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Ultrahigh Vacuum Cryostat System for Extended Low Temperature Space Environment Testing

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The range of temperature measurements have been significantly extended for an existing space environment simulation test chamber used in the study of electron emission, sample charging and discharge, electrostatic discharge and arcing, electron transport, and luminescence of spacecraft materials. This was accomplished by incorporating a new two-stage, closed-cycle helium cryostat which has an extended sample temperature range from -30 K to 450 K, with long-term controlled stability of <0.5 K. The system was designed to maintain compatibility with an existing ultrahigh vacuum chamber (base pressure <10^-7 Pa) that can simulate diverse space environments. These existing capabilities include controllable vacuum and ambient neutral gases conditions (<10^-4 up to 10^-1 Pa), electron fluxes (5 eV to 30 keV monoenergetic, focused, pulsed sources over 10^10 to 10^12 eV-sec^-1-mm^-2), ion fluxes (<0.1 to 5 keV monoenergetic sources for inert and reactive gases with pulsing capabilities), and photon irradiation (numerous continuous and pulsed monochromated and broad band IR/Vis/UV (0.5 to 7 eV) sources). The new sample mount accommodates 1 to 4 samples of 1 cm to 2.5 cm diameter in a low temperature carousel, which allows rapid sample exchange and controlled exposure of the individual samples. Custom hemispherical grid retarding field analyzer and Faraday cup detectors, custom high speed, high sensitivity electronics, and charge neutralization capabilities used (with <50 pA, <5 µs, <3 x 10^9 electrons/pulse pulsed-beam sources permit high-accuracy electron-emission measurements of extreme insulators with minimal charging effects. In situ monitoring of surface voltage, arcing, and luminescence (250 nm to 5000 nm) have recently been added.

To highlight the capabilities of the low temperature cryostat incorporated into the space environment simulation test chamber, we present data from a study of the temperature dependence of electron-induced luminescence and arcing from spacecraft materials. With the various imaging detectors all focused on the sample, a wide range of spectral analysis is possible (4). Operation in a closed chamber in a dark room makes it possible to measure very low intensity sources.

An example of this is shown in still frames captured with a CCD video camera. Figure (a) above shows a 1 cm sample, which is illuminated using a dim fiber optic timing light to show the region to be exposed to the electron flux. Figures (b) and (c) show a comparison of the effect temperature has on this material; the glow at 293 K is barely detected with this imaging camera, but as the temperature is decreased to 40 K intensity increases and a prominent glow is clearly evident. If enough charge is built up in the material arc events were observed where in the sample found a conduction path to the edge of the grounded sample holder (F). The very intense optical signature of the arc has been captured in a video frame shown in Figure (d).

Figure below shows simultaneous measurements from an arc event as recorded by the electrometer and CCD camera. Here a constant current density of 1 nA/cm^2 is incident on the 1 cm sample and at ~91 s elapsed time the sample current spiked to over 40 nA. Additional measurements from a digital storage oscilloscope showed that these arcs were typically less than 1 µs in duration. The image from the CCD video camera provides optical confirmation of the electrical signature and provides additional information about the spatial location of the arc; note the currents from the central region of the sample and from the sample edge region are measured independently.