From Spaceflight to EUV Lithography: High-Reliability Outgassing and RGA Testing

Methods, Case Studies, and Industry Impact

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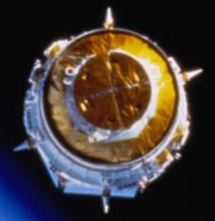
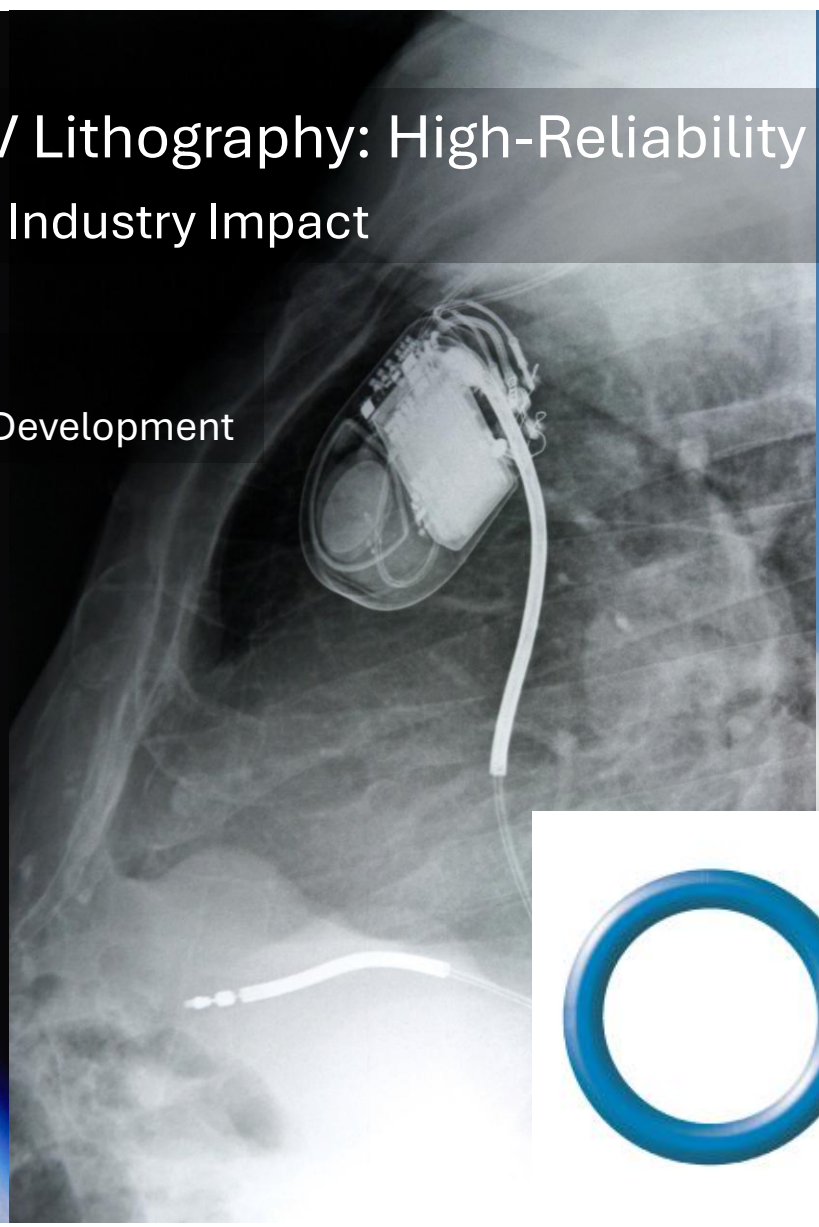
Director of Technology & Business Development





CMSE
"WHERE COMPONENT ENGINEERS MEET"

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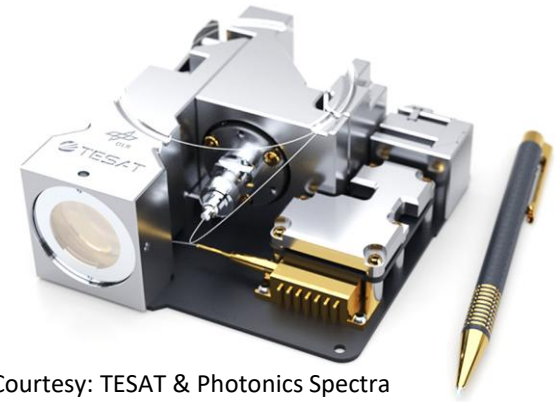
Why outgassing matters?

- Contamination directly impacts **optical performance, sensor stability, and long-term reliability**
- Volatile species can **condense on cold surfaces**, degrading spacecraft optics and detectors
- Outgassing residues lead to **film defects, particle generation, and yield loss** in microelectronics
- EUV lithography optics are extremely sensitive to **hydrocarbons, siloxanes, and moisture**
- Advanced semiconductor tools require **sub-ppb cleanliness** to protect mirrors, pellicles, and reticles
- High-density packaging and 3D integration increase risk of **trapped volatiles and hermetic failures**
- Materials used in high-tech manufacturing must be screened for **molecular contamination pathways**
- Qualification data is essential for **supplier certification and process control** across industries



Courtesy: TESAT & Photonics Spectra

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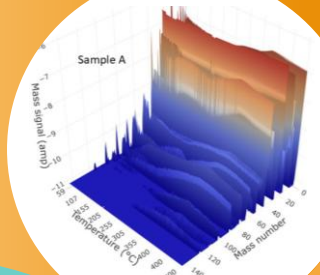
ORS Capabilities Overview

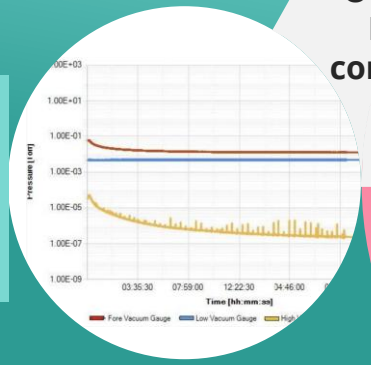
UHV-EGA



Mass resolved species
Thermal Desorption
Moisture/volatile/non-volatile profiling

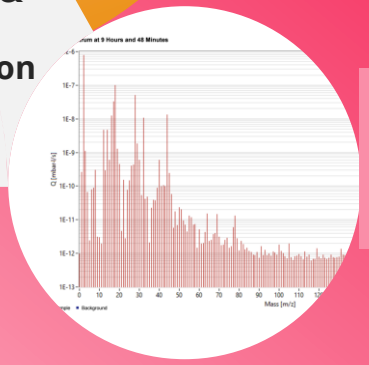
Complete Outgassing & Molecular contamination Insight

ASTM E595



Total Mass Loss (TML)
Collected volatile Condensable Materials (CVCM)
Water Vapor Regained (WVR)
Aerospace Qualification

ASML RGA



ISO 7 clean lab facility
GSA 07 2221 Grade 2 verification
EUV contamination control

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Last updated on 3/24/2026

ISO 7 ASML RGA Laboratory

- ISO 7 Certified clean laboratory
- ESD moisture barrier vacuum or UHP Nitrogen sealing
- ASML GSA 07-2221 compliance

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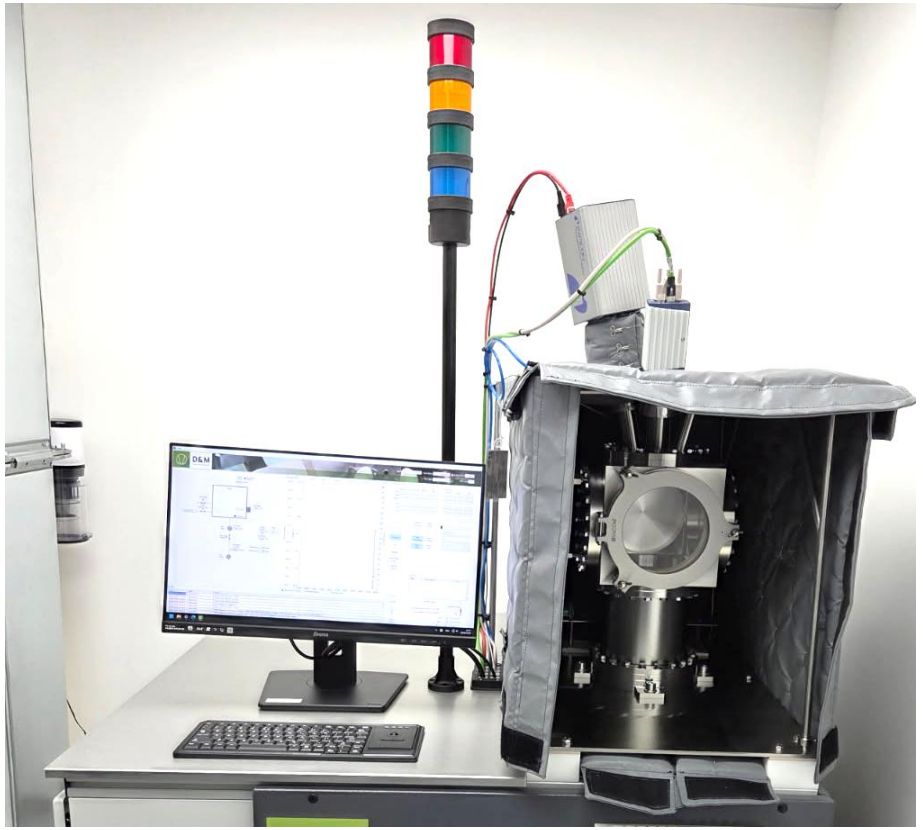
Grade 2 vacuum cleanliness compliance

- For high-tech sectors cleanliness compliance for the components are critical for their products.
- ORS is adding a unique capability to confirm the vacuum cleanliness for variety of parts.

Sector	Key Technologies & Practices
Semiconductors	Cleanroom fabrication (Class 1–100), photolithography, plasma etching, nanometer-scale precision
Aerospace	CNC machining of composites, digital twin simulations, robotic assembly, non-destructive testing
Medical Devices	Micro-molding, laser micromachining, sterile production zones, FDA/ISO regulatory compliance
Automotive	Smart factories with AGVs, AI-driven quality control, 3D printing for prototyping and tooling
Pharmaceuticals	Automated bioreactors, continuous manufacturing, real-time analytics, contamination control
Electronics	SMT lines for PCB assembly, optical and X-ray inspection, flexible reconfigurable production
Defense & Space	Cryogenic testing, vacuum systems, high-strength alloys, secure classified manufacturing zones



Max allowed dimension: < 8”

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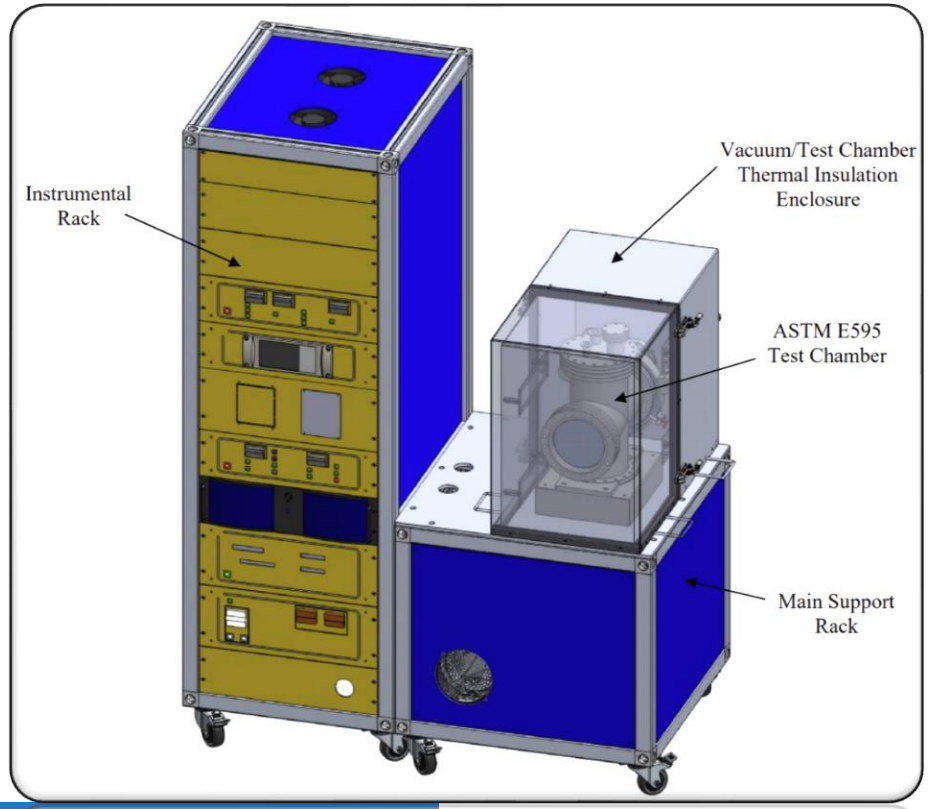
Materials outgassing in a vacuum environment

Designation: E595 – 15 (Reapproved 2021)

Standard Test Method for
Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment[1]



Test conditions: 125°C at less than 5×10^{-5} (Torr) for 24 h

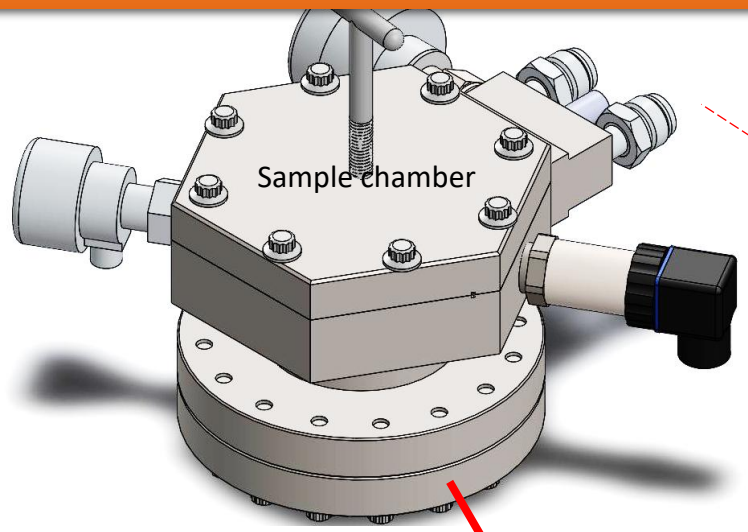
Sample: Organic, polymeric and inorganic materials
(e.g., Polymer potting compounds, foams, elastomers, films, tapes, insulations, Shrink tubing, adhesives, coatings, fabrics, tie cords and lubricants)

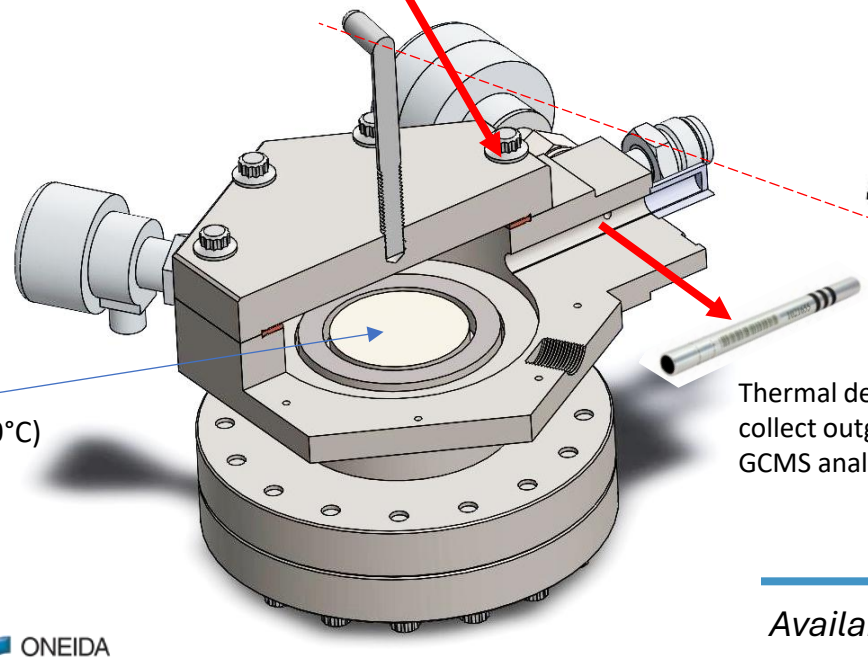
Determination: Total Mass Loss (TML) and Collected Volatile Condensable Materials (CVCM)
(e.g., TML of 1.00% and CVCM of 0.10% as screening levels for rejection of spacecraft materials.)

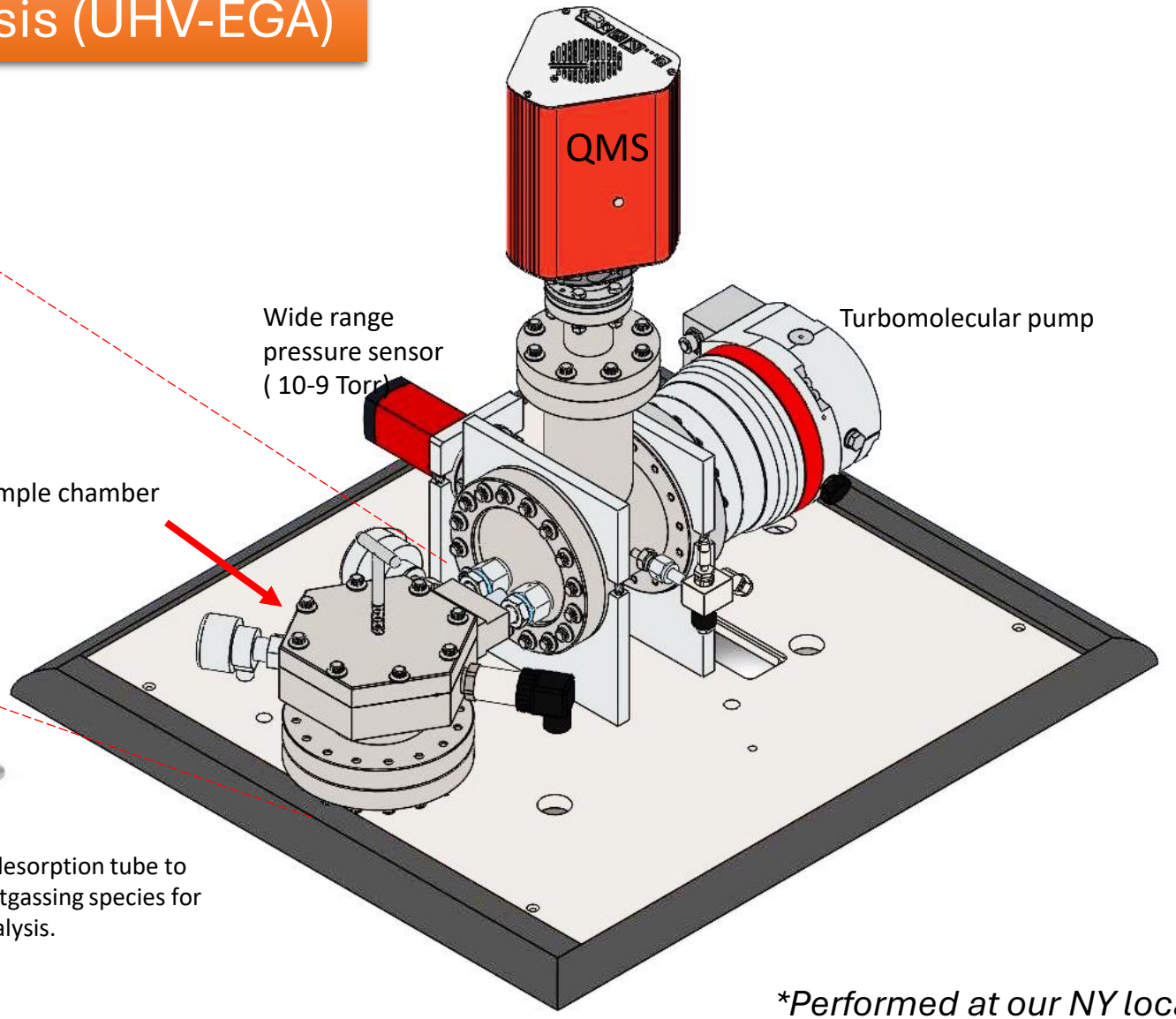
**Performed at ORS, NY.*

Testing will also support: *MSFC-SPEC-1238*
Revision B, Effective date: Jan 10, 2020

Ultra-High Vacuum Evolved Gas Analysis (UHV-EGA)







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Available as equipment to perform test at your own facility.

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Complementary Strengths of the three methods

Method	What It Measures	Strengths	Limitations	Best Use Cases
ASTM E595	TML, CVCM, WVR (bulk outgassing metrics)	• Simple, standardized • Aerospace heritage • Good for screening large material sets	• No species identification • No mass-resolved data • Limited sensitivity	• Spaceflight materials screening • Supplier qualification • Early-stage material down-selection
UHV-EGA	Mass-resolved evolved gas species during thermal desorption	• Identifies specific molecules • High sensitivity to moisture, volatiles, non-volatiles • Excellent for root-cause analysis	• Requires UHV conditions • More complex data interpretation	• Contamination root-cause analysis • Material/process optimization • Failure analysis
ASML RGA (GSA 07-2221)	Outgassing behavior under EUV-relevant conditions; Grade 2 verification	• ISO 7 controlled environment • EUV-specific acceptance criteria • Directly tied to semiconductor supplier requirements	• Narrower scope (EUV-focused) • Requires strict environmental controls	• EUV lithography components • Semiconductor supplier certification • High-tech manufacturing cleanliness validation

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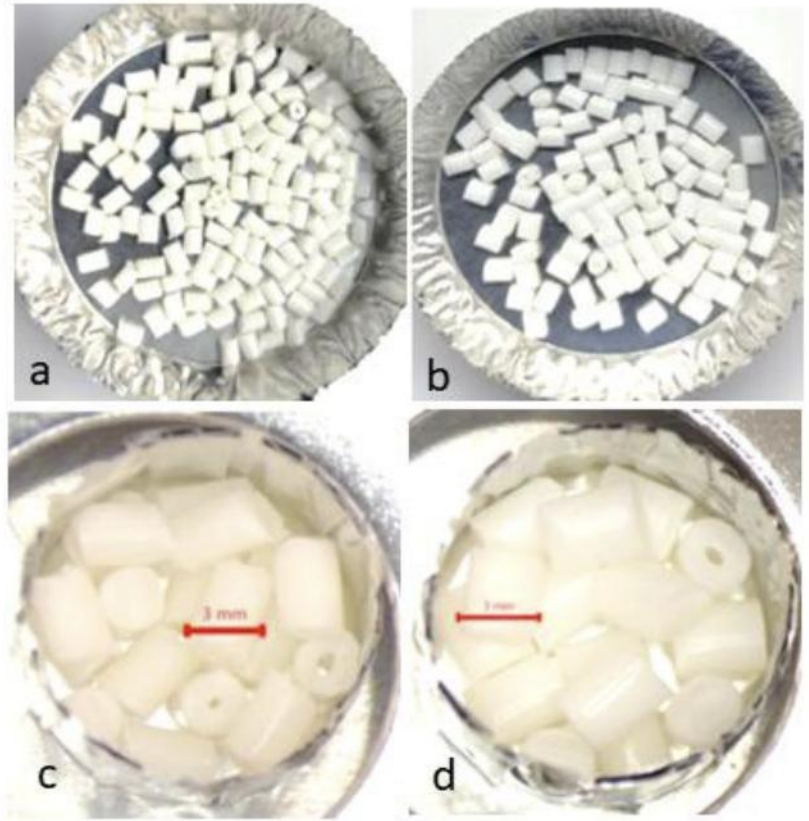
Case Study 1, ASTM E595



Pre-conditioning protocol:

- 23°C at 50% RH for 24 hours in a thermal humidity chamber
- Sample handling: Class 5 laminar flow cabinet with ULPA filter.

Test Conditions:

- Temperature: 125°C ± 1°C
- Vacuum: $< 5 \times 10^{-5}$ torr for 24 hours
- Collector Plates: Held at 25°C ± 1°C
- Test time: 24.0 hours

Fig. 2: Optical images of samples: (a): Sample 1 (b) Sample 2 (c) Sample 1 after precondition (d) Sample 2 after precondition

Case Study 1, ASTM E595

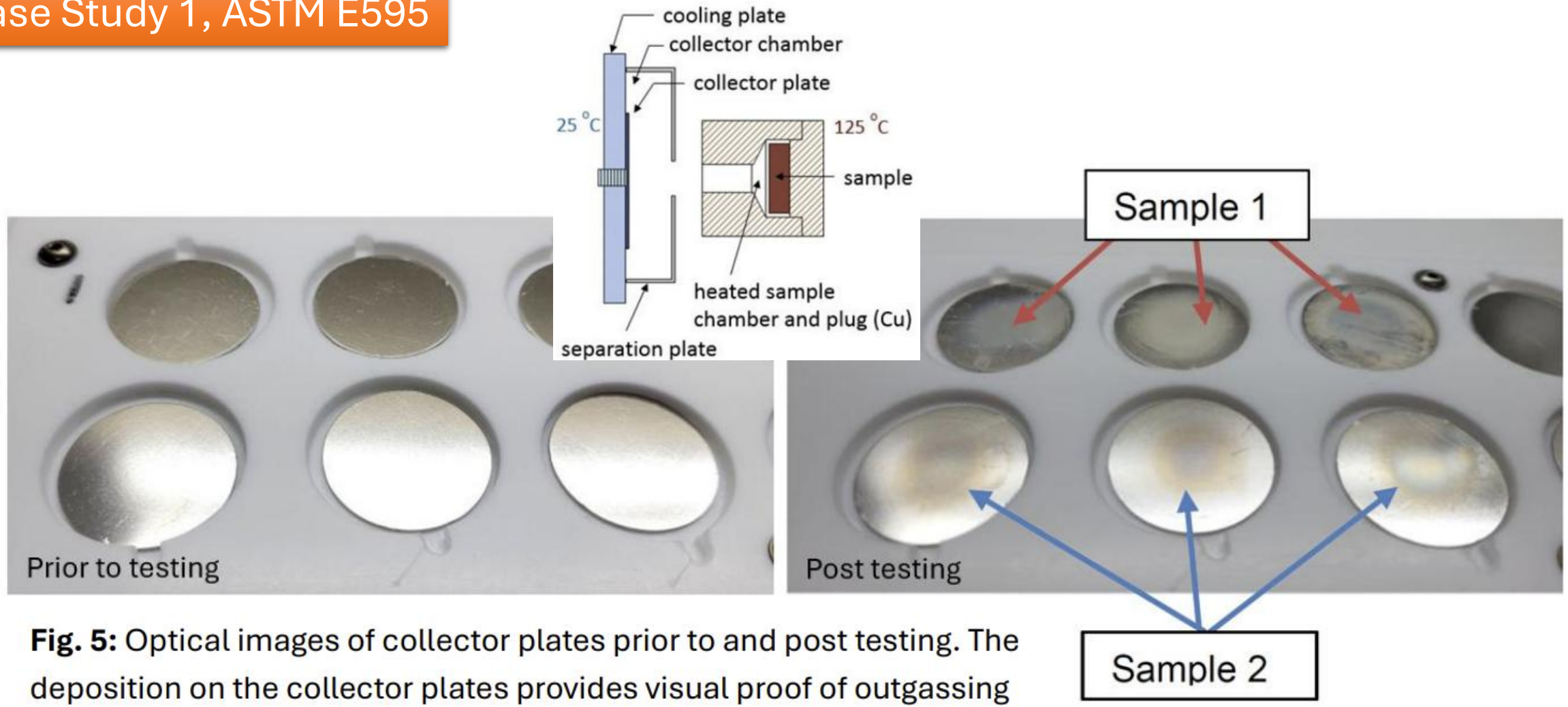


Fig. 5: Optical images of collector plates prior to and post testing. The deposition on the collector plates provides visual proof of outgassing occurred during the testing.

Case Study 1, ASTM E595

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ASTM E595

Job #(s) Case study

Tested By: BJC/MEW

Precondition Date/Time In: 7/9/25 @ 1209 Out: 7/10/25 @ 1210 Test Date/Time Start: 7/10/25 @ 1412 End: 7/11/25 @ 1415

Balance auto-cal Precond MEW Balance auto-cal Init MEW Chiller H2O check MEW Balance auto-cal Final MEW

Sample Cup	Sample ID	Collector Mass (i)	Collector Mass (f)	Cup Mass	Sample + Cup	Sample Mass	Final Mass (sample + Cup)	Δ Mass Sample	Δ Mass Collector
1	Sample 1-1	5.866790	5.866849	0.062456	0.348906	0.286450	0.343882	0.005024	0.000059
2	Sample 1-2	5.830589	5.830628	0.062172	0.355687	0.293515	0.350579	0.005108	0.000039
3	Sample 1-3	5.848152	5.848246	0.062758	0.359000	0.296242	0.353729	0.005271	0.000094
4	blank	5.836423	5.836415	0.062518	0.062521	0.000003	0.062519	0.000002	-0.000008
5	ref 6502	5.756956	5.757289	0.062119	0.346602	0.284483	0.345142	0.001460	0.000333
6	blank	5.780336	5.780330	0.062120	0.062124	0.000004	0.062123	0.000001	-0.000006
7	Sample 2-1	5.768387	5.768399	0.062203	0.347763	0.285560	0.343688	0.004075	0.000012
8	Sample 2-2	5.815883	5.815900	0.061664	0.350559	0.288895	0.346440	0.004119	0.000017
9	Sample 2-3	5.816346	5.816374	0.062129	0.344226	0.282097	0.340161	0.004065	0.000028

Sample Cup	Sample ID	TML (%)	AVG TML	CVCM (%)	AVG CVCM	TV (TML)	% Rec TML	TV(CVCM)	% Rec CVCM
1	Sample 1-1	1.75	1.76	0.02	0.02				
2	Sample 1-2	1.74		0.01					
3	Sample 1-3	1.78		0.03					
4	blank	<20 ug		<20 ug					
5	ref 6502	0.51		0.12		0.60	85.54%	0.15	78.04%
6	blank	<20 ug		<20 ug					
7	Sample 2-1	1.43	1.43	0.00	0.01				
8	Sample 2-2	1.43		0.01					
9	Sample 2-3	1.44		0.01					

Fig. 6: ASTM E595 test results for Sample 1 and Sample 2.

Sample ID	Avg. TML (%)	TML Status	Avg. CVCM (%)	CVCM Status
Sample 1	1.76	❌ Fail	0.02	✅ Pass
Sample 2	1.43	❌ Fail	0.01	✅ Pass

ASTM E595 compliance thresholds: TML ≤ 1.0%, CVCM ≤ 0.1%

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ASML RGA, Case Study 2

ORS_Cube1-260415-010-Q
Serial nr: 70306961

RESULT OVERVIEW

System Information

Identification:	ORS_Cube1	**Pumpspeed:**	10.0 L/s
Facility:	Cube + plate + plug	**RGA Type:**	MPH200

Batch Information

Start Pump Down:	15 April 2026 at 14:48 Hr	**ICtot:**	3.16E-7 A
Start Pressure:	991.00 mbar	**Ptot:**	4.88E-7 mbar
Start RGA Time:	0 Hours and 40 Minutes	**Ptot/ICtot:**	1.5 mbar / A
Verification Time:	9 Hours and 49 Minutes	**EM Voltage:**	1060 V
Information:	Background subtracted	**Temperature:**	27.9 C
		Filament:	1

Background Information

Start Pump Down:	08 April 2026 at 22:13 Hr	**ICtot:**	2.57E-7 A
Start RGA Time:	0 Hours and 37 Minutes	**Ptot:**	3.51E-7 mbar
Verification Time:	9 Hours and 50 Minutes	**Ptot/ICtot:**	1.4 mbar / A
Report:	ORS_Cube1-260408-009-B	**EM Voltage:**	1065 V
Remarks:	-	**Temperature:**	27.1 C
		Filament:	1

Validation Information

Start Verification	31 March 2026 at 17:01 Hr	**Verification Result**	PASS
Remaining time	15 Days	**Report Status:**	Valid
Report:	ORS_Cube1-260331-017-V	**Remarks:**	-
		Filament:	1

Outgas Values

	Qmeasrd [mbar•l/s]	Qbckgrnd [mbar•l/s]	Qbatch [mbar•l/s]	Qspec [mbar•l/s]	Accept. factor *)	Qbatch/A [mbar•l/(s•cm²)]	t spec [hr]	t LDL [hr]
H2O	2.54E-6	1.68E-6	8.57E-7	1.36E-5	0.06	-	0.98	-
CxHy v	1.02E-8	2.34E-9	7.90E-9	5.86E-8	0.13	-	1.13	-
CxHy nv	7.59E-10	1.21E-10	6.38E-10	3.29E-9	0.19	-	2.03	-
N2	2.12E-7	1.33E-7	7.86E-8	1.00E-6	0.08	-	0.98	-
O2	7.89E-8	6.91E-8	<3.45E-8	6.00E-7	0.06	-	0.98	3.85
Ar	2.99E-9	1.73E-9	1.26E-9	2.00E-8	0.06	-	0.98	-

*) According to GSA-07-9510 a factor 2 out of specification is accepted to avoid 'False Negative' conclusions.
The Qbatch is determined by summarizing each peak for Qmeasrd-Qbckgrnd with a minimum value of 0.5*Qbckgrnd.

ICtot	Sum of all Ion Currents in the RGA
Ptot	Total Pressure within the Chamber
EM	Electron Multiplier
Q	Outgas rate
t spec	The time between the start of the pump down and the third outgas value in a row lower than the specification value
t LDL	The time between the start of the pump down and the third outgas value in a row lower than the LDL value

Batch Information

Start Pump Down:	15 April 2026 at 14:48 Hr	**ICtot:**	3.16E-7 A
Start Pressure:	991.00 mbar	**Ptot:**	4.88E-7 mbar
Start RGA Time:	0 Hours and 40 Minutes	**Ptot/ICtot:**	1.5 mbar / A
Verification Time:	9 Hours and 49 Minutes	**EM Voltage:**	1060 V
Information:	Background subtracted	**Temperature:**	27.9 C
		Filament:	1

Background Information

Start Pump Down:	08 April 2026 at 22:13 Hr	**ICtot:**	2.57E-7 A
Start RGA Time:	0 Hours and 37 Minutes	**Ptot:**	3.51E-7 mbar
Verification Time:	9 Hours and 50 Minutes	**Ptot/ICtot:**	1.4 mbar / A
Report:	ORS_Cube1-260408-009-B	**EM Voltage:**	1065 V
Remarks:	-	**Temperature:**	27.1 C
		Filament:	1

Outgas Values

	Qmeasrd [mbar•l/s]	Qbckgrnd [mbar•l/s]	Qbatch [mbar•l/s]	Qspec [mbar•l/s]	Accept. factor *)	Qbatch/A [mbar•l/(s•cm²)]	t spec [hr]	t LDL [hr]
H2O	2.54E-6	1.68E-6	8.57E-7	1.36E-5	0.06	-	0.98	-
CxHy v	1.02E-8	2.34E-9	7.90E-9	5.86E-8	0.13	-	1.13	-
CxHy nv	7.59E-10	1.21E-10	6.38E-10	3.29E-9	0.19	-	2.03	-
N2	2.12E-7	1.33E-7	7.86E-8	1.00E-6	0.08	-	0.98	-
O2	7.89E-8	6.91E-8	<3.45E-8	6.00E-7	0.06	-	0.98	3.85
Ar	2.99E-9	1.73E-9	1.26E-9	2.00E-8	0.06	-	0.98	-

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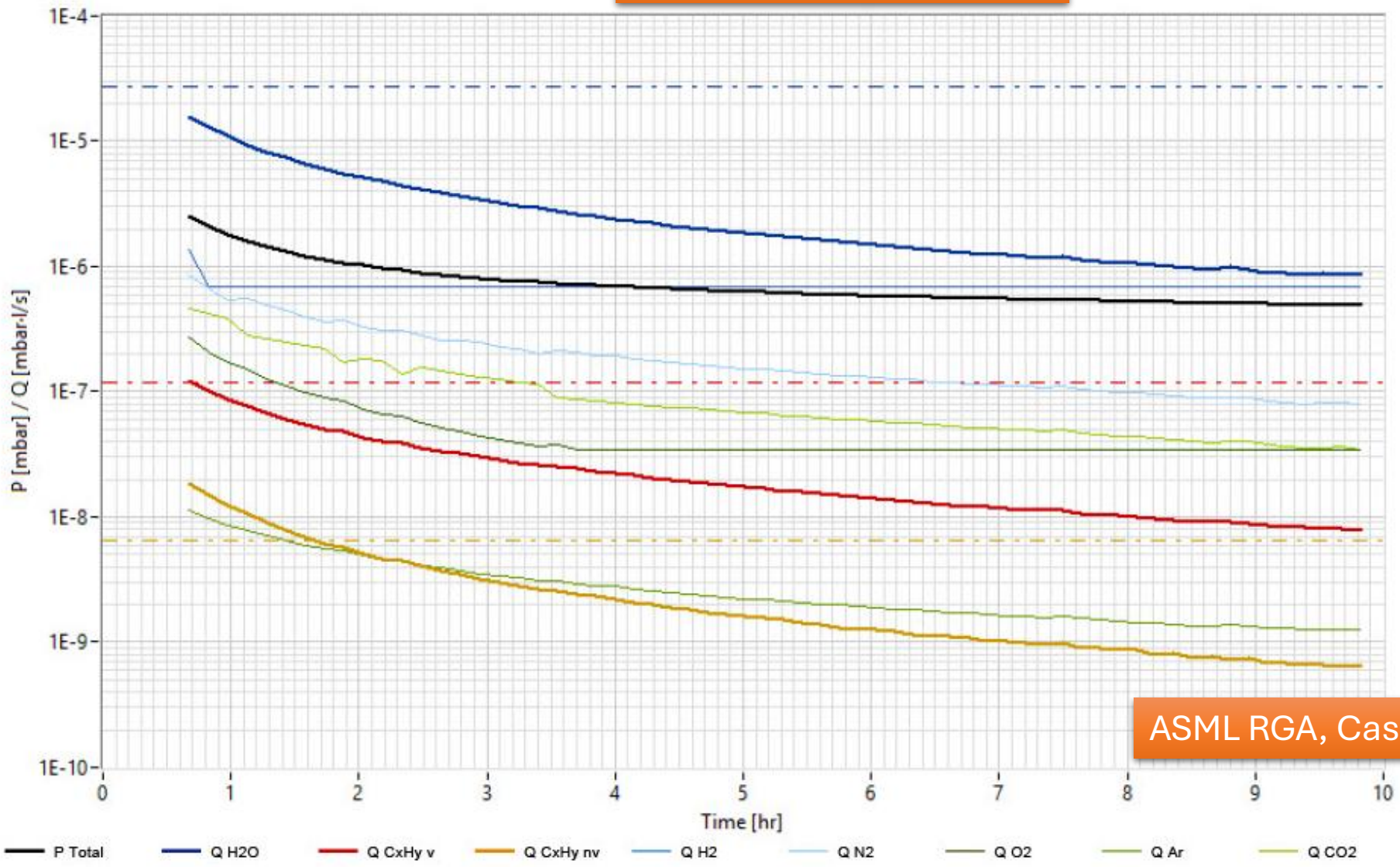
ORS_Cube1-260415-010-Q
Serial nr: 70306961

Graph

Pressure and partial outgassing in time (background subtracted)

RGA spectra over ~10 hours



ASML RGA, Case Study 2

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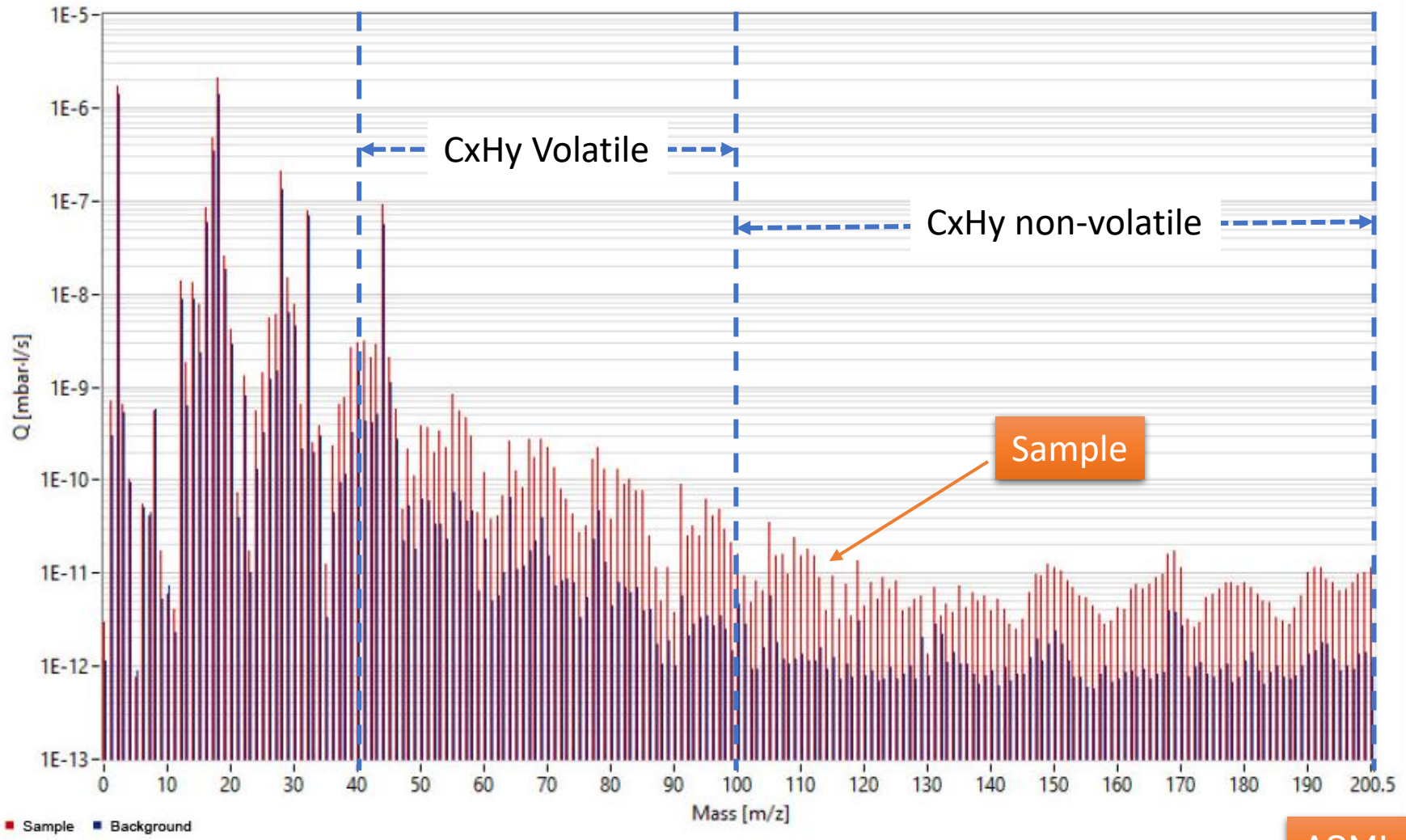
ORS_Cube1-260415-010-Q
Serial nr: 70306961

Graph

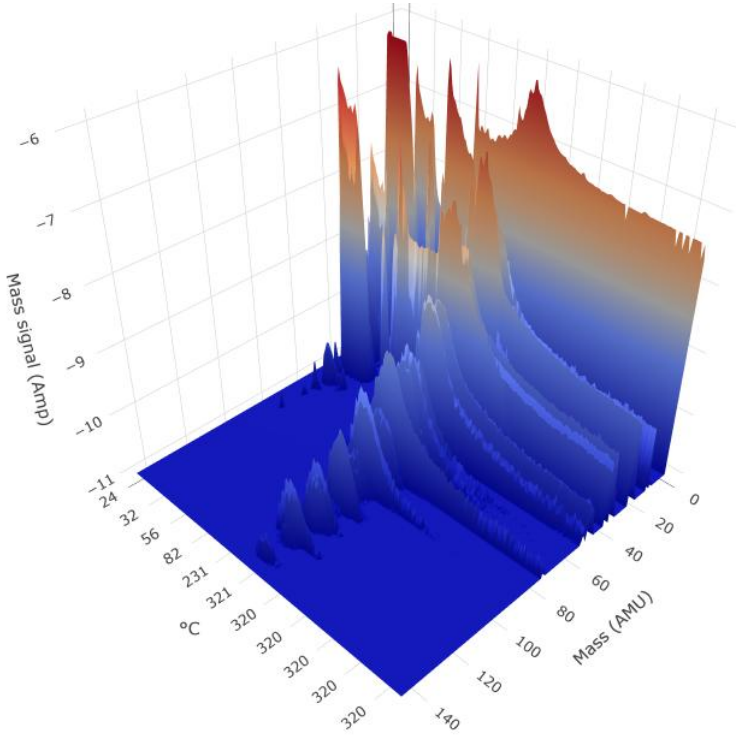
Mass spectrum at 9 Hours and 49 Minutes

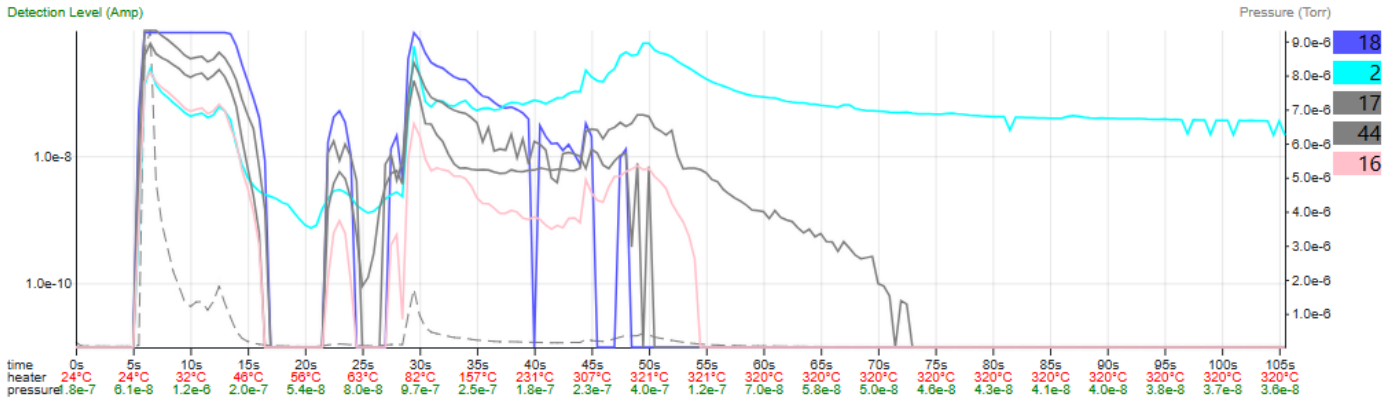


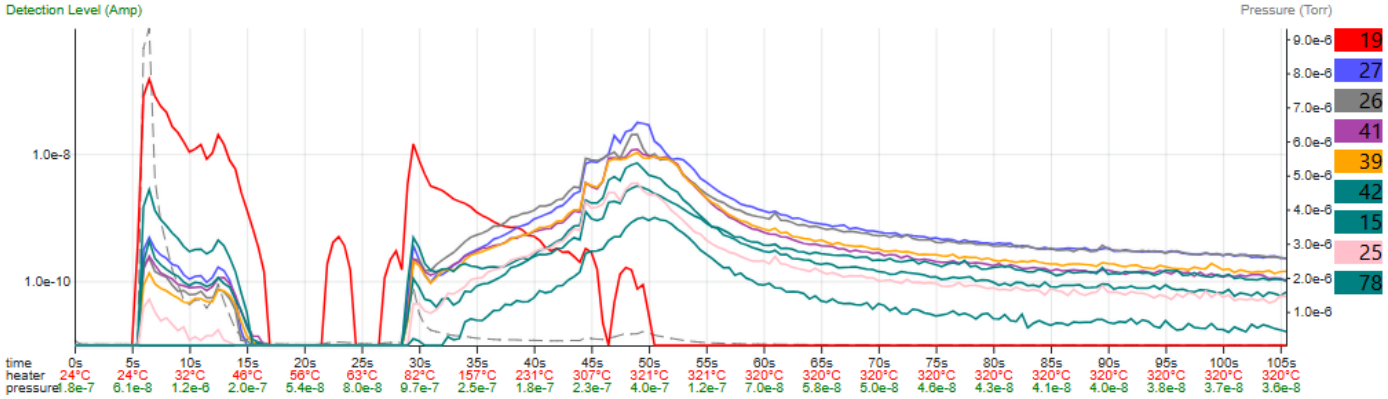
ASML RGA, Case Study 2

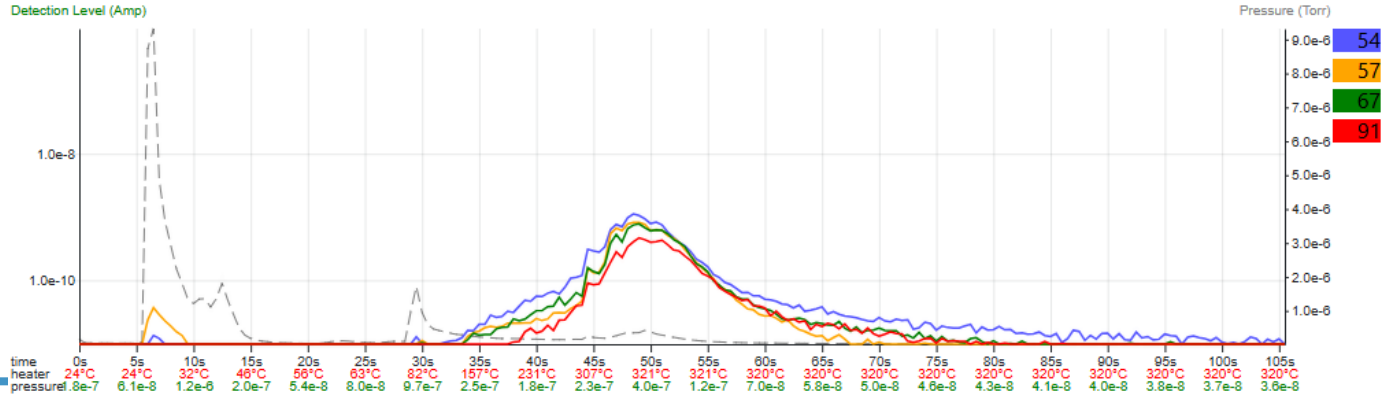
- Temperature range: 28°C – 1200°C, Heating rates: 1°C-15°C/min
- Mass range: 1-300 amu, Vacuum range: ~10^{-5} Torr to 10^{-9} Torr
- Outgassing rates (e.g., moles/cm^2/sec)
- Thermal desorption tube for GCMS, Detection limit: ~100 ppm
- 3D and 2D data representation

Samples:
solids or encapsulated liquids
(e.g., Wafers, Ceramics, Battery raw materials, electronics package materials, metals, polymers, alloys used in UHV applications)









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UHV-EGA, Case Study 3

Key Takeaways and Next Steps

- Outgassing Control Drives Reliability
  - Contamination impacts optics, sensors, and yield in spaceflight and microelectronics.
- Three Testing Methods, Complementary Strengths
  - ASTM E595, UHV-EGA, and ASML RGA each target different contamination risks and industry needs.
  - Combining methods enables both broad screening and root-cause analysis.
- Industry Standards Guide Best Practices
  - ISO 7 labs, Grade 2 vacuum cleanliness, and ASTM E595 thresholds ensure supplier and process qualification.
- Case Studies Demonstrate Real-World Impact
  - Material screening and RGA validation support high-tech manufacturing and aerospace reliability.