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Enhanced Test Facility for Survivability and Characterization of Evolving Multiscale Materials in Extreme Plasma Environments

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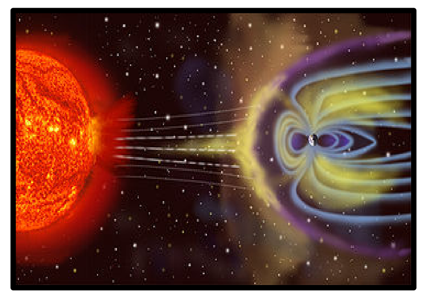
Enhanced Test Facility for Survivability and Characterization of Evolving Multiscale Materials in Extreme Plasma Environments

Air Force Office of Scientific Research DURIP Program

JR Dennison

Utah State University Materials Physics Group

Overview



A major upgrade to the Utah State University Space Environment Effects Materials Test Facility is proposed. Ensuing research focuses on scientific models and wide-ranging applications related to the evolution of complex materials (including layered and nanostructured materials and composites) due to exposure to extreme plasma environments, electric fields, temperatures, and vacuum. Two new synergistic vacuum test chambers will be developed, through the addition of novel instrumentation to existing systems. This will greatly enhance and extend our capabilities and ranges to investigate extreme environmental effects on materials and components and to determine long-term survivability of space assets

Current/Pending SEEM Projects

Current and pending projects employing the DURIP instrumentation cover a wide array of scientific fields; these include:

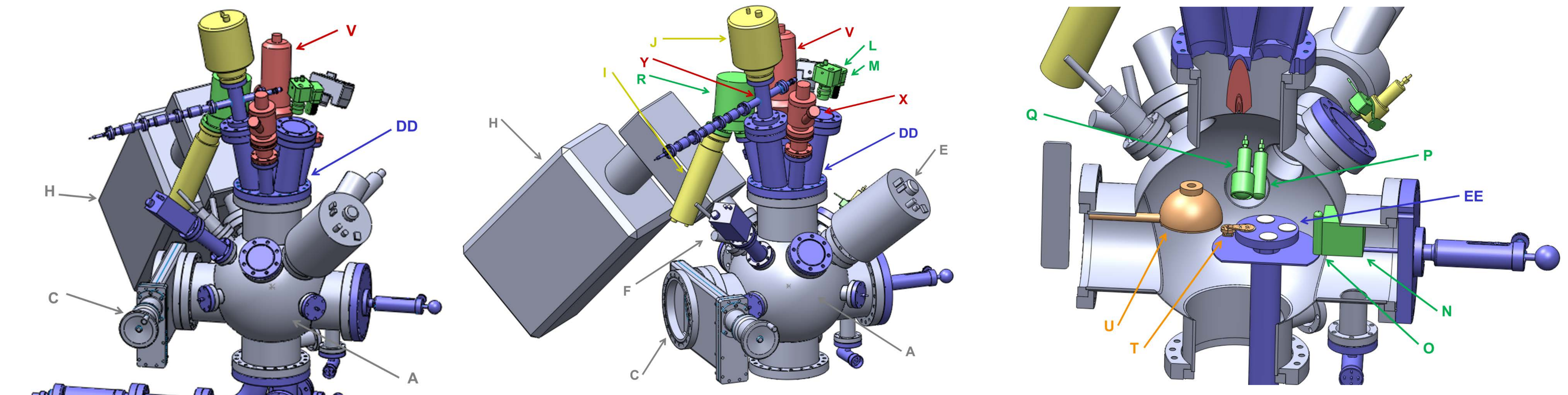
- **Electrostatic discharge events induced by β-radiation in high frequency RF antenna dielectric components for telecommunications satellites. *ViaSat funded.***
- ***In-Situ* permittivity characterization and long-term cumulative effects of β-radiation on high performance RF communications cabling accelerated testing of full multi-year mission. *Times Microwave funded.***
- **VUV degradation of antennas and thermal control coatings. *Aerospace company funded***
- **UV degradation of thermal control materials. *Aerospace company funded.***
- **Radiation induced conductivity (RIC) of perovskite dielectric materials by total ionizing dose (TID). *Sandia National Labs funding pending.***
- **Effects of radiation on conductivity and permittivity of space polymers for NASA Europa Mission. *NASA* Jet Propulsion Lab *funding pending.***
- **Electron transport studies of spacecraft antenna coating materials. *Aerospace company funding pending.***
- **Radiation Modification of Space Flight CCD Array. *Space Dynamics Lab funded.***
- **Electron emission studies of thermal control coating materials. *Aerospace company funding pending.***
- **Electron emission studies of low yield multipactor coating materials. *Nokomis AFRL SBIR funded.***
- **Electron Emission Studies of Orion Backshell Materials. *NASA and Lockheed Martin funded.***
- **COTS microcontrollers radiation hardening tests for CubeSat missions. *USU Physics Funded. SparkFun funding pending.***
- **β radiation TID effects on electronic components. *Aerospace company funding pending.***
- **Comparison of germination rates of radish seeds flown on Russian BION-M1 mission to simulated radiation and vibrations. *Funded through DoEd USUStars Gear Up Program and Tsukuba University Japan Student Space Collaboration Program. Proposed funding through NASA BION-M2 mission.***
- **Space environment effects on muscle and skeletal cells through in-vitro tests of irradiated muscles cells. *Funded through NASA USGC. Funding pending through NASA Space Radiobiology and Human Health Countermeasures Topics.***
- **Pre-flight space environment hybrid thruster tests for Terrier Malamute rocket mission. *NASA Undergraduate Student Instrument Project (USIP) funding pending.***

Space Materials Analysis Research Test (SMART)

The SMART chamber probes electron emission, charging, and charge-transport properties of samples under extremes in electron-, ion-, and VUV/UV/Vis/NIR radiation-fluxes and cryogenic to high temperatures. Notable enhancements include: (i) multiple simultaneous electron and photon fluxes over extended energy ranges to test synergistic effects; (ii) enhanced capabilities for high-precision and high-accuracy electron-, ion- and photon-induced electron yield, emission and transport properties of conducting through extreme insulating materials; (iii) extended wavelength ranges, sensitivity, and imaging speed of absolute VUV/UV/Vis/NIR radiation detection for discharge and luminescence studies; (iv) extended range, sensitivity, and acquisition speed of surface voltage measurements; (v) VUV radiation for photoyield testing and radiation damage.

USU SMART Chamber

(a) Front view of chamber exterior showing full pumping well assembly. (b) Left isometric view of upper chamber. (c) Cutaway view of upper chamber showing the various sample stage and detector components. The sample position is at the intersection of the vertical chamber axis and the horizontal axis through the 8" flanges



EXISTING COMPONENTS
A SPHERICAL CHAMBER
B ION PUMP
C GATE VALVE
D SMALL ION GUN
E LARGE ION GUN
F SECONDARY ELECTRON DETECTOR
G SLR CAMERA
H MONOCHROMATOR

OPTICAL SOURCES
I MONOCHROMATOR UV SOURCE
J PHOTO-ELECTRON GUN UV SOURCE
K TIMING LIGHT

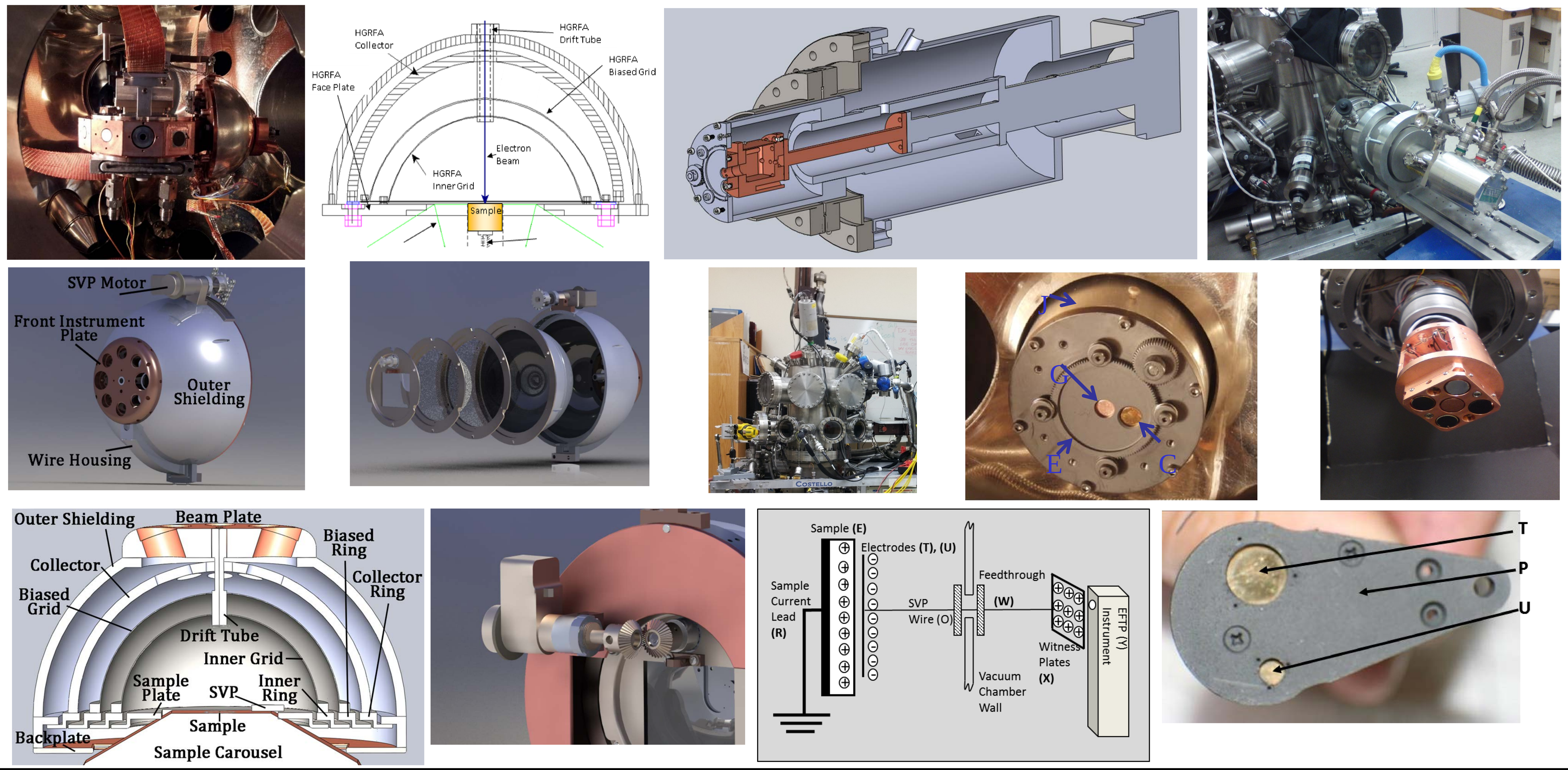
OPTICAL DETECTORS
L InGaAs CAMERA
M XYBION CAMERA
N INTEGRATING SPHERE
O EMISSIVITY PROBE
P X-RAY DETECTOR
Q COLLIMATING LENSE
R UV MONOCHROMATOR
S WEBCAM

ELECTRON/ION DETECTORS
T FLIPPER
U HGRFA

ELECTRON/ION SOURCES
V HEED GUN
W SSC FLOOD GUN
X LOW-ENERGY ELECTRON GUN
Y PHOTO-ELECTRON FLOOD GUN

NEW VACUUM COMPONENTS
Z TURBO PUMP
AA XYZ TRANSLATOR
BB ROTARY FLANGE
CC CUSTOM BOTTOM ADAPTER FLANGE
DD CUSTOM TOP ADAPTER FLANGE
EE SAMPLE STAGE
FF CRYOSTAT

USU SMART Chamber Components

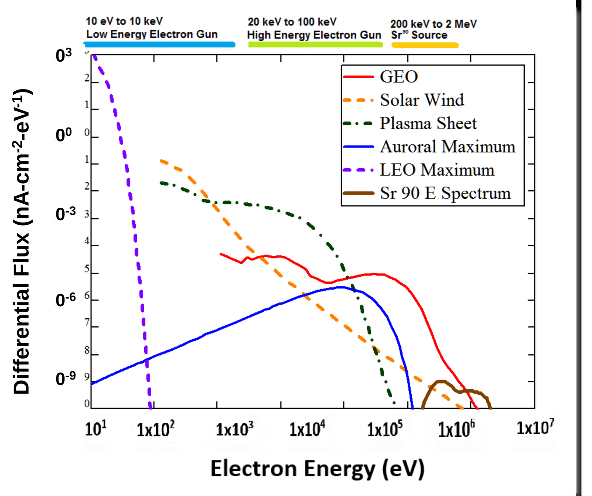


Space Survivability Test (SST) Chamber

The SST chamber [2] is a high vacuum system particularly well suited for cost-effective tests of multiple small scale materials samples over prolonged exposure to simulate critical environmental components. Exposure is uniform to within <5% at intensities for >5X accelerated testing. An automated data acquisition system periodically records real-time environmental conditions—and *in situ* monitoring of key satellite/component/sample performance metrics and characterization of material properties and calibration standards—during the sample exposure cycle [5].

Electron Radiation

A high energy (~10-80 keV) and three lower energy (~10 eV to 5 keV) electron guns provide high electron fluxes.



Ionizing Radiation

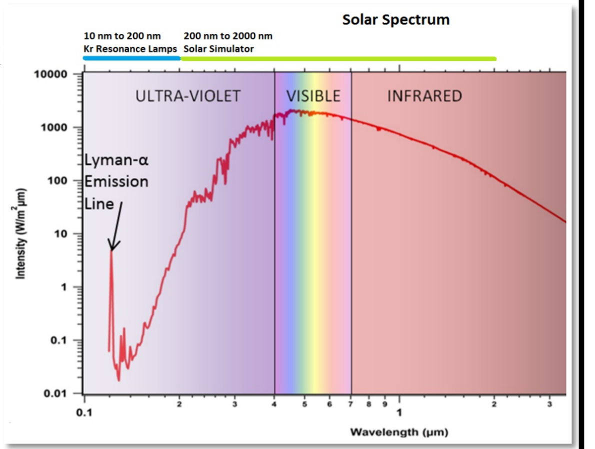
100 mCi encapsulated Sr^{90} β-radiation source (~200 keV to >2.5 MeV) mimics high energy (~250 keV to 2.5 MeV) geostationary electron flux.

Infrared/Visible/Ultraviolet Flux

Commercial Class AAA solar simulator provides NIR/Vis/UVA/UVB electromagnetic radiation (from 200 nm to 1700 nm) at up to 4 times sun equivalent intensity.

Far Ultraviolet Flux

Kr resonance lamps provide FUV radiation flux (ranging from 10 to 200 nm) at 4X sun equivalent intensity.



Temperature Control

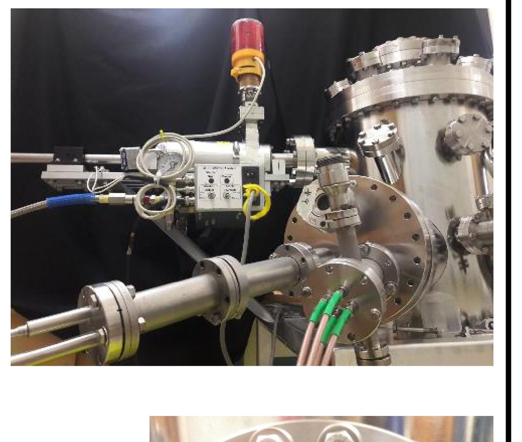
Temperature range from 60 K [4] to 450 K is maintained to ±2 K [3].

Controlled Atmosphere and Vacuum

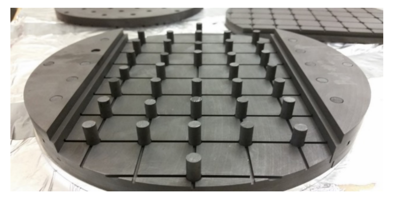
Ultrahigh vacuum chamber allows for pressures <10^{-7} Pa to simulate LEO.

Video Discharge Monitoring

Using custom developed software, live video capture and processing of electrostatic discharge events allows for real-time visual identification of discharge location, intensity, spectral range, and frequency.



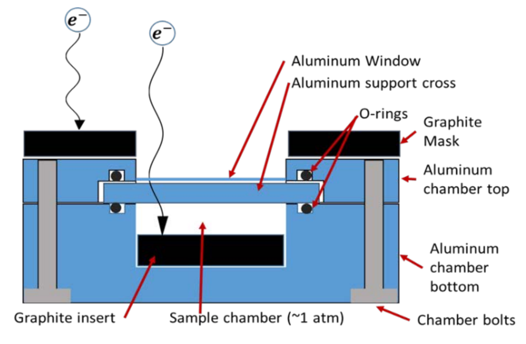
Flexible Sample Mounting



Rotating graphite carousel, ensures uniform irradiation and allows for custom mounting of samples. Or a flange mounted fixture allows for electrostatic discharge testing. Radiation source to sample distance is adjustable.

Biological Testing

Biological samples, which are vacuum incompatible, can use a custom designed chamber with controlled atmosphere and temperature.



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