2021 NASA Contamination, Coatings, Materials, and Planetary Protection Workshop (CCMPP)

Contamination Control Approach to Mitigating Radiation Induced Outgassing on Europa Clipper

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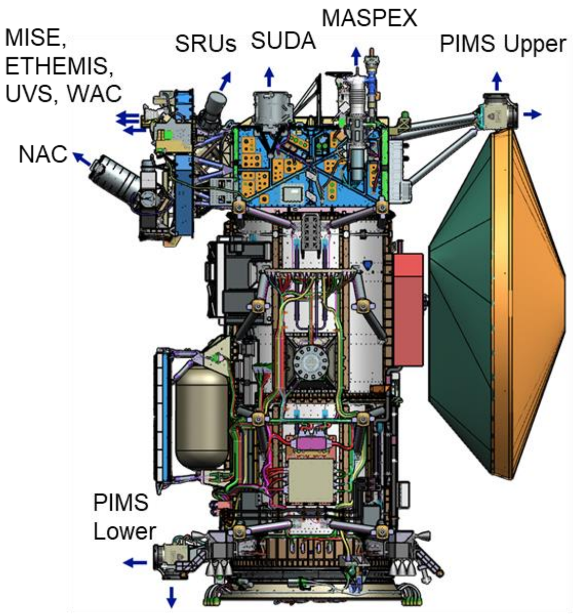
Europa Clipper Sensitivities

Europa Clipper carries many instruments sensitive to both molecular and particulate contamination.

- The Contamination Control (CC) team evaluates **molecular outgassing contamination**; particle contamination (e.g. dusts, fibers); and thruster and propellant contamination vectors.
- This presentation will focus primarily on molecular outgassing contamination.

Clipper Instruments and their Aperture Open Directions



Sensitive Instrument	Function	Contamination Sensitivity Effects / Threats
MASPEX	Mass spectrometer	Signal noise / Particle redistribution and outgassing
UVS	UV spectrograph	Signal noise / Humidity (purge reqt.), particulate redistribution and outgassing
SUDA	Dust Analyzer	Signal noise / Particle redistribution and outgassing
NAC	Camera	Obscuration, scatter, signal noise / Particle redistribution and outgassing
WAC	Camera	Obscuration, scatter, signal noise / Particle redistribution and outgassing
E-THEMIS	Thermal imager	Obscuration and signal noise / Particle redistribution and outgassing
PIMS Upper	Plasma sensor	Electrical shorting / Particle redistribution from fairing Voltage loss / molecular outgassing
PIMS Lower	Plasma sensor	Electrical shorting / Particle redistribution from fairing and thruster firing Voltage loss / molecular outgassing
MISE	IR spectrometer	Obscuration and signal noise / Particle redistribution and outgassing
SRUs	Imager	Obscuration and scatter / Particle redistribution from fairing Throughput loss / molecular outgassing

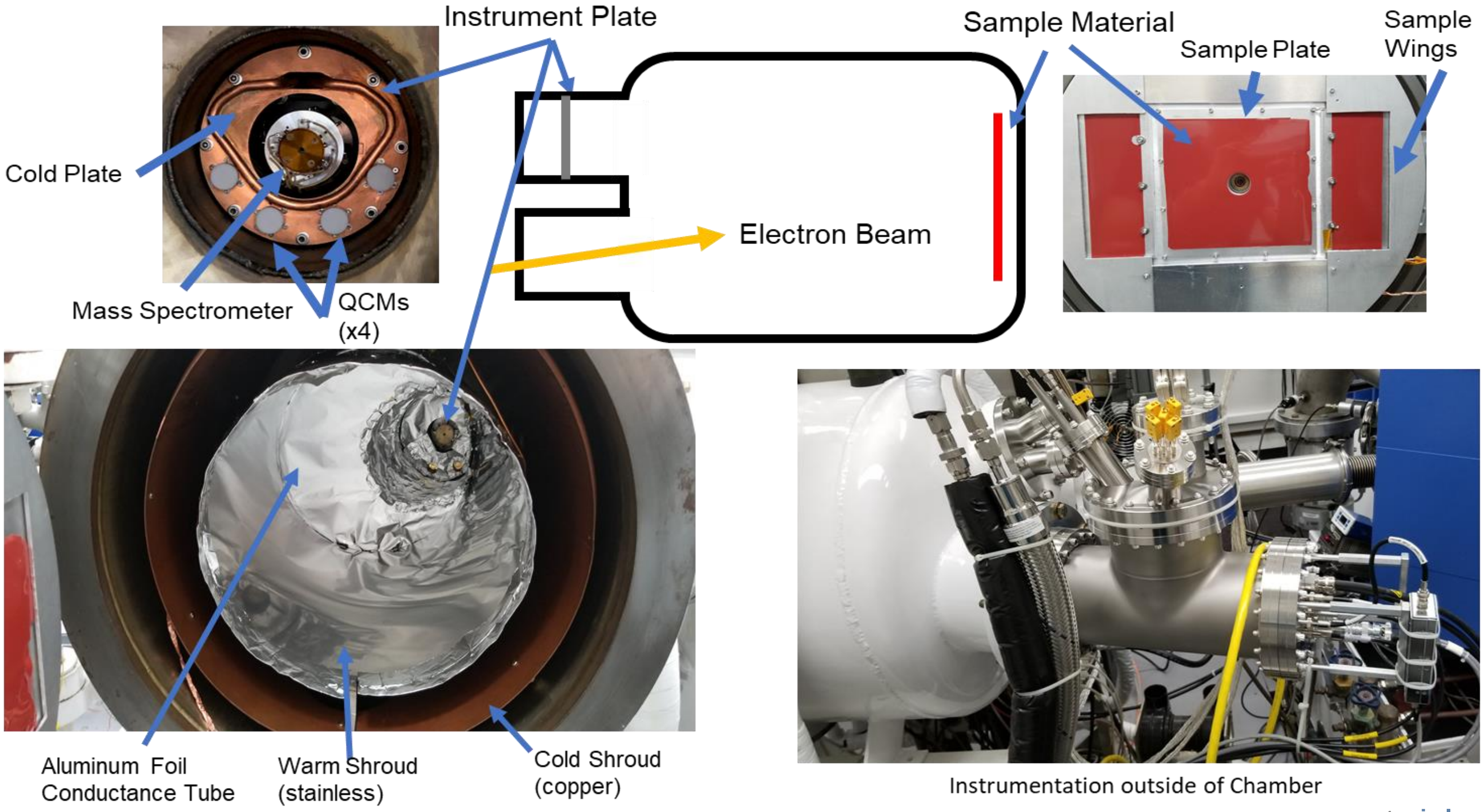
Materials Outgassing Testing

Material outgassing is characterized for Europa Clipper with two different tests:

- ASTM-E1559 testing offers high chamber sensitivity and has extensive flight heritage, but cannot provide Europa-like cold sample temperatures or ionizing radiation.
- **Radiation Induced Contamination Testing (RadCon) was developed at JPL to determine the effects of Europa-like cold temperature and electron radiation on spacecraft materials.**

	ASTM E-1559	RadCon
Heritage	Significant (ISS, M2020)	Newly Developed JPL Capability
Instrumentation	CQCMs to measure outgassing rate Mass Spectrometer to measure species	
Instrument Measurement Time	Always On	
Test Duration	1 week	1-2 weeks
Sample Temperature	5° C (cannot go lower)	**-113° C (matches hot solar array at Europa)**
Radiation Exposure	None	**High energy electron exposure that matches Europa dosage rates of average fly-by (653 rad/sec)**
Chamber Sensitivity	~5x10^{-15} g/cm^2/sec	~1x10^{-11} g/cm^2/sec

RadCon Chamber Configuration



Summary of Status in 2020

- CC team identified with RadCon that thermal blankets outgassing increased significantly under Europa-like radiation exposure when compared to the standard ASTM-E1559 test.
  - When implemented into CC molecular transport models, thermal blanket outgassing preliminary results predicted that deposition limits would be exceeded on instrument sensitive surfaces during tour phase.
- The testing goals for 2021 included:
  - Improving RadCon test configuration with new sample plate holder to limit transport of outgassing molecules from sample backside and increase facility LN2 capability to enable long duration testing.
  - Performing outgassing measurements post-radiation while maintaining flight-like temperatures, to assess change in outgassing rate.
  - Testing multiple thermal blanket material compositions in support of blanket trade studies.
- The Clipper project formed a Tiger Team in October 2020 to enact the above testing goals and develop mitigations, with the end goal being that updated CC analysis showed all instruments meeting their contamination limits.

Thermal Blanket Results as of Oct. 2020	**ASTM-E1559: Stamet Coated Kapton Only**	**RadCon: Stamet Coated Kapton Only**	**RadCon: Full Blanket**
Outgassing Rate on 80K QCM (g/cm^2/sec)	1.1×10^{-12}	2.8×10^{-10}	**2.6×10^{-9}**
Outgassing Rate on 160K QCM (g/cm^2/sec)	1.1×10^{-14}	4.5×10^{-11}	**8.6×10^{-11}**

RadCon Long Duration Test Procedure

Week 1

Hardware installation (1 day):

- Clean chamber and accessible surfaces with solvents
- Install RadCon Hardware
    - Sample mounting plate
    - Radiation shields
    - RadCon inner shield
    - Air-side control boxes and cabling
- Begin vacuum pump down for background test

Background Test (1 day):

Taken before each material tests to confirm chamber cleanliness, no sample installed

- ~ 3 hours test at sample temperature, no radiation
- Radiation background periodically tested to confirm instrument response – in general instruments are insensitive to radiation exposure on sample plates

Sample Installation (1 Day):

- Install sample and return chamber to vacuum

Week 2

Extended Test Period:

- ~5 hours sample cooldown to test temperatures
- 2 hours measurement without radiation
- 8 hour measurement with first radiation exposure
- 8 hour measurement without radiation
- 8 hour measurement with second radiation exposure
- 8 hour measurement without radiation exposure
- 10 hour contingency period
- 3 hour QTGA

- **Total time between 42 and 52 hours consecutive testing**.
- Test prep and completion takes about 2 weeks of Dynamitron time and support.

Chamber Temperatures

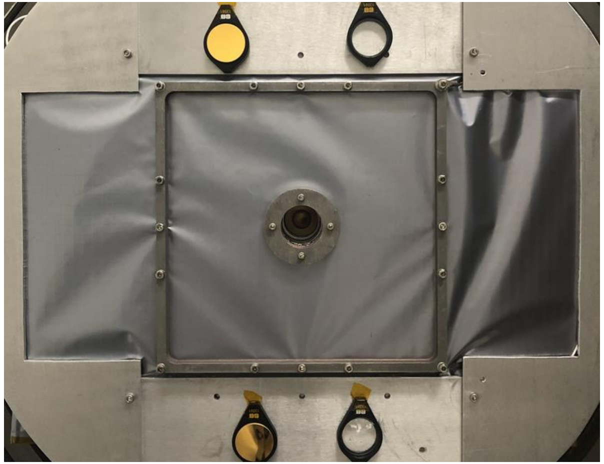
Surface	Temperature (°C)
Sample Plate	-110/-116
Sample Wings	-106/-112
Inner Shroud	-20/-28
Radiation Shield	-24/-32

- Sample is held at Europa operating temperature (as low as -113°C), while non-sample surfaces are kept warm to prevent contamination trapping
- Temperature delta between sample plate and inner shroud increases molecular transport to sensors

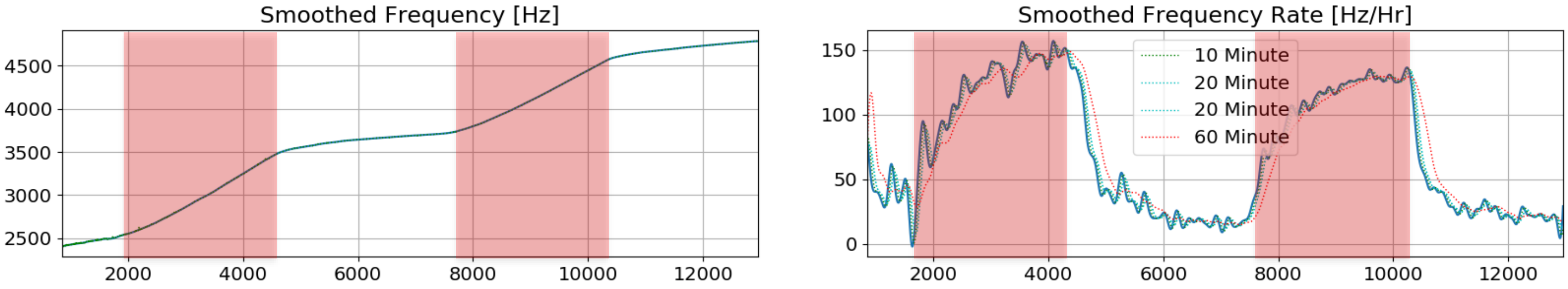
Stamet Coated Black Kapton with Scrim

Stamet Coated Black Kapton sample with scrim backing was tested in late November 2020.

- This test included the updated "picture frame" sample fixture for Dynamitron mounting and liquid nitrogen supply/exhaust lines.
- Improved LN_2 supply allows for longer thermal control and test durations, and the dedicated exhaust line allows for higher LN_2 operating pressure yielding more stable QCM temperatures.
- The longer duration test allows for both radiation on and post radiation outgassing measurements. This allows for calculation of an average outgassing rate throughout Europa Tour weighted with on-orbit exposure durations.



-173˚C QCM through 42 hours sample test. Red bars indicate radiation exposure



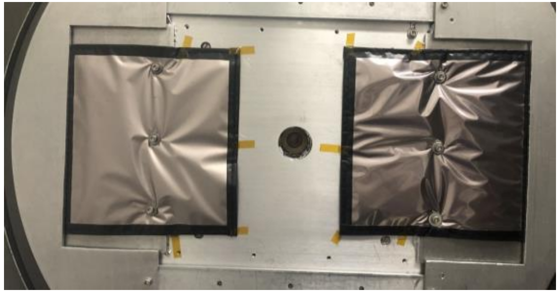
Summary of Thermal Blanket Results

Sample	-173˚C QCM
Stamet Coated Black Kapton (Film Only, July 2020)	$1.48 \times 10^{-10}\ \frac{g}{cm^2 s}$
First Stamet Coated Black Kapton MLI (July 2020)	$2.65 \times 10^{-09}\ \frac{g}{cm^2 s}$
Stamet Coated Black Kapton (Film Only, Nov 2020)	$2.90 \times 10^{-10}\ \frac{g}{cm^2 s}$
Black Kapton (Film Only, Nov 2020)	$1.55 \times 10^{-10}\ \frac{g}{cm^2 s}$
Tiger Team Stamet Coated Black Kapton MLI (Jan 2021)	$5.99 \times 10^{-11}\ \frac{g}{cm^2 s}$
Foil Outer Layer MLI (Jan 2021)	$<1 \times 10^{-11}\ \frac{g}{cm^2 s}$
VDA Kapton (April 2021)	$2.34 \times 10^{-11}\ \frac{g}{cm^2 s}$

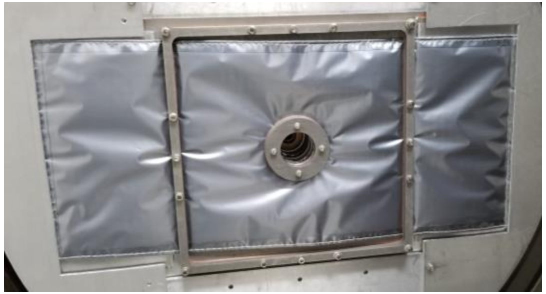
Preliminary blanket outgassing rate (highlighted yellow) kicked off the Tiger team effort to understand blanket outgassing.

- New sample fixture constrained the geometry and view factor from the backside of the blanket to instruments resulting in lower outgassing measurement.
- Long duration testing allowed for measurement of the post-irradiation outgassing rate. *Updated rates are the weighted average outgassing rates with radiation and post-radiation measurements incorporated.*

Even though the updated outgassing rate (highlighted green) was significantly lower than previously measured rate, additional mitigations were required to bring instrument predicted depositions to within molecular contamination limits.



July 2020 Blanket Sample



January 2021 Blanket Sample

Outgassing Mitigations

Mitigations for high outgassing thermal blanket and solar arrays caused by radiation fall into 3 main categories:

[1] Interior Instrument Analysis:

- CC team modeled detailed interior instrument geometries and thermal gradients for MISE, SRU, and SUDA to determine deposition on optical surfaces.
- Deposition analysis was conducted with Molflow+ ray tracing code.
- MISE and SRU showed significantly reduced deposition on internal optics.
- Lessons from MISE, SRU, and SUDA internal models were applied to WAC and PIMS.

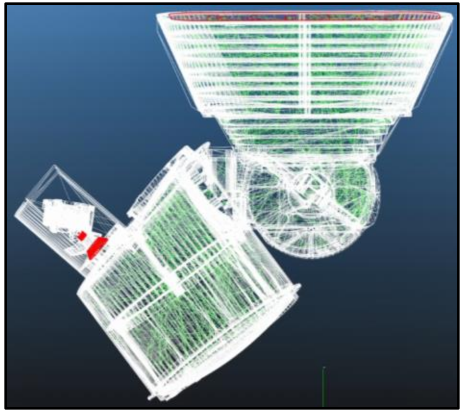
[2] Contamination Shields:

- Contamination shields would block view factors (and therefore direct contamination transport) between sensitive surfaces and their highest-contributing sources.
- Conceptual shields are proposed for UVS and SUDA. Shields in design.

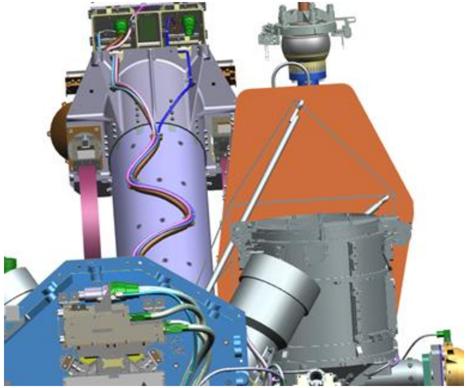
[3] Thermal Blanket Change:

- Alternate blanket layups were shown to have reduced outgassing under radiation.
- Ultimately not needed to bring instruments to within contamination limits.

With interior instrument analysis and contamination shields incorporated most instruments now have a clear path to closure with their molecular contamination requirements.



MISE Interior CC Model



Proposed SUDA Shield (redesigned Vault sunshade)

Deposition Results for Clipper

The table below shows the results of the contamination deposition modeling with the solar array and thermal blankets as contamination sources.

Both sets of presented results show the deposition values using updated radiation induced outgassing rates from the thermal blanket.

Sensitive Surface	Requirement (Å)	Deposition without Mitigation (Å)	Mitigation Performed	Deposition with Mitigation (Å)
MASPEX Entrance	25	19		19
UVS Entrance	28	116	UVS Shield	14
UVS Solar Port	28	159	UVS Shield	3
SUDA Inside	50	184	SUDA Shield	7
EIS – NAC	200	3		3
E-THEMIS	200	101		101
MISE	500	20864	Internal Contamination Model	250
EIS – WAC	200	245	Updated Contamination Model	69
PIMS Lower Y	200	136		40
PIMS Lower Z	200	762	Updated Contamination Model	180
PIMS Upper Y	200	1423	Updated Contamination Model	495
PIMS Upper Z	200	206		20
DSS Lower -X	600	581		581
DSS Lower +X	600	598		598
DSS Upper -X	600	334		334
DSS Upper +X	600	333		333
SRU -X	100	1396	Internal Contamination Model	28
SRU+X	100	4776	Internal Contamination Model	16

Legend
Meets Requirement
Exceeds Requirement

PIMS assessment still in work. JPL CC is working with the spacecraft and science teams to develop approach.

Conclusions

- The JPL CC Team developed radiation induced outgassing contamination testing (RadCon) to measure material outgassing at Europa flight conditions:
    - Flight hardware temperatures at Europa (-113° C).
    - Average electron radiation flux during science measurements.
- In 2020, JPL CC Team found that the thermal blankets used on Clipper demonstrated significantly increased outgassing under radiation compared to the ASTM-E1559 test.
- The JPL CC team made multiple improvements to the RadCon facility to better characterize blanket outgassing, including:
    - Developed a sample picture frame to reduce outgassing from the sample backside.
    - Added dedicated LN2 supply lines to allow for longer duration testing and measurement of the blanket outgassing post radiation.
- The updated testing measured lower outgassing rates on the Stamet Coated Kapton blanket than the original testing, attributed to the improvements made to the RadCon configuration.
- The Clipper Thermal Blanket Tiger Team developed mitigations to support the instruments such that instrument deposition limits are not exceeded. These included:
    - Internal instrument modeling with Molflow+ to determine deposition on specific sensitive surfaces in the instrument.
    - Adding contamination shields to block the view factor between outgassing sources and sensitive instruments.
    - Testing both the baseline thermal blanket and alternate thermal blanket layups that showed lower outgassing.
- **With the updated RadCon test results, internal instrument analyses, and contamination shields incorporated, most instruments now have a path to closure with their molecular contamination limits. The approach for one instrument (PIMS) is still in work with the spacecraft and science teams.**

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