 9) Current values fluctuated about zero, within the range of ambient noise.

- Alumina (Al₂O₃): An insulator used in the Solar Probe Mission study. White light illumination, high emittance ceramic for use as possible coating on solar probe. ~1 mm thick. No photo-induced current detected. (See Fig. 10) Current values fluctuated about zero, within the range of ambient noise.

- Six P.E. x VDA: A semiconductor used in James Webb Space Telescope study.

- Xenon deposited conductors used in James Webb Space Telescope study. Top layer: 10 nm layer of Vapor Deposited Aluminum (VDA). Middle layer: 10 nm layer of Chromium (Cr), Nickel (Ni). Back layer: 60 nm layer of silicon alloyed with Iron (Fe), Chromium (Cr), Nickel (Ni). No photo-induced current detected. (See Fig. 13) Current values fluctuated about zero, within the range of ambient noise.

- High reflectivity in monochromator range (2 eV to 6.75 eV). (See Fig. 14)

CONCLUSIONS

Photoemission spectra correlate with conductivity and reflectivity of materials.

- Metals
  - Gold (Au): Measured work function value (4.65 eV) agrees with accepted value for gold (4.4–4.8 eV).
  - Used as standard to verify that upgraded instrumentation is accurate.

- Vapor Deposited Aluminum (VDA): Measured work function value is ~5 eV, within the monochromator’s range, but no photo-induced current was observed. Absence of photoemission likely due to high reflectivity of Vapor Deposed Aluminum (see Fig. 14).

- Semiconductors
  - Six P.E. x VDA: Observed photo-induced current beginning at ~3.5 eV correlates with band gap of Si alloy. Photon energy intensity must be much lower than gold (relative to the noise level). This is expected, since gold (conductive) is more conductive than the Si alloy (a semiconductor).

- Insulators
  - Polycrystalline Nitride (PNB): No photo-induced current was observed, likely because the band gap of PNB exceeds the monochromator transmission threshold.

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