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Simulation Chamber for Space Environment Survivability Testing

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Space Environment Effects

The space environment can modify materials and cause detrimental effects to satellites. Some of these effects are change in reflectivity and emissivity, which lead to changes in thermal, optical, and charging properties. If these are severe enough the spacecraft will not operate as expected. The key to predicting and mitigating these effects is the ability to accurately simulate space environment effects through long-duration, well-characterized testing in an accelerated, versatile laboratory environment.

Abstract

A vacuum chamber was designed and built that simulates the space environment making possible the testing of material modification due to exposure of solar radiation. Critical environmental components required include an ultra high vacuum (10^-6 Torr), a UVVIS/NIR solar spectrum source, an electron gun and charge plasma, temperature extremes, and long exposure duration. To simulate the solar spectrum, a solar simulator was attached to the chamber with a range of 200 to 1700 nm. The exposure time can be accelerated by scaling the solar intensity up to four suns. A Krypton lamp imitates the 120 nm ultraviolet hydrogen Lyman alpha emission not produced by the solar simulator. A temperature range from 100K to 450K is achieved using an attached cryogenic reservoir and resistance heaters. An electron flood gun (mono-energetic, 20 eV to 10 keV) is calibrated to replicate solar wind at desired distances from the sun. The chamber maintains 99% uniformity of the electron and electromagnetic radiation exposure relative to the center. The chamber allows for a cost-effective investigation of multiple small-scale samples. An automated data acquisition system monitors and records the reflectivity, absorptivity, and emissivity of the samples throughout the test. An integrating sphere and an IR absorptivity/ emissivity probe are used to collect this data. The system allows for measurements to be taken while the samples are still under vacuum and exposed to radiation. With these accurate simulations we can closely predict the material’s behavior in near proximity to the sun. This information is vital in determining materials for satellites, probes, and any other spacecraft.

In Situ Analysis Capability

UVVIS/NIR Reflectivity—Two fiber optic spectrometers (7) measure reflectivity of UVVIS/NIR (200-1060 nm) NIR (858-1700 nm) ranges with <1 nm resolution. Integrating Sphere—A 2.5 cm diameter integrating sphere (8) can be extended over the sample with a retractable probe. Linear translation stage (9). The sample stage can be rotated to position different samples under the probes. Light from a deuterium/W-halogen calibrated light source enters the integrating sphere through one fiber optic connection; reflected light from the sample exits through another fiber optic to spectrometers. IR Emissivity—Measured with retractable probe (4 µm to 15 µm) [10] Mounted on probe translation stage. Calibration Standards—In situ high and low reflectivity/emissivity calibration standards (11) are mounted behind the probe translation stage.

Light Flux—Continuously monitored with in situ photodiodes (12) equipped with appropriate filters to measure UV, VIS, NIR, VIS, UVI, univoltages. Exterior sensor feedback used to regulate the solar simulator intensity.

Pressure—Absolute pressure monitored with Convectron and ion gauges (13). Partial pressure measured with a Residual Gas Analyzer (14).

Vacuum—Chamber uses standard mechanical and turbomolecular vacuum pumps. Temperature—Two thermocouples (15) monitor temperature during exposure. Chamber maintains 98% uniformity on the sample stage as a contour plot. Not sure we have this vet, could add an alternate thermal camera. Temperature—Monitored with platinum RTDs (16). Sample Stage—Sample stage (17) connected to 360º rotary feedthrough (18) to position samples under probe translation stage (19) and enhance flux uniformly by rotating samples. Sample stage shown has six 2.5 cm diameter samples (L) plus flux sensors (I, J, K). Alternate configurations have up to one 10 cm diameter sample. Uniform temperature over ~100 K to 450 K controlled using attached cryogenic reservoir (1) and resistance heaters (16). Large thermal mass helps maintain stable thermal equilibrium.

Experimental Test Chamber Design

Versatile ultrahigh vacuum test chamber provides controlled temperature and vacuum environment with detailed, uniform, long-duration electron and UVVIS/NIR fluxes at up to 4 times sun equivalent intensities for accelerated testing for a sample area of 8 cm by 8 cm. Particularly well suited for cost-effective tests of multiple small-scale samples over prolonged exposure.

Chamber Components


Legend of Components

Sample Carousel

C UVVIS/NIR Reflectivity Spectrometers

F IR Emissivity Probe

H Integrating Sphere

I Photodiodes/UVVIS/NIR Flux Monitor

J Farady Cup—Electron Flux Monitor

K Platinum Resistance Temperature Probe

Instrumentation (Not Shown)

Data Acquisition System

Temperature Controller Electron Gas Controller UVVIS/NIR Solar Simulator Controller UVVIS/NIR Reflectivity Lamp Controller Reflectivity Light

Chamber Components

Electron Gun—Electron flood gun (A) provides ≤5·10^10 electrons/cm^2 (＜1 pA/cm^2) flux needed to simulate the solar wind at more than the 100X cumulative electron fluence. Mono-energetic energy range is <4 to 15 eV, total energy flux of 6.08±0.61 km. Gun provides a 98% uniform flux distribution over the full sample area, with “hot” swappable filaments for continued exposure over the entire long duration testing. The electron gun was custom designed at LSU after work by Tsunematsu [2004].

Infrared/Visible/Ultraviolet Flux—A commercial Class AAA solar simulator (B) provides NIR/VIS/UV/UVB electromagnetic radiation from 200 nm to 1700 nm at 4 times sun equivalent intensity. The electron gun is a 120º apart provide ≥98% flux uniformity. Lamp’s emission lines reproduce the H Lyman-alpha line (121.6 nm) that dominates the solar flux spectrum. Krypton has been used most for its extended lifetimes for long duration studies.

Far Ultraviolet Flux—The Kr resonance lamp (C) provide FUV radiation flux (ranging from 10 to 200 nm) at 4 times sun equivalent intensity. Three lamps oriented 120º apart provide >98% flux uniformity. Lamp’s emission lines reproduce the H Lyman-alpha line (121.6 nm) that dominates the solar flux spectrum. Far Ultraviolet Flux—The Kr resonance lamp (C) provide FUV radiation flux (ranging from 10 to 200 nm) at 4 times sun equivalent intensity.

Simulation Chamber for Space Environment Survivability Testing

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MARCH 29-31, 2012

Space Environment Characteristics

There are certain characteristics of the space environment that are critical for a true simulation of a space environment. These critical characteristics are electron flux, electromagnetic radiation, vacuum, and temperature. The electron flux is critical because the solar winds through space bombards spacecraft. The electromagnetic radiation has many critical aspects in itself. As can be seen in figure 10, the solar wind has a very broad range of wavelengths. The visible/Infrared to Ultra Violet, specifically the Hydrogen Lyman Alpha emission at 121.6 nm, a vacuum, mean, varies very few particles. The temperature is critical because it changes drastically depending on proximity to the sun. Things not covered by this chamber are photons/ions, and atomic oxygen.

Space Simulation Capabilities

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