



Modeling Radiation Influence on Spacecraft Materials Outgassing

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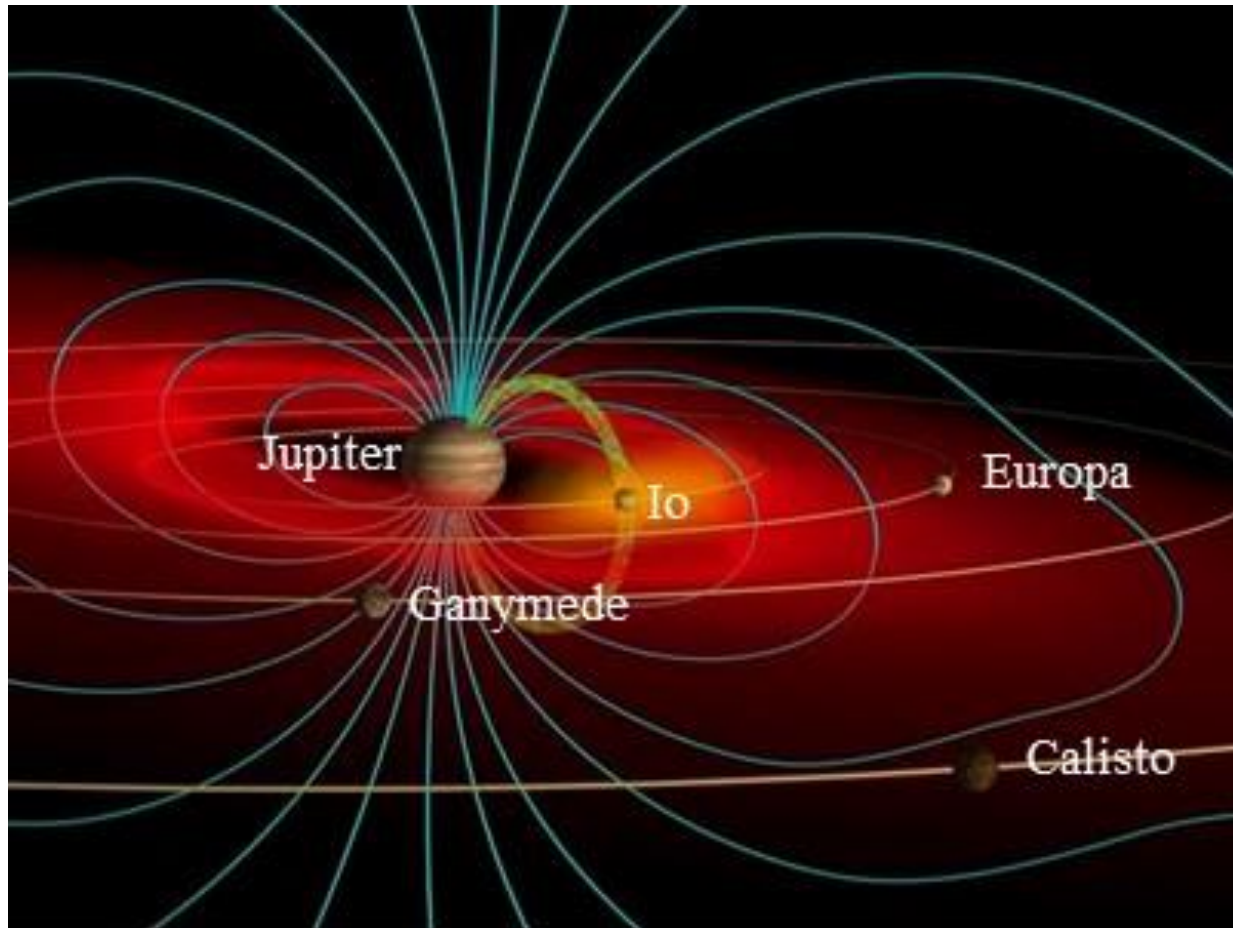
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Jovian Magnetosphere and Radiation Environment



John Spencer's Astronomical Visualizations,
<https://www.boulder.swri.edu/~spencer/digipics.html>

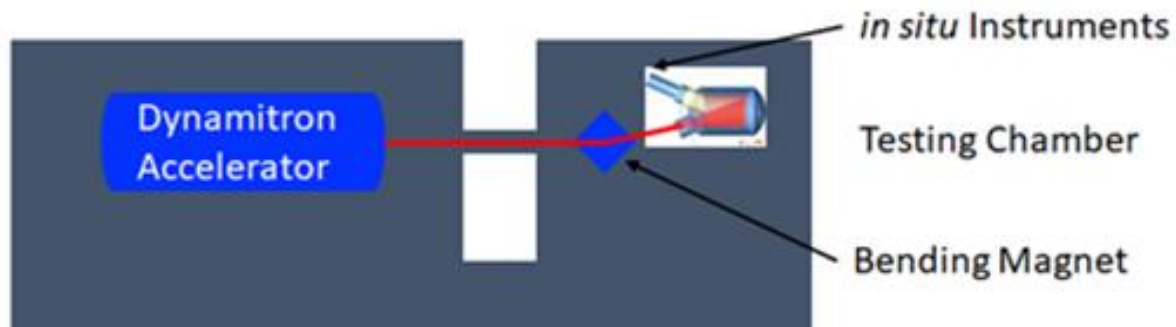
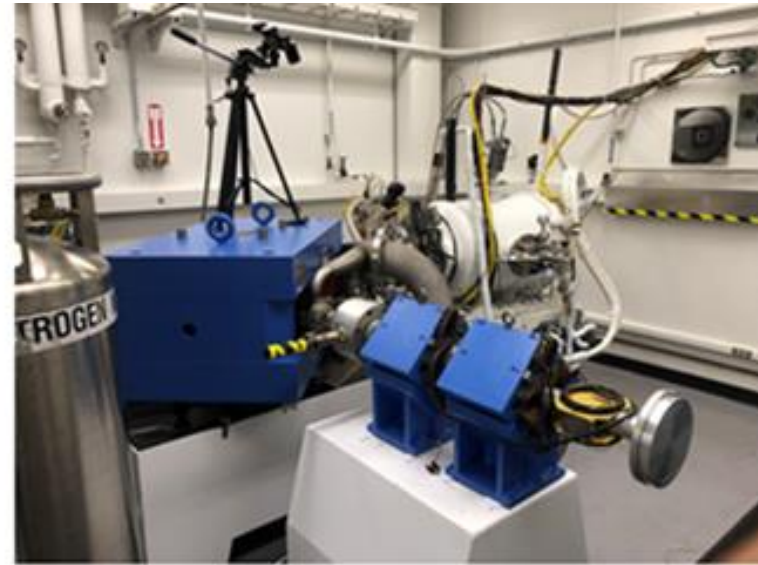
Contamination Control Terminology

- Outgassing
 - Outgassing is volatile material emitted from material (measured as a function of time using ASTM E 1559 test)
 - Outgassed material can condense on sensitive surfaces or be collected by mass spectrometers
- CVCM—Collected Volatile Condensable Material
 - CVCM is fraction of material sample condensed during testing (measured using ASTM E 595 test)
 - Test material held at 125° C for 24 hours in vacuum
 - Condensable material is collected on a plate held at 25 ° C

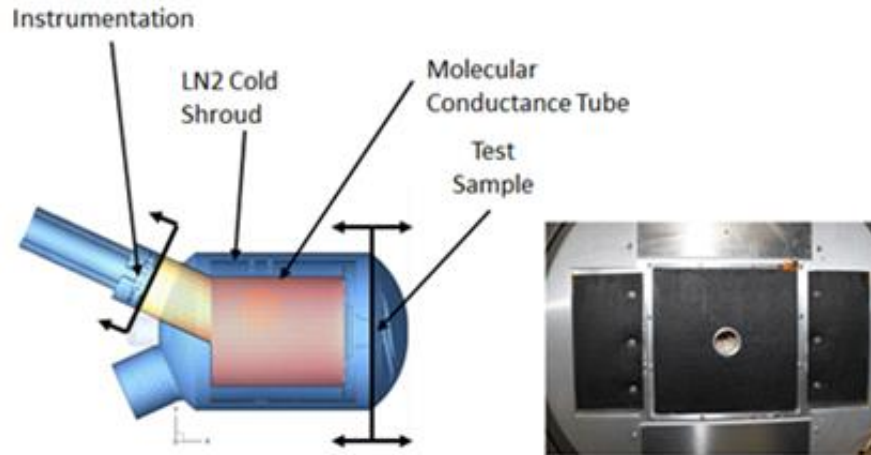
Radiation Induced Outgassing Test (RIOT) Goals

- Test materials in relevant radiation environment
 - Radiation environment
 - Testing performed with 1.5 MeV electrons at a flux of 2.6×10^{10} electrons/cm²/s
 - Sample material and temperature
 - Silicone materials tested at temperatures from -83° C to 30° C
- Identify molecules emitted from materials during and subsequent to radiation exposure
- Use test data to estimate radiation induced outgassing rates during Europa Clipper mission

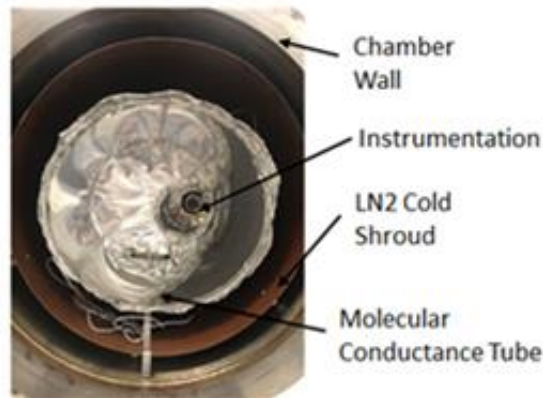
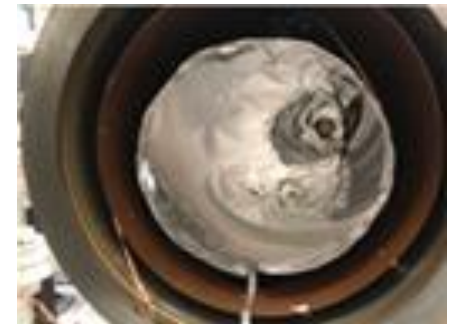
JPL Dynamitron Facility Configuration for Radiation Induced Outgassing Testing



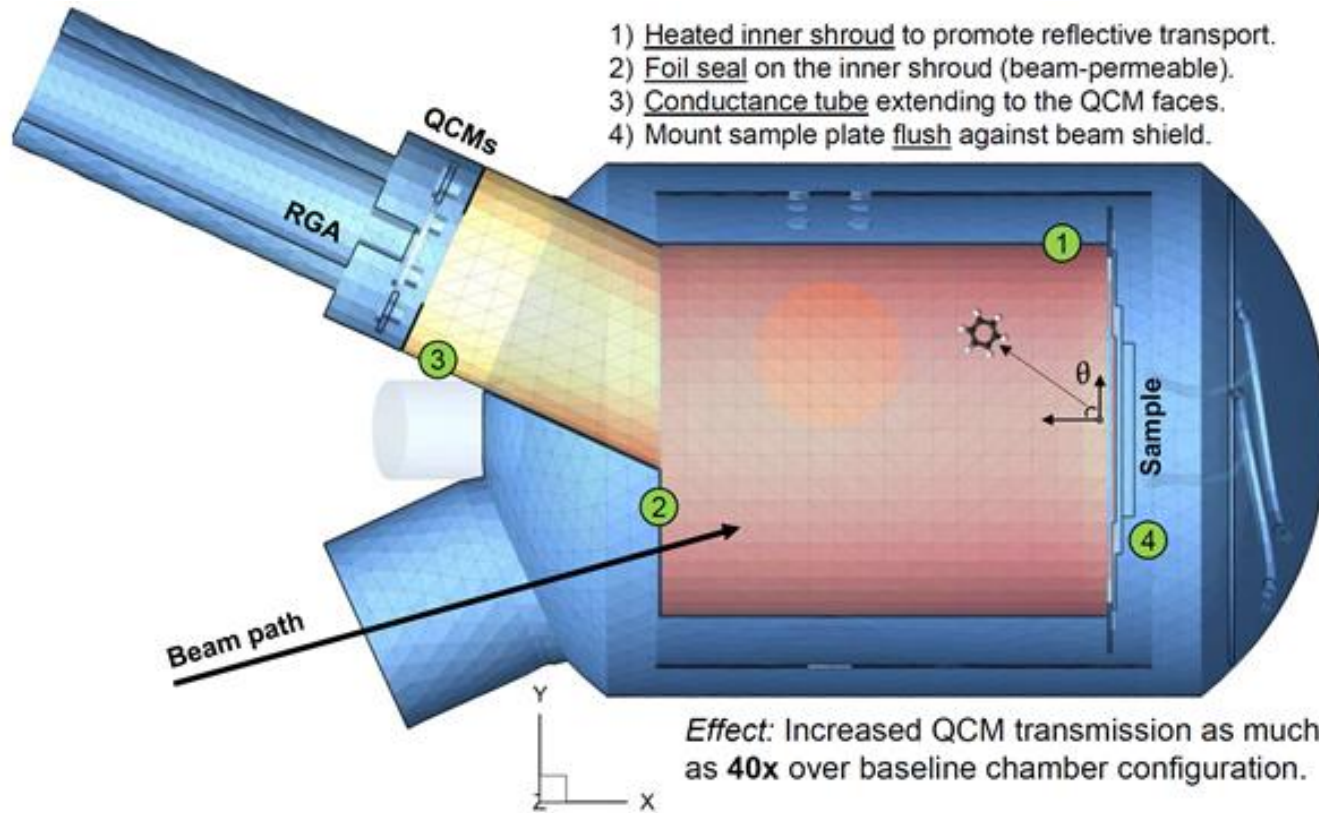
RIOT Chamber, Instrumentation, and Test Sample



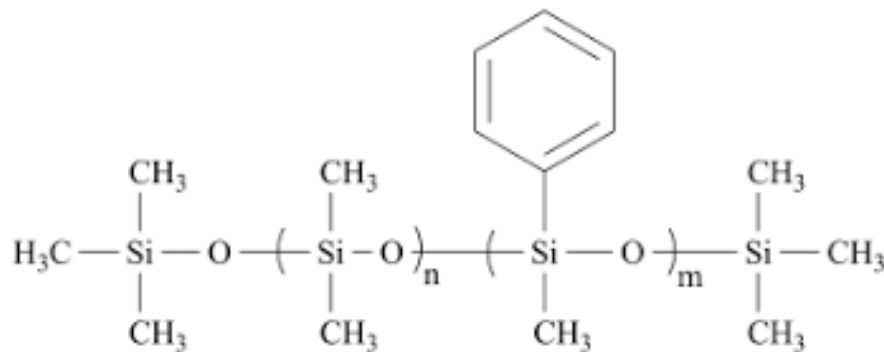
Test Sample



Conduction Tube Design

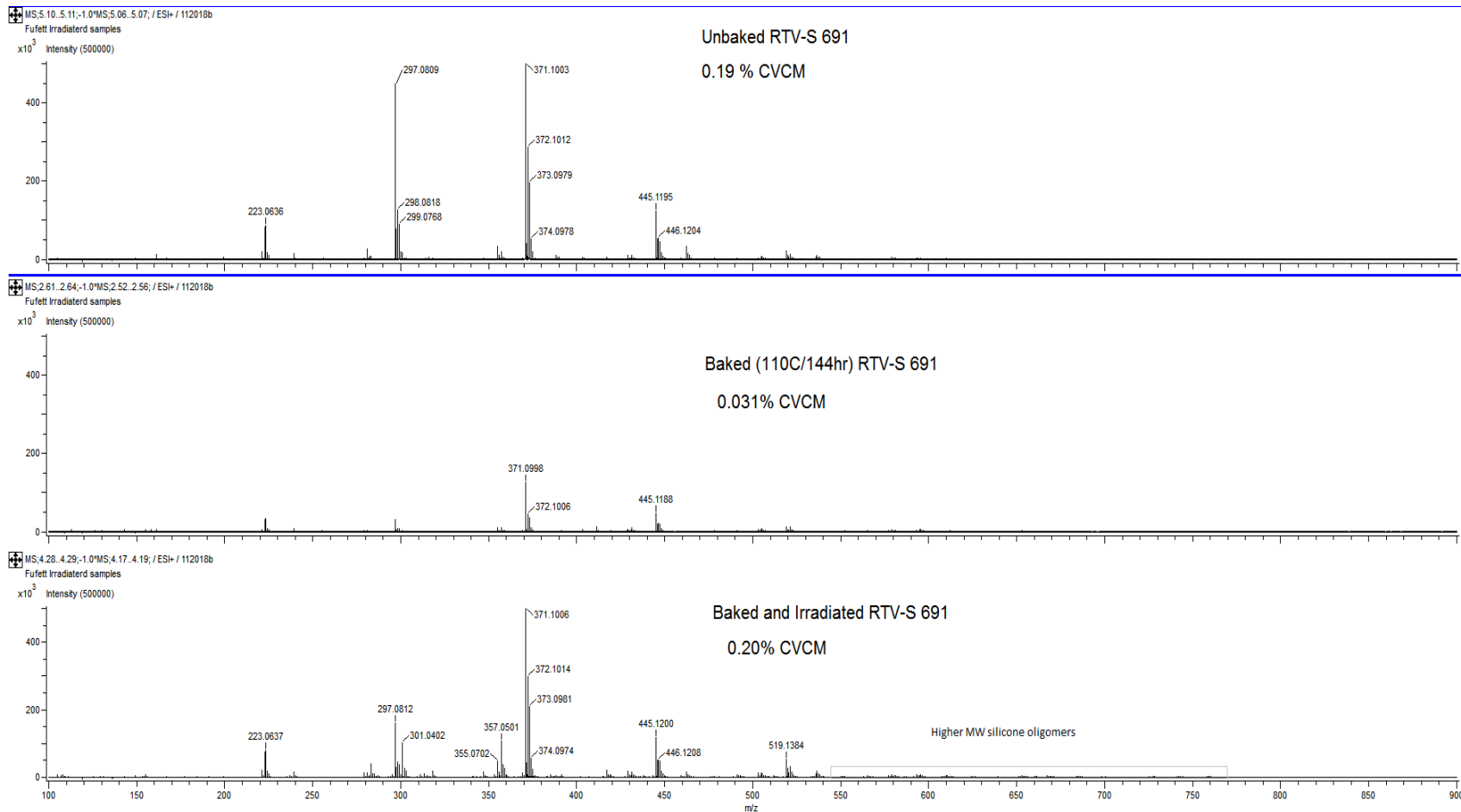


Methyl Phenyl PolySiloxane

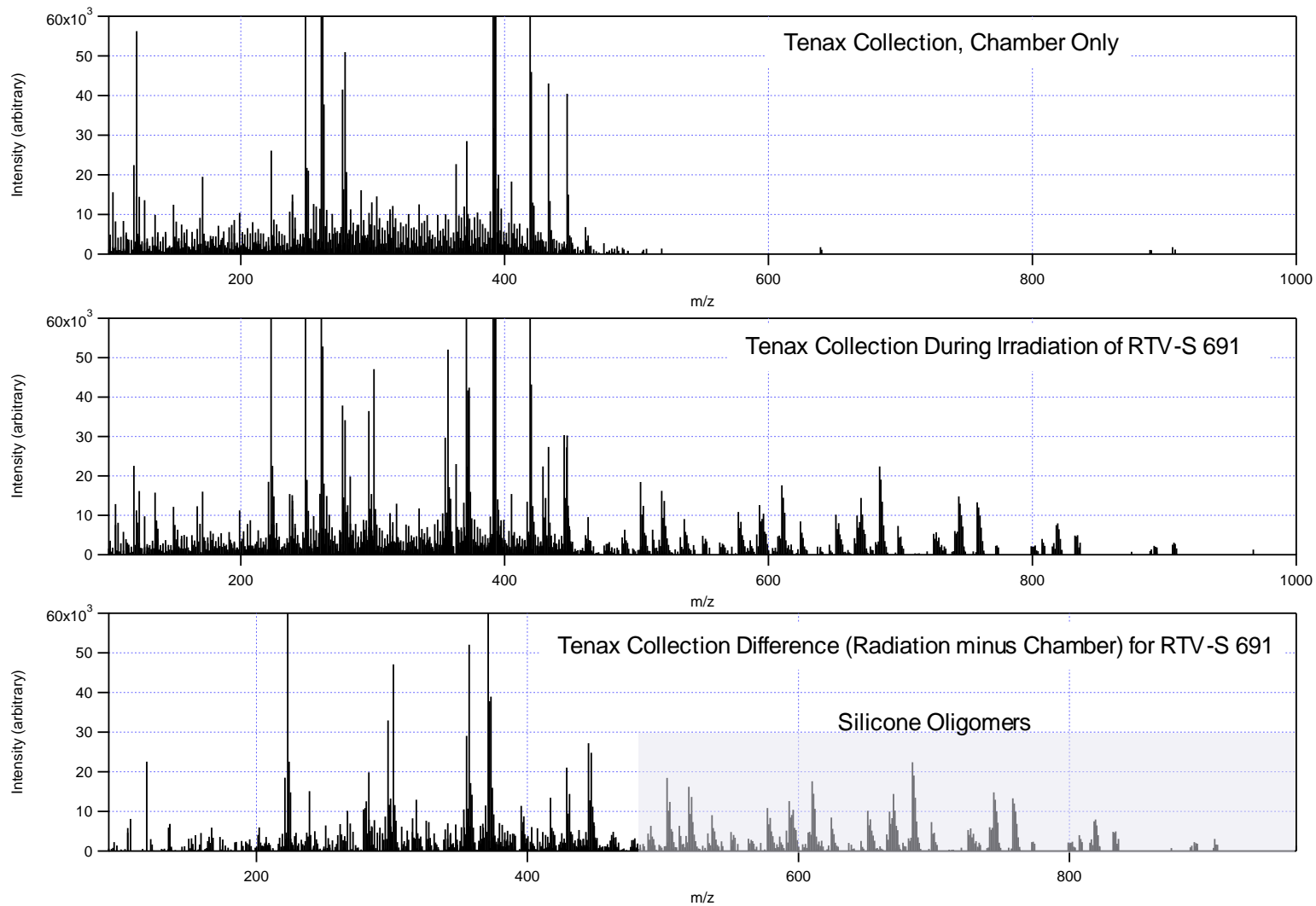


<http://www.topsilicone.com/>

Direct Analysis in Real Time with Mass Spectrometry (DART-MS) results for RTV-S 691 Test Sample Material



DART-MS results for Tenax Getter Material from RTV-S691 Testing



Summary of Mass Spectrometry Results

Silicone Sample	Mass Signal Increases Due to Irradiation	Identified Species
Wacker RTV-S 691	13, 14, 15, 16, 32, 50, 51, 52, 78, 59, 91, 147, 207, 281	Methyl Group, Oxygen, Silicones, Phenyl Group
Nusil CV-1500	13, 14, 15, 16, 32, 50, 51, 52, 78, 92, 193, 207	Methyl Group, Oxygen, Silicones, Phenyl Group
Nusil SCV-2596	13, 14, 15, 16, 32, 51, 59, 73, 78, 91	Methyl Group, Oxygen, Silicones, Phenyl Group
Nusil SCV-2585	13, 14, 15, 16, 32, 46, 69, 78, 119	Methyl Group, Oxygen, Silicones
DC 93-500	13, 14, 15, 16, 32, 66, 119	Methyl Group, Oxygen, Silicones

Outgassing Rate at Jupiter

$$\frac{\partial \rho}{\partial t} = -\vec{\nabla} \cdot \vec{\Gamma} + \dot{\rho} + \gamma \rho$$

$$\vec{\Gamma} = -D \vec{\nabla} \rho$$

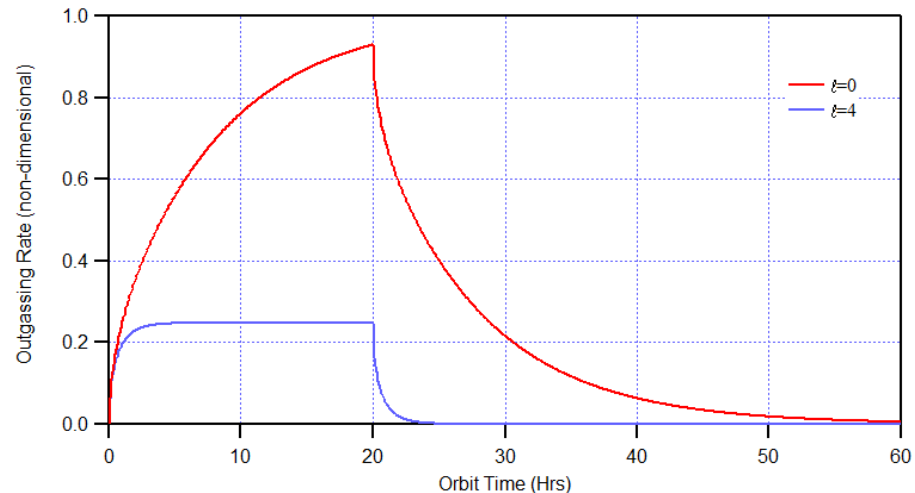
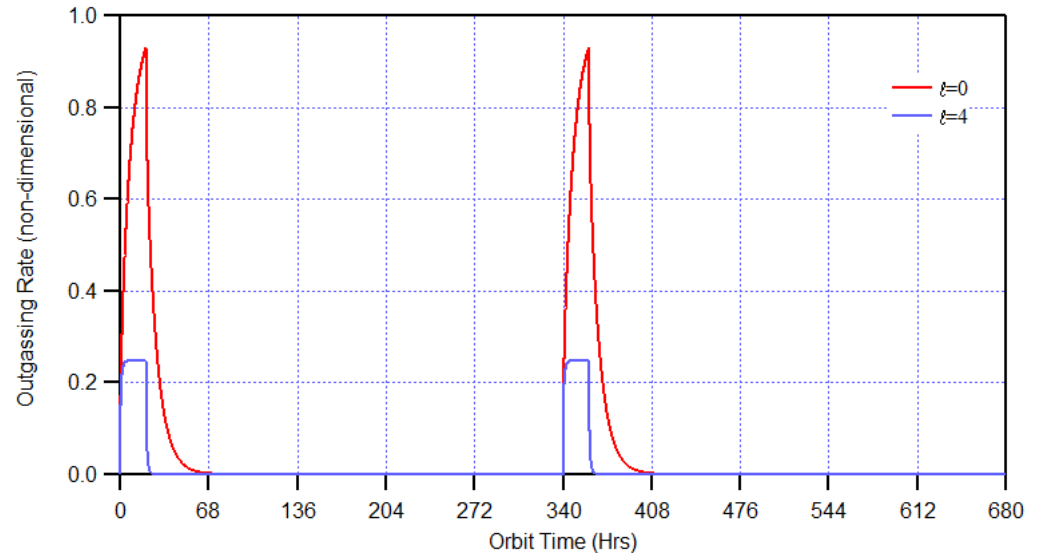
$$x = \mathbb{X} L$$

$$\rho = \frac{\dot{\rho} L^2}{D} \mathcal{P}$$

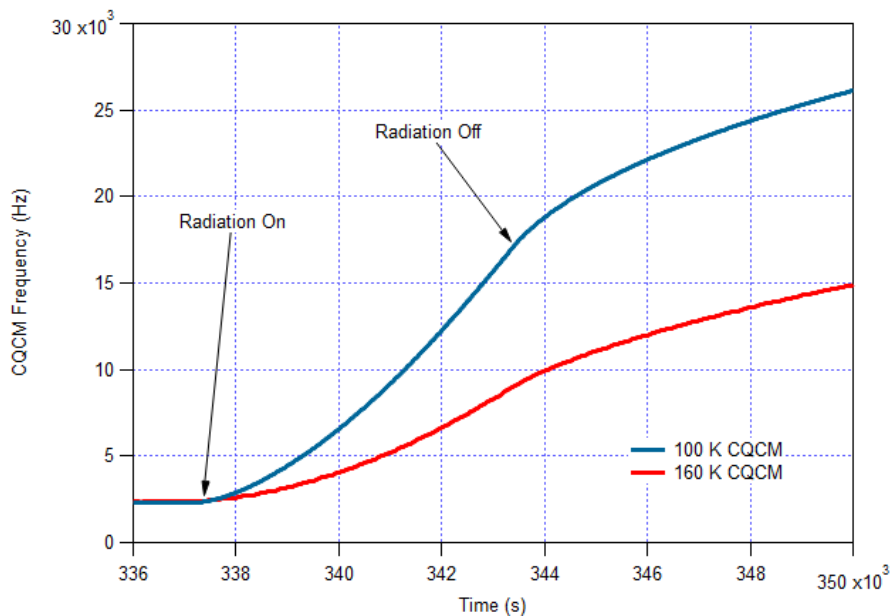
$$t = \frac{L^2}{D} \mathcal{T}$$

$$\ell = \sqrt{\frac{\gamma}{D}} L$$

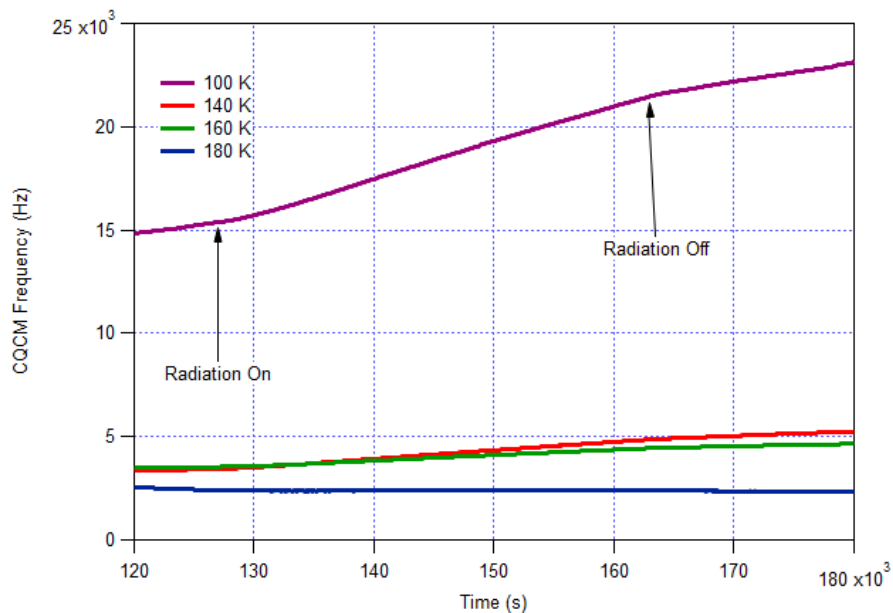
$$\dot{\rho} \left[\frac{\partial \mathcal{P}}{\partial \mathcal{T}} - \nabla^2 \mathcal{P} - 1 + \ell^2 \mathcal{P} \right] = 0$$



RIOT Chamber CQCM Data for RTV-S 691 (CQCM Data)



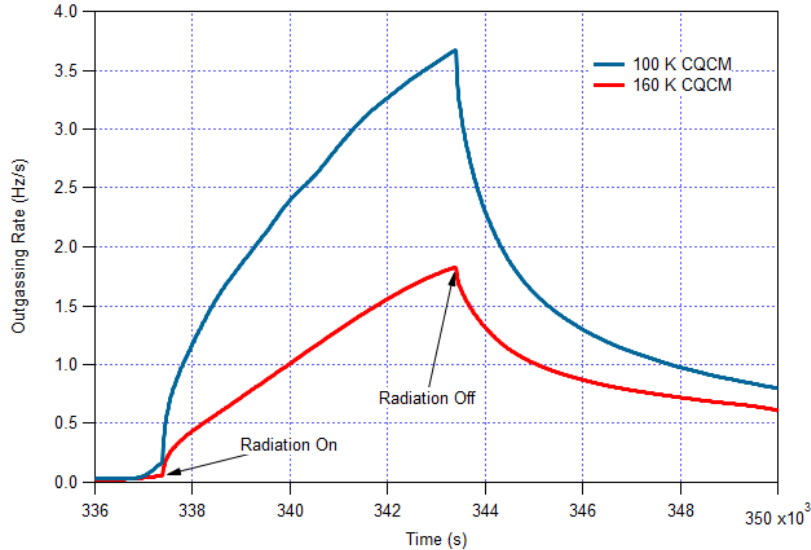
Sample Temperature 303 K



Sample Temperature 190 K

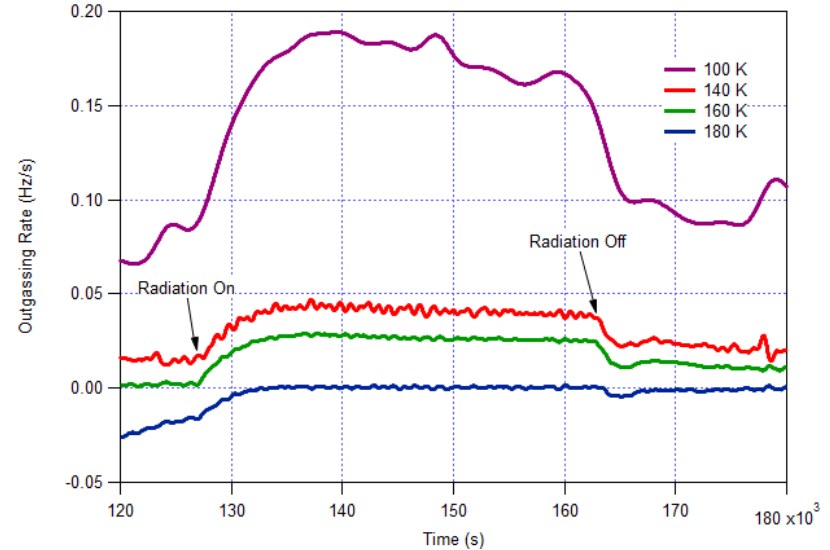
RIOT Chamber CQCM Data for RTV-S 691 (Outgassing Rate)

Peak outgassing rate: 7 ng/cm²/s



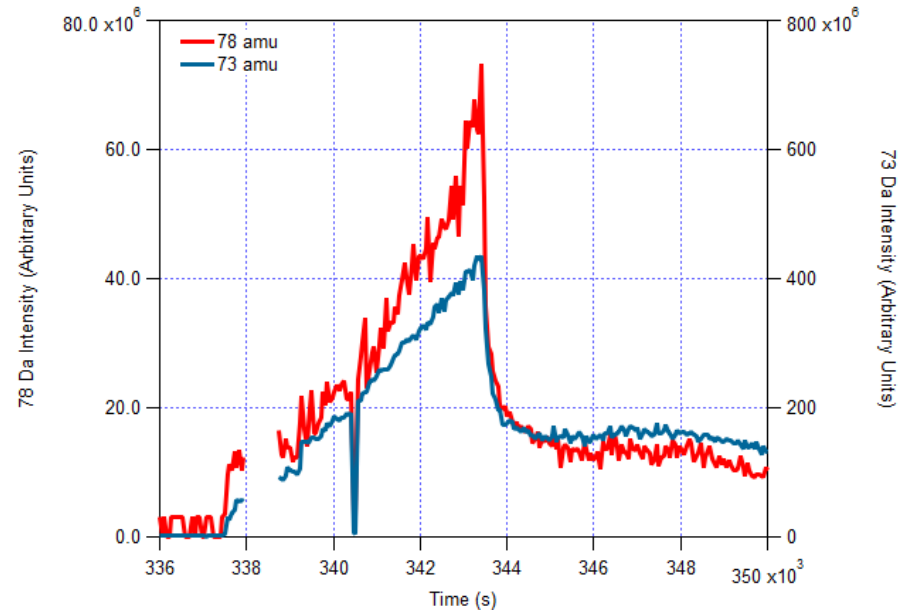
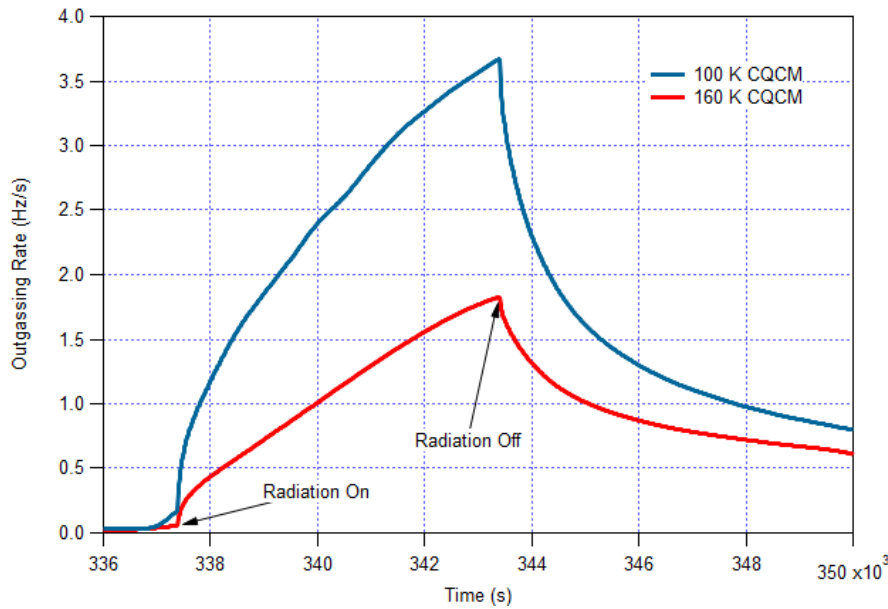
Sample Temperature 303 K

Peak outgassing rate: 0.2 ng/cm²/s



Sample Temperature 190 K

RIOT Chamber CQCM Data for RTV-S 691 (Outgassing Rate)



Sample Temperature 303 K (30° C)

Conclusions

- RIOT has produced useful information that can be used to analyze radiation induced contamination effects
- Radiation induced outgassing species identified
- Although upper bounds can be placed on outgassing rates reduction in the uncertainty of the outgassing rate estimates is desired
 - Further work is needed to better understand:
 - Radiation interactions with facility and instrumentation
 - Sample temperature effects on diffusion and cross-linking within sample



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