Contamination Simulation: Importance of geometry for the test sample

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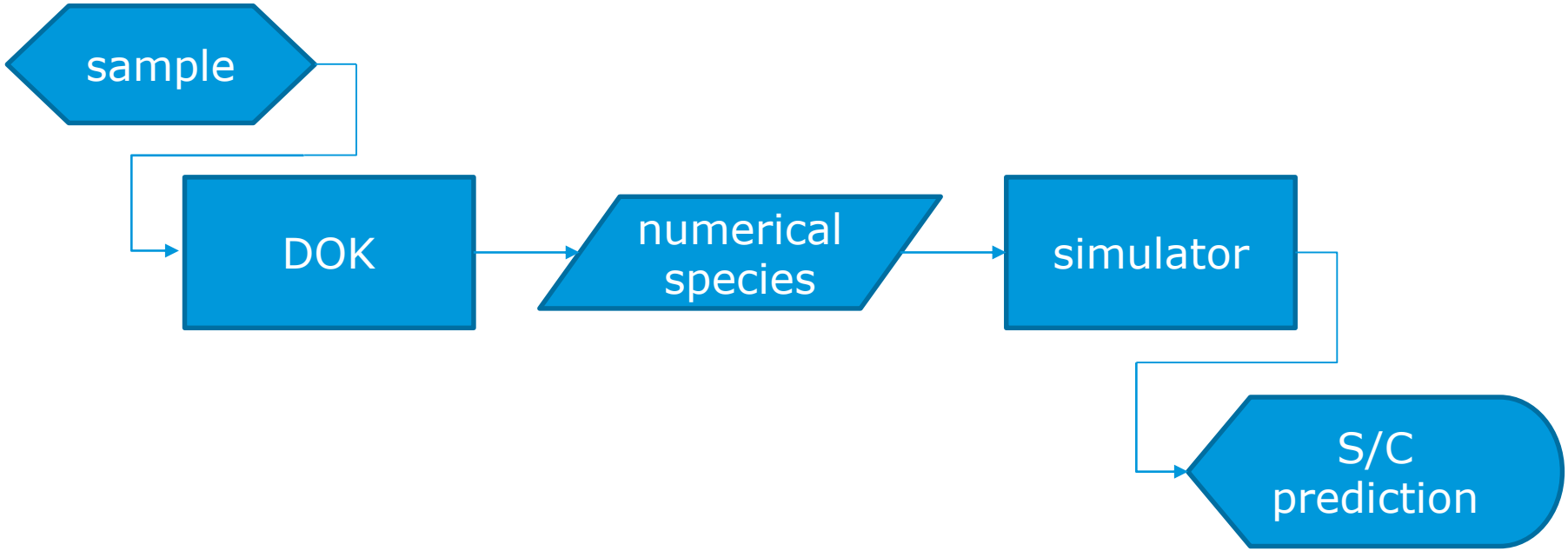
Outline

- Objective
- Terminology recapping
- Information on the facility and test
- Experiment with different sample geometries
- Simulation results
- Conclusion

Objective

To analyze the effect of the geometry of the sample on the results of the numerical contamination simulations.



Some terminology recapping (ECSS-Q-TM-70-52A)

Quartz Crystal Microbalance(QCM) Thermogravimetric analysis (TGA): Measures weight/mass change(loss/gain) and the rate of weight change as a function of temperature, time and atmosphere.

TML : Total Mass Loss

RML : Recovered mass loss

CVCM : Collected volatile condensable material

KC: Knudsen Cell

LN2: Liquid Nitrogen

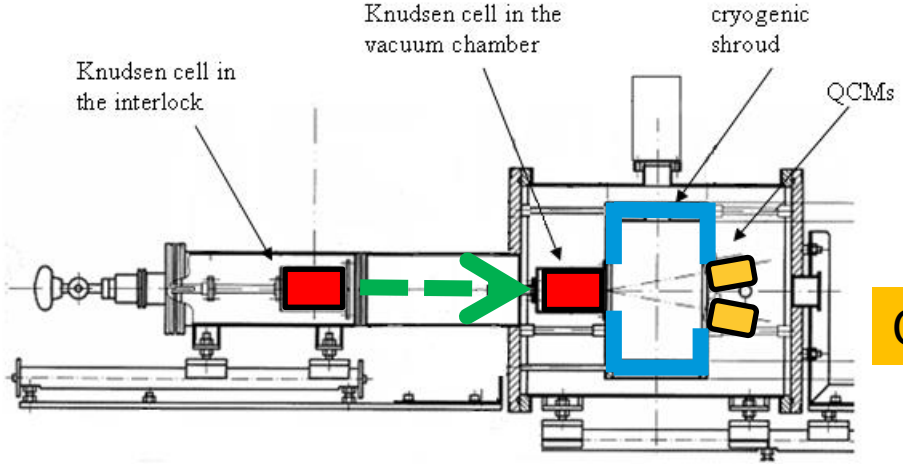
DOK: Dynamic outgassing Knudsen

Standard Test: TGA performed at the end of the test

EOT: End of Test

The DOK schematic & Multi-step temperature test method

Sample temperature is increased from 25°C to X°C by steps of 25°C every 24h. The number of steps and the duration at the max. test temperature is adjusted based on the real application temperature and the max. permitted test temperature of the sample.



$T_{max} \cong 450°C$

$\bar{T} \cong -175°C$

$P < 5 \times 10^{-6} mbar$

$T_{QCM,1} \cong -170°C$
$T_{QCM,2} \cong -25°C$
$T_{QCM,3} \cong -75°C$
$T_{QCM,4} \cong -50°C$

Input parameters generated by current approach

1) Mathematical species

Time constant $\tau_{0,i}$ (h)	Initial mass $W_{0,i}$ (%)
0.5	0.0058
4.482096	0
40.17836	0.13660
360.1665	0.14052
3228.602	0.04488
28941.81	0.00067
259439.9	0.00312
2325669	0.00356
20847740	0.01035

2) A table which contains activation energies and temperature-time constant

Period	Temperature (°C)	Acceleration Factor $K_{i\rightarrow i+1}$	Apparent Activation Energy $E_{i\rightarrow i+1}$ (kJ·mol^{-1})	Residence time-temperature dependency coefficient k_e
I→II	75	4.12	52.9	0.0834
II→III	100	3.65	52.9	
III→IV	125	5.66	56.0	
IV→V	150	20.68	85.7	
V→VI	175	23.18	169.7	

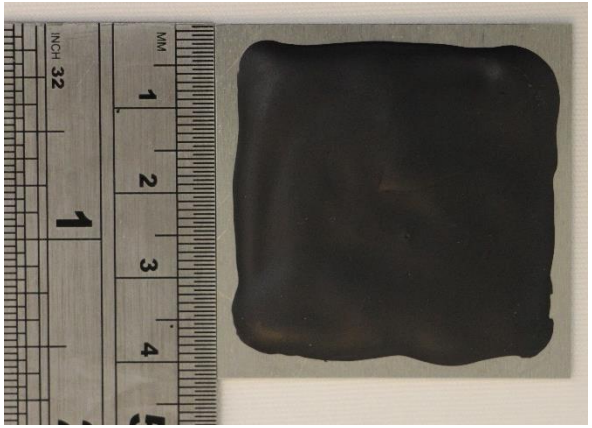
3) TML, RML and CVCM of the sample

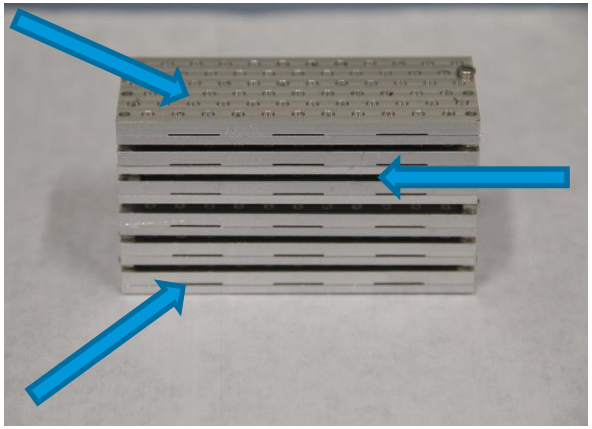
4) A clear description of the sample and the test methodology

5) TGA analysis which contains further information which may improve contamination modelling

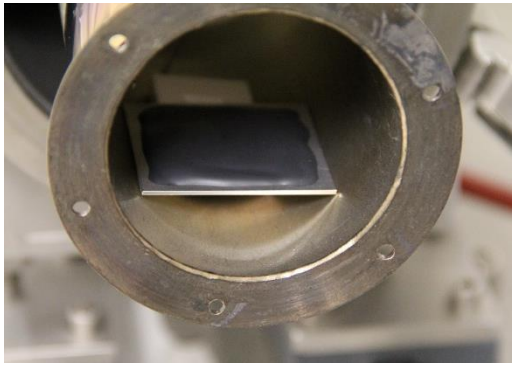
6) Reemission parameters are calculated by the assumption of $T_{ref} + 50K$

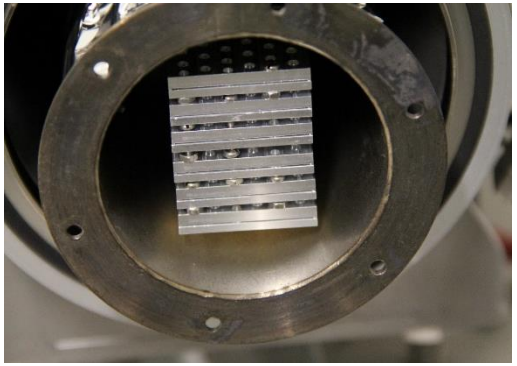
Samples used to compare the effect of geometry





Sample 1





Sample 2

Mathematical Species

Obtained results for the same test conditions at reference Temperature of 25°C.

Sample 1

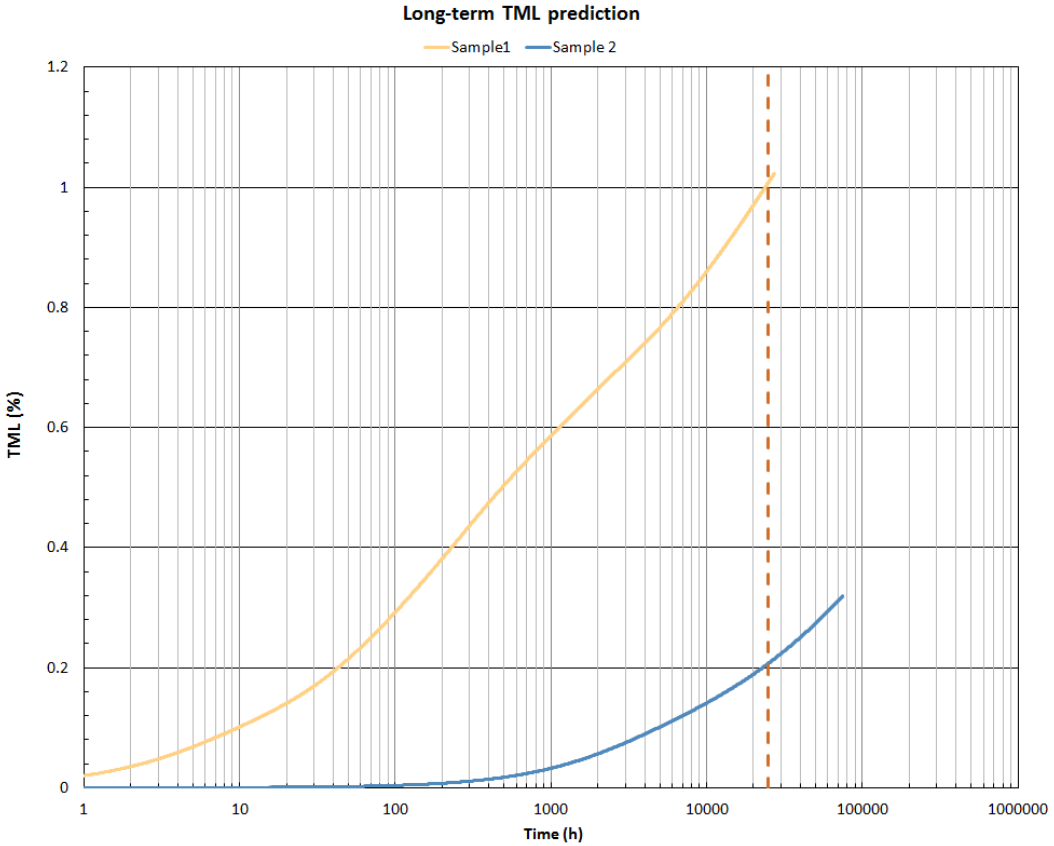
Initial mass $W_{0,I}$ (%)	Time constant (h)
0.0000	0.50
0.0000	4.57
0.0000	41.8
0.0000	182.53
0.0000	798
0.0933	3487
0.2872	15243
0.1710	66627
0.4155	291230

Sample 2

Initial mass $W_{0,I}$ (%)	Time constant (h)
0.0000	0.50
0.0000	4.15
0.0000	34.39
0.0000	140.90
0.0000	577
0.0649	2365
0.0589	9690
0.0882	39703
0.3286	162670

Comparison of Long-term TML predictions

The red line marks 25000h, approx. 1040 days



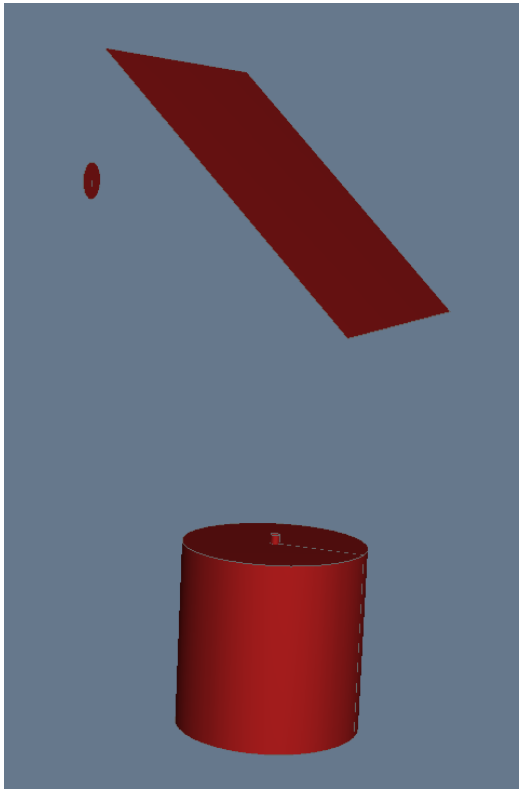
Simulated geometry [1]

Constants:

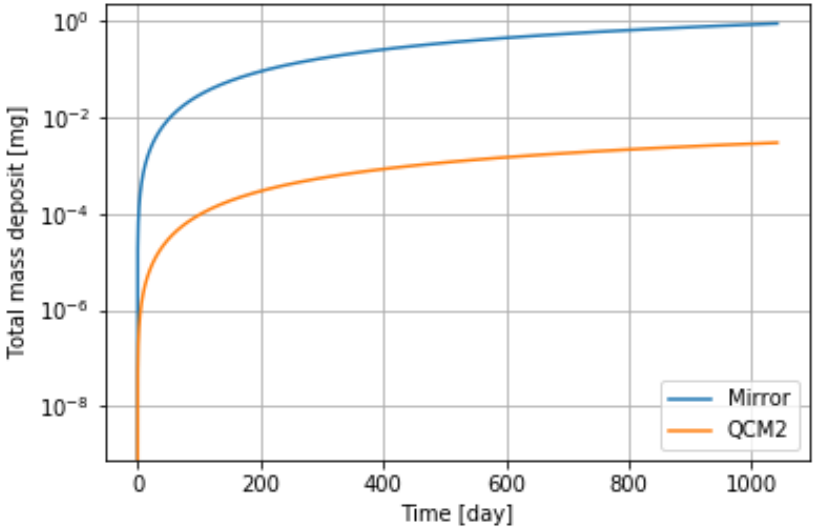
- Effusion cell walls: 130°C
- Effusion cell bottom surface: 50°C
- QCM: -170°C
- The mirror is rotated 45°
- 10g of material

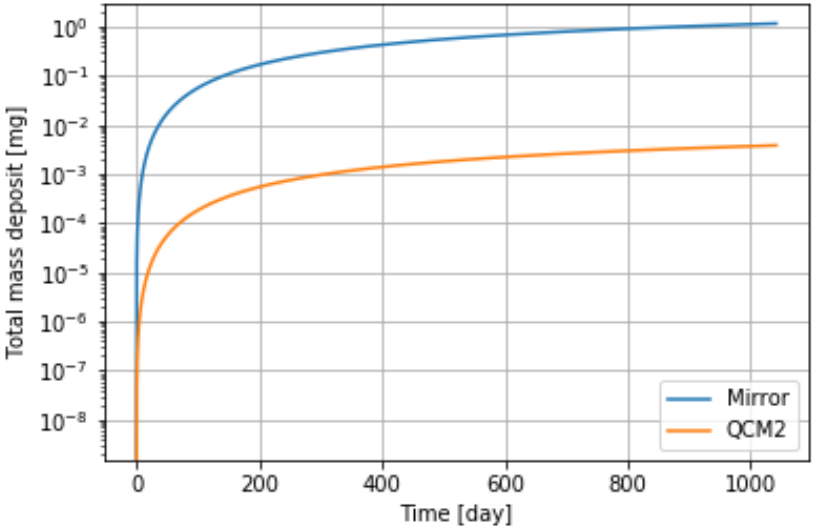
Variated:

- Temperature of the mirror: -100°C, 10°C, 130°C
- The material on the bottom surface of the effusion cell



Results Mirror at -100°C



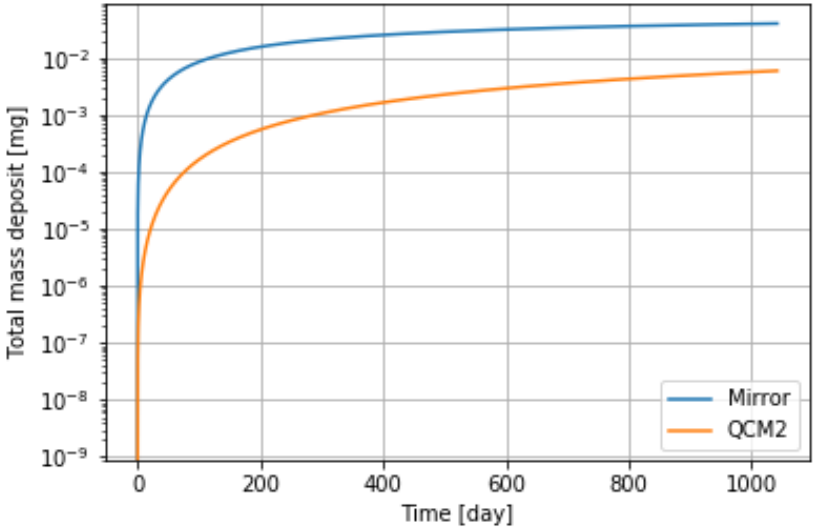


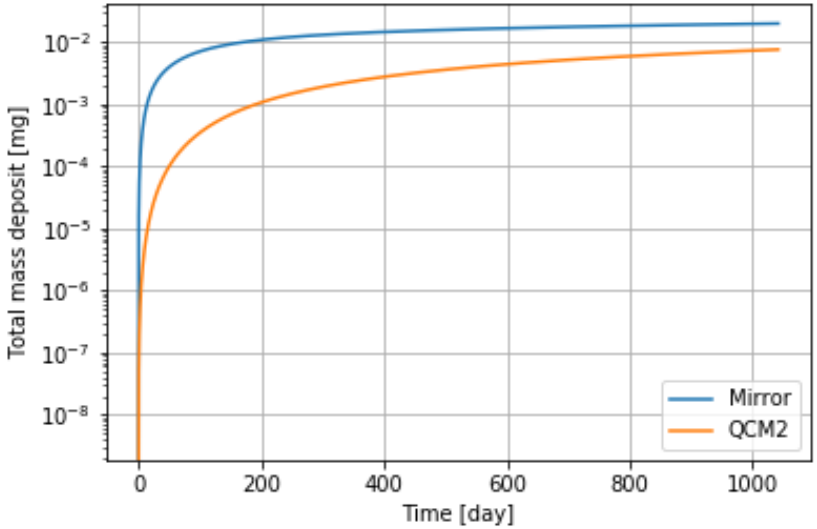
Mirror: 0.9064 mg
QCM2: 0.0030 mg
Mass outgassed: 41.0676 mg

29% additional Error
30% additional Error
100% additional Error

Mirror: 1.1681 mg
QCM2: 0.0039 mg
Mass outgassed: 20.6350 mg

Results Mirror at 10°C



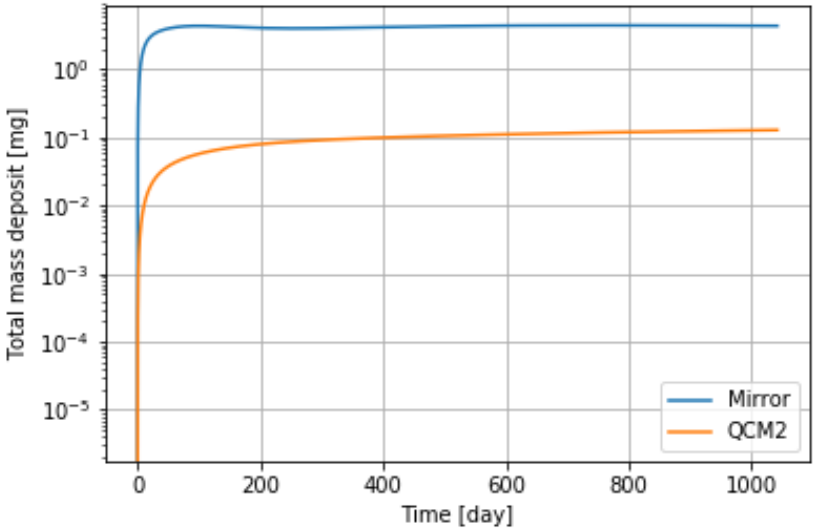


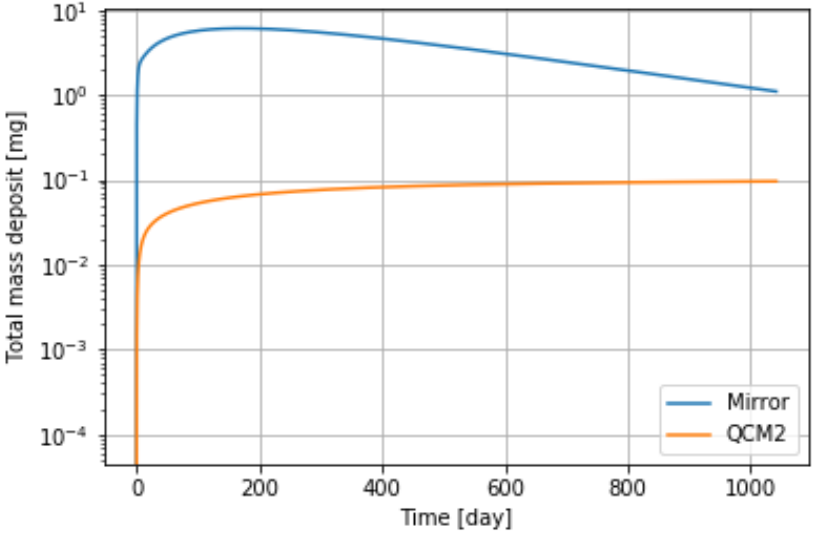
Mirror: 0.0398 mg
QCM2: 0.0059 mg
Mass outgassed: 41.0675 mg

97% additional Error
29% additional Error
99% additional Error

Mirror: 0.0202 mg
QCM2: 0.0076 mg
Mass outgassed: 20.6349 mg

Results Mirror at 130°C





Mirror: 4.3218 mg
QCM2: 0.1279 mg
Mass outgassed: 96.6999 mg

294% additional Error
33% additional Error
79% additional Error

Mirror: 1.0979 mg
QCM2: 0.0958 mg
Mass outgassed: 54.0599 mg

Conclusion

Outgassing parameters obtained during a dynamic outgassing test are strongly related to the geometry of the sample. This is due to the physical processes involved in the outgassing of molecules (evaporation, desorption, diffusion and decomposition).

When simulating a mission, depending of the size of the mission more than a dozen materials are distributed around the S/C on multiple surfaces. These additional cumulative errors, can have severe implications on the decision taking process of the design/AIT flow/schedule of the S/C and missions.