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Conducting Outgassing Measurement on Representative Coupon of the Europa Clipper Solar Arrays

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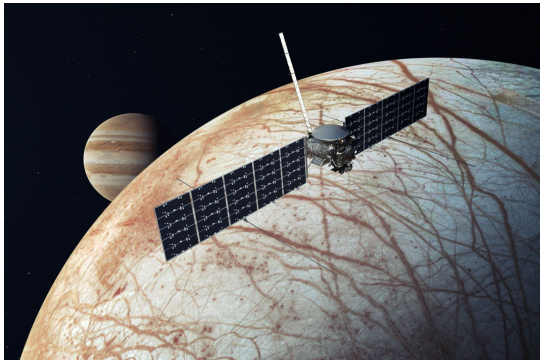
Introduction

The Europa Clipper spacecraft includes large solar arrays that will power the spacecraft during the duration of its mission at Jupiter. Each solar array wing is approximately 46.5 feet (14.2 meters) long and about 13.5 feet (4.1 meters) high.

Due to their size, orientation, and material composition, the solar array outgassing can have a significant effect on the Europa Clipper sensitive surfaces. However, performing an outgassing measurement poses a challenge due to the solar array size and differences in material usage on the front side versus the back side.

An accurate measurement on the solar array outgassing is necessary to assess the impact to Europa Clipper instruments over the duration of the mission.



Visualization of Europa Clipper Spacecraft at Europa

Europa Clipper Solar Arrays at Airbus

Europa Clipper Outgassing Requirements

The JPL CC team implemented outgassing rate requirements for every major Clipper component in order to support science return.

Outgassing Rate Requirement

Each flight system surface shall have a pre-launch outgassing rate as defined below:

View Factor	Definition	Example Components	Outgassing Rate ($g/cm^2/sec$)	Outgassing Rate ($ng/cm^2/hr$)
High	**Exposed**	**Solar Array, MLI**	**$1x10^{-14}$**	**0.036**
Moderate	Underneath MLI	Prop Module Electronics	$5x10^{-14}$	0.18
Limited	Inside Vault	Vault Electronics	$1x10^{-12}$	3.6

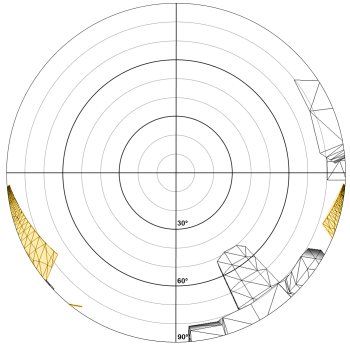
- Outgassing rate requirement verification must involve a quantitative measurement of outgassing rate. In most cases, this involves a QCM measurement at the assembly level.
- Outgassing rate is measured with hardware at Europa flight temperature and QCM at -113°C (corresponding to Clipper sensitive surface temperature at Europa).

Based on its location, the Solar Array is included in the most stringent outgassing rate requirement.

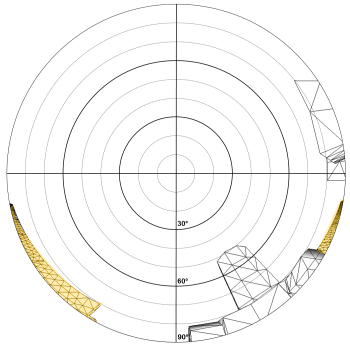
Solar Array Outgassing Effects

- The Solar Arrays are gimbaled and will change in orientation throughout the Europa Clipper mission phases.
- Additionally, the REASON instrument antennas are mounted to the solar array and determine the orientation of the arrays during Europa flybys.

- The solar arrays have a view factor to instruments pointing in the Nadir direction (e.g. MISE, UVS) as shown in the fish-eye diagrams. The solar array is highlighted in yellow.
- Outgassed contamination from the solar arrays can have a direct transport to instrument sensitive surfaces.



Fisheye view of UVS Entrance, Solar Array at 117°



Fisheye view of UVS Entrance, Solar Array at 68°

The Solar Array outgassing primarily impacts the Nadir-pointing instruments.

Test Objectives

1. Measure the outgassing rate of the Solar Array at flight-like conditions
   - The Solar Array has a hot case for both cruise and tour phase, which will be the targeted conditions for the outgassing rate measurements.
   - The cruise phase outgassing will be used to assess risks to instruments without or with early deployed covers. The tour phase outgassing will affect all instruments during their operation.

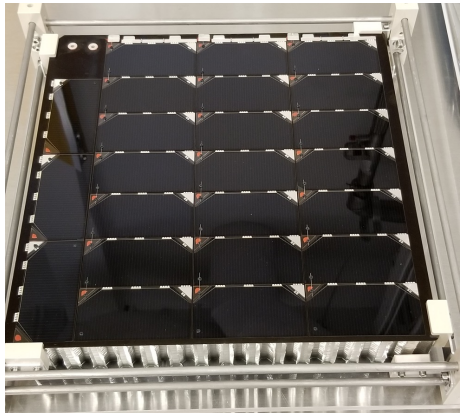
2. Assess the effectiveness of bakeout duration ranging from 7 to 10 days
   - The initial bakeout requirement for the flight Solar Arrays was 120°C for 240 hours.
   - Due to size and chamber constraints, all 10 flight Solar Array panels must be baked out in series. Any reduction in duration for the panel bakeout will have significant schedule benefit.
   - Prior to the outgassing test, the solar array coupon was baked out at 120°C for 168 hours.
   - During the outgassing test, hot dwells were performed at 120°C in 24 hour increments between outgassing measurements.

Solar Array Test Coupon

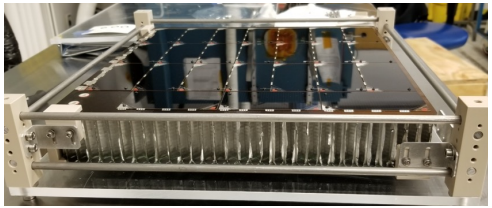
The JPL CC team was provided a test coupon by Airbus to perform outgassing tests.

The flight panel constituent materials are represented in proportional quantities.

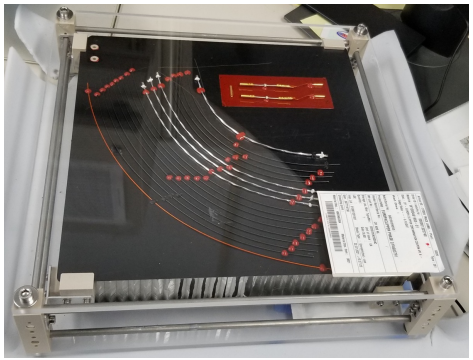
- Test coupon is 11.8 in. x 11.8 in. x 3 in. (30 cm x 30 cm x 7.6 cm)
- Front side: Solar cells with cover glass and silicone adhesive
- Back side: Exposed composite, wiring, and silicone adhesive



Solar Array Coupon: Front Side



Solar Array Coupon: Side View



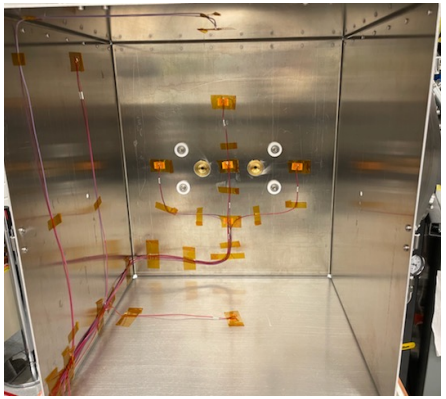
Solar Array Coupon: Back Side

Test Configuration

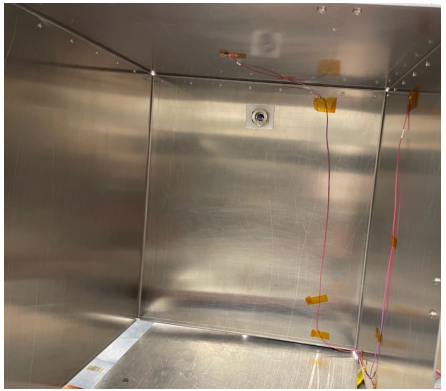
- The outgassing test was performed inside an effusion cell to promote molecular transport to the QCM sensors and improve the outgassing rate sensitivity floor.

- The vacuum chamber is equipped with:
  - Vacuum gauge, for measuring the chamber pressure
  - Heat exchange plate, to control the temperature of the effusion cell
  - Effusion cell, to improve the transport of outgassing to the QCMs

- The effusion cell is equipped with:
  - Two QCM sensors, to measure hardware outgassing rate
  - One internal pressure gauge, to measure the effusion cell pressure
  - Twelve thermocouples, to measure the hardware temperature and temperature gradients across the effusion cell surfaces



Effusion Cell Interior with QCM Sensor Heads and Thermocouples

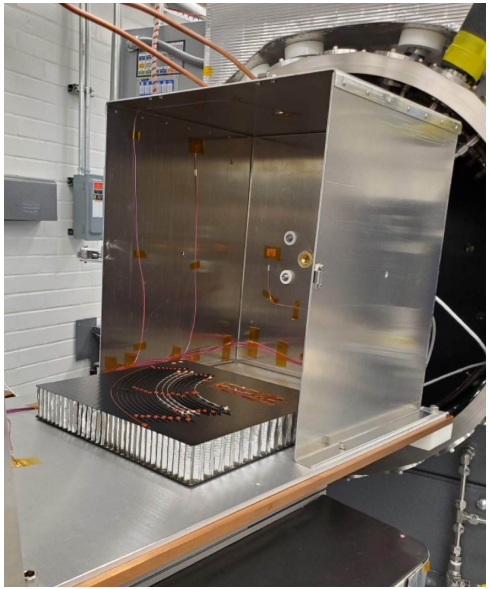


Effusion Cell Interior with Pressure Gauge

Outgassing Measurement Conditions

- The QCM measurements were taken at different temperature conditions to assess the Solar Array outgassing during cruise versus tour.
- The test coupon temperature was set to:
  - 40°C, cruise phase hot case
  - -100°C, tour phase hot case
- For each test coupon temperature, the QCM temperatures were set to:
  - -113°C, verification requirement based on PIMS Instrument sensitive surface temperature during tour
  - -143°C, informational data that includes water outgassing relevant to MASPEX and MISE Instrument measurements

- For the majority of the test, the solar array coupon was oriented with the back side up. The back side outgassing rate was expected to be higher than the front side due to significant silicone adhesive usage on the back side.
- After the final back side measurement, the chamber was opened to reconfigure the test coupon to front side up for the final two measurements.

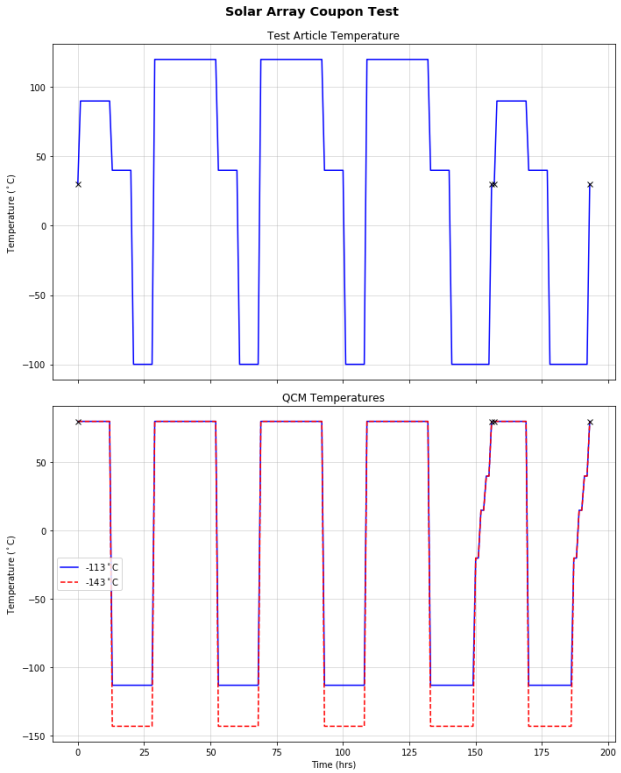


Solar Array Coupon in Effusion Cell

Performed Outgassing Measurements

Measurement	Test Coupon	Bakeout Duration	Test Temperature	Frequency Rate at -113°C
#1	Back Side	7 days	40°C	66.0 ± 11.1
#2	Back Side	7 days	-100°C	<1 ± <1
#3	Back Side	8 days	40°C	38.1 ± 1.5
#4	Back Side	8 days	-100°C	<1 ± 6.0
#5	Back Side	9 days	40°C	29.4 ± 1.8
	~~Back Side~~	~~9 days~~	~~-100°C~~	
#6	Back Side	10 days	40°C	22.2 ± 1.9
#7	Back Side	10 days	-100°C	<1 ± 2.9
#8	Front Side	10 days	40°C	26.9 ± <1
#9	Front Side	10 days	-100°C	<1 ± <1

Ten total outgassing measurements were planned. During the test, JPL CC elected to skip the measurement at -100°C with 9 days of bakeout due to the consistency of the measured outgassing at -100°C.



Planned Temperature Profile during Test (temperature ramps not to scale)

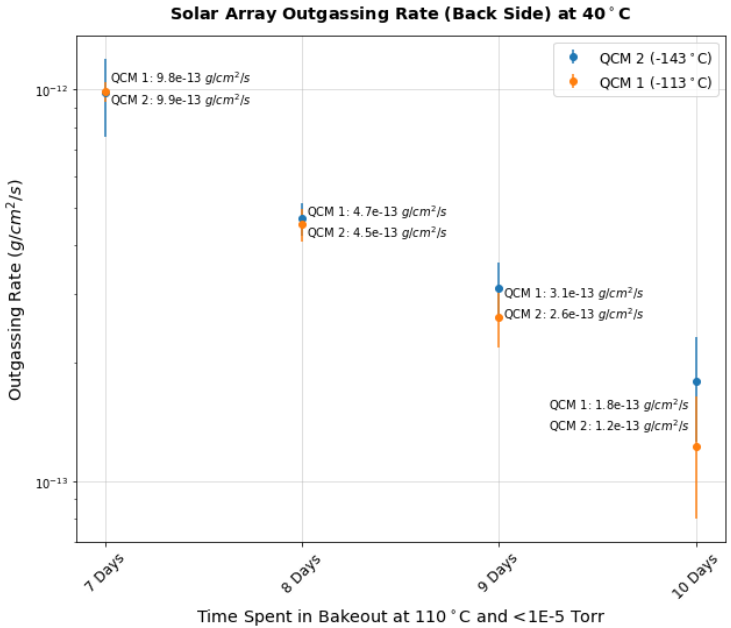
Results – Outgassing Rate at -100°C & 40°C

- Results at -100°C
  - The outgassing measurements reached the sensitivity floor of the chamber (<1 Hz/hr) at all bakeout durations.
  - This corresponds to a measured outgassing rate of the solar array coupon at <1.8e-14 g/cm^2/s.
- Results at 40°C
  - The outgassing rate decreased with each 24-hour increase in bakeout duration.
  - The measured outgassing rates of the back side corresponded to a maximum of 9.8e-13 g/cm^2/s at 7 days of bakeout to a minimum of 1.2e-13 g/cm^2/s at 10 days of bakeout.

The measured solar array outgassing at Europa operating temperature is in family with its outgassing rate requirement of 1e-14 g/cm^2/s.

Results – Bakeout Duration Assessment

- Since the outgassing rates measured at -100°C showed no change with increased bakeout duration, the outgassing rates measured at 40°C were used to assess the bakeout duration for the flight Solar Array.
- During the cruise hot case, the outgassing deposition from the Solar Array to the Clipper instruments is minimal because most instrument covers will not be deployed yet.
- JPL CC assessed that a bakeout reduction from 10 days to 9 days would be low risk and have minimal molecular deposition effects on Clipper instruments while recovering schedule margin for the Solar Array.



The outgassing measurement results at 40°C allowed for a bakeout duration reduction by 24 hours.

Conclusion

- JPL CC designed and performed a test to measure the outgassing from a Solar Array test coupon.
- The Solar Array outgassing was measured at <1.8e-14 g/cm^2/s at Europa operating temperature of -100°C.
- Analysis based on the hot cruise case outgassing measurements (40°C) demonstrated that the flight Solar Array bakeout duration could be reduced from 10 days to 9 days.
- JPL CC also later used the Solar Array test coupon to measure outgassing rates under radiation, similar to conditions during operations at Jupiter.

JPL CC Engineers loading Solar Array Coupon into Effusion Cell

JPL CC successfully used a flight-like test coupon to measure the outgassing rate of the flight Solar Arrays. The use of a test coupon provided greater flexibility of test cases and conditions than what was possible with the flight Solar Arrays.

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