Simulation Chamber for Space Environment Survivability Testing

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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 intended.

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 (10-9 Torr), a UVVIS/NIR solar spectrum, 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 200nm to 2000nm. 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 15keV) is calibrated to replicate solar wind at desired distances from the sun.

The chamber maintains 98% 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 (F) measure reflectivity by UVVIS/NIR (200-1000 nm) NR (850-1700 nm) ranges with <1 nm resolution.

Integrating Sphere-A 2.5 cm diameter integrating sphere (H) can be extended over the samples with a retractable probe linear translation stage (T). The sample stage can be rotated to position different samples under the probes. Light from a deuterium/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)

Calibration Standards-In situ high and low reflectivity/emissivity calibration standards (H) are mounted behind the probe translation stage.

Light Intensity-Continuously monitored with in situ photodiodes (D)

Calibration Equipment-98% uniformity by monitoring NIR, VIS, UV intensities. Exterior sensor feedback used to regulate the solar simulator intensity.

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

Temperature—Monitored with platinum RTDs (K).

NIR, VIS, UV intensities. Exterior sensor feedback used to regulate the solar simulator intensity.

Experimental Test Chamber Design

UVVIS/NIR Reflectivity Two fiber optic spectrometers (F) measure reflectivity by UVVIS/NIR (200-1000 nm) NR (850-1700 nm) ranges with <1 nm resolution.

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Radiation Sources

A Electron Gun
B UVVIS/NIR Solar Simulator
C FUV Krypton Discharge Lamps
D Air Mass Zero Filter Set
E Flux Mask

Legend of Components

Sample Carrousel: G Cryogenic Vacuum Feedthrough
I Temperature Controller
J Electronic Gas Controller
K UVVIS/NIR Solar Simulator Controller
L UVVIS/NIR Reflectometry System
M Resistance Heater
N Cryogenic Reservoir
P Cryogenic Vacuum Feedthrough
Q Sample Carrousel
R Reflectivity/Emissivity/Calib. Standards
S Remote Control
T Electron Gun Controller
U Data Acquisition System
V Turbulomolecular/Vacuum Pump
W Ion Vacuum Pump
X Ion Vacuum Pump
Y Ion/Convection Gauges—Pressure
Z Residual Gas Analyzer—Gase Species

Chamber Components

There are certain characteristics of the space environment that are critical for a true simulation. These critical characteristics are electron flux, electromagnetic radiation, vacuum, and temperature. The electron flux is critical because the solar winds through space bombard 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 covering the Visual/Infrared to Ultra Violet, specifically the Hydrogen Lyman alpha emission at 121.6 nm. A vacuum, visualizing 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

Versatile ultrahigh vacuum test chamber provides controlled temperature and vacuum environment with uniform, long-duration electron and UVVIS/NIR fluxes 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.

Acknowledgements/References