Simulation Chamber for Space Environment Survivability Testing

Lisa Montierth  
*Space Dynamics Laboratory, Utah State University*

Robert H. Johnson  
*Utah State University*

JR Dennison  
*Utah State University*

James S. Dyer  
*Space Dynamics Laboratory, Utah State University*

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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 planned. The key to predicting and mitigating these various 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 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 200nm to 2000nm. The exposure time can be accelerated by scaling the solar intensity up to four suns. A Krypton lamp imitates the 121.6 nm ultraviolet hydrogen Lymann 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 10keV) 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 absorbivity/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 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 at UVVIS/NIR (200-1080 nm) NIR (850-1700 nm) ranges with <1% resolution. Integrating Sphere-A 2.5 cm diameter integrating sphere (K) can be translated over the sample with a retractable probe linear translation stage. The sample stage can be rotated to position different samples under the probes. Light from a deuterium/ftelyl halogen calibrated tight source enters the integrating sphere through one fiber optic connection; reflected light from the sample exits through another fiber optic spectrometers.

IR Emissivity-Measured with retractable probe (4 μm to 15 μm) mounted on probe translation stage. Calibration Samples-At high and low reflectivity/emissivity calibration standards (H) are mounted behind the probe translation stage.

Light Flux-Continuously monitored with in situ photodiodes (J) located near upper source components to other SDL/USU experiments. Light flux is monitored by a pyroelectric infrared sensor (H) for NIR, VIS, UV intensities. Exterior sensor feedback used to regulate the solar simulator intensity.

Sample Temperature-Monitored with platinum RTDs (K).

Pressure-Absolute pressure monitored with Convectron and residual gas analyzer (L). Partial pressure measured with a Residual Gas Analyzer (O).

Experimental Test Chamber Design

The simulation chamber for space environment survivability testing is a versatile ultrahigh vacuum test chamber designed to provide controlled temperature and vacuum environment with variable, 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.

Space Environment Characteristics

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 both critical aspects. As can be seen in figure 10, the environment changes from the Visual/Infrared to Ultra Violet, specifically the Hydrogen Lyman Alpha emission at 121.6 nm. A vacuum environment can change drastically depending on proximity to the sun. Things not covered by this chamber are photons, ions, and atomic oxygen.

Electron Flux—Electron flood gun (A) provides ≤5×10^11 electrons/cm^2 (≤10^15 cm^2) electron flux needed to simulate the solar wind at more than the 100X cumulative electron flux. Mono-energetic energy range is 0.5 to 15,960±10 eV. Gun provides a >98% uniform flux distribution over the full sample area, with “hot swapable” filament for continuous exposure over the entire long duration testing. The electron gun was custom designed at USU after work by Swaminathan [2004].

Infrared/Visible/Ultraviolet Flux—A commercial class AAA solar simulator (B) provides NRVIS/UVA/UVB electromagnetic radiation (200 nm to 1700 nm) calibrated to 4 times sun equivalent intensity for accelerated testing over an area 8mmx8mm. Source uses a Xenon discharge tube, parabolic reflector, collimating lens, and standard Air Mass Zero filters (D) to match the incident radiation spectrum to the solar spectrum. Xen bulbs have >1 month 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. lamp’s emission lines reproduce the H Lymann-Alpha emission at 121.6 nm that dominates the solar FUV spectrum. Kr bulbs have >3 month lifetimes for long duration studies.

Gas Flux-Mask flux (E) located near the chamber’s top ports restricts the flux boundaries to the sample stage, limiting equipment exposure and reducing scattering to accommodate uniform exposure. Chamber is readily modifiable. Spectroscopically measured gas mixtures are used in the view port. Gas is injected into the chamber through lines from the gas mixing station. The inlet gases are then monitored and analyzed throughout the test. The pressure of the gases is controlled using a gas control computer.

Vacuum—Chamber uses standard mechanical and turbomolecular pump (K) for roughing and a ion pump (P) for continuous maintenance-free operation (base pressure <10^-10 Pa).

Temperature—A temperature range from 100 K to 450 K is maintained ±2 K by a standard PID temperature controller, using a cryogenic reservoir (G) and resistance heaters (F) attached to a large thermal mass sample stage (H).

Acknowledgements/References

References