

Ultra-High Vacuum Evolved Gas Analysis (UHV-EGA) Application Note 4: Identifying Root Cause of Moisture Failures in Hermetic Packages with UHV-EGA

Introduction

Ultra-High Vacuum Evolved Gas Analyzer (UHV-EGA), model 510, is a mass spectrometer system that has been developed by Oneida Research Services, Inc. to identify gases evolved from any type of solid or semi-solid sample (1) under ultra-high vacuum conditions and (2) over a temperature range. This method is particularly valuable in the microelectronics industry where hermetically sealed packages are manufactured using variety of components including adhesives, metal and/or ceramic substrates and lids. Prior to sealing these components in hermetic packages, baking of these components at a specific temperature for a fixed time is critical. Improper baking will result in outgassing that could cause the presence of unwanted gases inside the package and lead to moisture failures per MIL-STD 883, TM 1018 - also known as internal gas analysis (IGA) testing.

Principle of Operation

UHV-EGA involves heating a sample in an ultra-high vacuum environment ($< 5E-8$ Torr) to temperatures up to 1200°C. The gases released during this process are dynamically identified and characterized by a quadrupole mass spectrometer with a mass range of 1-300 amu. The specially designed ultra-high vacuum heater can achieve ramp rates from 0.1°C to 15°C per minute.

EVACS™ : Superior Operation and Data Processing

The UHV-EGA system runs on the dedicated EVACS™ software platform that provides user friendly procedure set up and operation, to conduct a seamless analysis. Developed by highly experienced programmers at ORS, EVACS™ facilitates precise control of the heating protocols along with mass spectrometer tuning and vacuum parameters, ensuring accurate and reproducible results. EVACS™ also provides multiple data processing methods to understand the acquired results. It features robust data processing capabilities, including real-time monitoring, automated peak identification, and comprehensive data analysis tools including matching unknown mass spectra with NIST database. The user-friendly interface streamlines the operation, making it accessible for researchers and engineers to achieve high-quality data with ease.

Applications

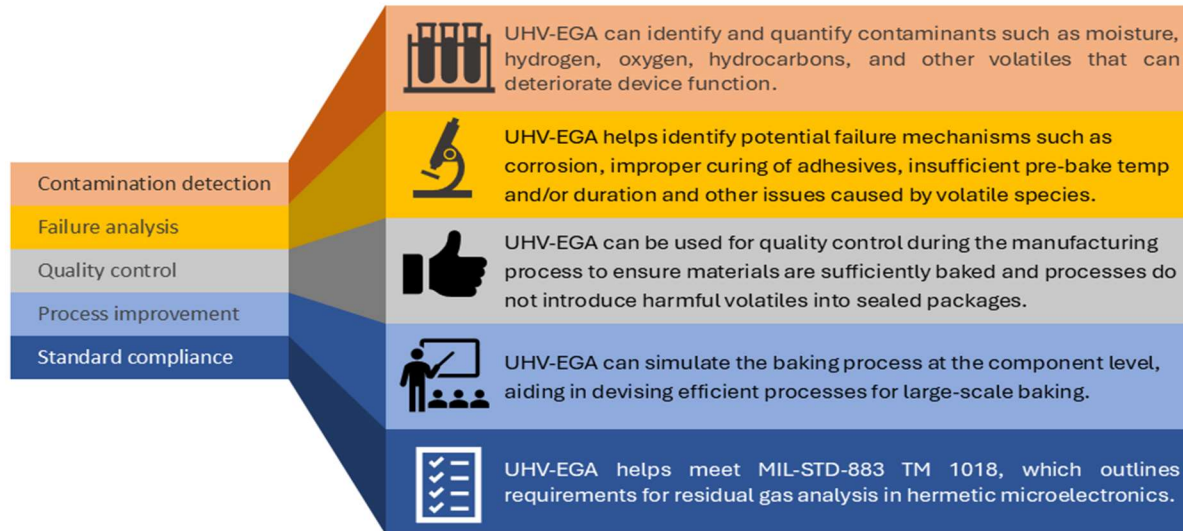


Fig. 1: Common applications for UHV-EGA

Case Study: Identifying Root Cause of Moisture Failures in Hermetic Packages

MIL-STD-883 Test Method 1018 is a standard test method used in microelectronics to analyze the internal gas composition of hermetically sealed devices. Also known as Residual Gas Analysis (RGA) and Internal Gas Analysis (IGA), this method is crucial for detecting and quantifying moisture and other gases within sealed packages. It ensures compliance with strict reliability requirements, particularly for mission-critical applications like aerospace and medical devices. MIL-STD-883 Test Method 1018 establishes pass/fail criteria primarily based on the internal moisture content of hermetically sealed devices. The key requirement is that the moisture level inside the package must not exceed 5000 parts per million by volume (ppmv). In addition to moisture, packages are also required to have oxygen must not exceed 10000 ppmv and fluorocarbon must not exceed 50 ppmv. However, the primary focus of MIL-STD-883 Test Method 1018 remains on moisture content. The test method ensures the reliability of hermetic packages by preventing issues such as corrosion or chemical reactions caused by excessive moisture.

The manufacturing of hermetically sealed parts involves meticulous attention to detail to ensure the highest quality and reliability. Each step in the process, from the selection of raw materials to the final assembly, is carefully controlled to meet strict standards. Despite these rigorous measures, failures due to excessive moisture content can occasionally occur, presenting a significant challenge for manufacturers.

When such failures arise, identifying the root cause requires an exhaustive analysis of every step involved in the production chain. This includes examining all materials used, such as the ceramic, metallic, or polymer components (e.g., adhesives), and evaluating their properties and handling procedures. Manufacturing processes, such as cleaning, plating, dicing, and sealing, must be reviewed to identify potential sources of contamination. Traceability becomes even more complex when multiple suppliers are involved. Each supplier's processes, materials, and quality control measures must be scrutinized to determine whether any contaminants were introduced upstream. Moisture may originate from residual impurities in raw materials,

incomplete removal of cleaning agents, or inefficient curing of adhesives and incomplete baking of packages prior to achieve hermetic seal. Given the interconnected nature of manufacturing and supplier chains, isolating the exact source of excessive moisture requires advanced analytical techniques, such as UHV-EGA (Ultra-High Vacuum Evolved Gas Analysis), to investigate the failure and pinpoint the source.

Sample strategy

For this case study, two hermetically sealed integrated circuit (IC) packages (sample 2, 3) were identified after subjected to the MIL-STD 883 TM 1018 test. Sample 2 has successfully met the test criteria with low moisture content, and sample 3 that failed the test due to excessive moisture content. The results of the test are given in Table 1.



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Internal Vapor Analysis - Test Report

ORS Report: 292665-001
Date Tested: 19 Mar 2025
Manufacturer:
Package Type: 10 PIN CFPK
Device Type: INTEGRATED CIRCUIT
Part No.:
Lot/Date Code:
Qty. Tested:
P.O. /Release No.:

Qualified Components

SAMPLE ID		1	2	3	4	5	6						
Pass/Fail		FAIL	PASS	FAIL	PASS	PASS	PASS						
Inlet Pressure	torr	N/A	N/A	N/A	N/A	N/A	N/A						
Sys. Pressure	torr	9.6e-6	9.3e-6	6.9e-6	1.0e-5	9.4e-6	7.1e-6						
Sample Temp.	°C	100.0	100.1	100.0	99.9	100.0	100.0						
Relative Humidity	RH%	1.7	0.2	3.6	0.3	0.4	0.3						
Volume	cc-atm	0.005	0.005	0.004	0.005	0.005	0.004						
Nitrogen	ppmv	978,154	994,018	923,602	992,936	991,055	993,081						
Oxygen	ppmv	ND	P	ND	P	ND	P						
Argon	ppmv	ND	ND	24	ND	ND	ND						
Carbon Dioxide	ppmv	6,766	4,201	44,895	3,865	5,032	3,862						
Moisture	ppmv	13,849	F	1,479	P	30,863	F	2,762	P	3,486	P	2,566	P
Hydrogen	ppmv	1,213	302	442	424	415	477						
Methane	ppmv	ND	ND	ND	ND	ND	ND						
Ammonia	ppmv	ND	ND	ND	ND	ND	ND						
Helium	ppmv	ND	ND	ND	ND	ND	ND						
Fluorocarbon	ppmv	ND	P	ND	P	ND	P	ND	P	ND	P	ND	P
UNKNOWN	ppmv	18	ND	174	12	13	14						

Tested by: J. Ford Package Thinned/Milled: No Lead Trim/Bend: Yes Fixture #: A706 ND: None Detected 1 %v = 10,000 ppmv

Procedure	ORS SOP MEL-1018: "DLA Land and Maritime Suitability for Military Devices - Internal Gas Analysis".
Prebake	16-24 hours at 100°C. Test at 100°C.
Test System	HR-IVA® 210s System 8 (EQ-19-002)
Failure Criteria	Moisture 5,000ppmv. Gross Leak Fluorocarbon 50ppmv. Oxygen 10,000ppmv (1%v) or greater unless oxygen is an intended constituent gas in the sealing atmosphere. Gas content indicative of a leak.

Table 1: Internal gas analysis results for IC samples. Sample 2 and 3 are selected for the case study. It should also be noted that high carbon dioxide content is also observed with excessive moisture. Sample 3 does not qualify as a leaker since no oxygen was detected, indicating the moisture is a trapped compound in this sealed package.

Sample 2 and 3 were analyzed using UHV-EGA for outgassing at temperature higher than 100°C (standard baking temperature for 16-24 hrs. prior to MIL-STD 881, TM 1018 testing). Observing additional outgassing will indicate that packages baked before sealing underwent incomplete baking. Each sample was analyzed independently by positioning it directly onto a heater surface within the UHV-EGA sample chamber. It is important to note that these samples had previously undergone MIL-STD-883, TM 1018 testing. As a result, each sample features a tiny puncture on its flat surface, enabling the internal gases from the cavity to be accurately analyzed. Following UHV-EGA procedure was used for the testing:

Name	MAX Initial System Pressure (torr)	MAX Time to Reach System Pressure (s)	MAX System Pressure Allowed (torr)
	5e-8	30	0.00003
First Scanned Mass (AMU)	Last Scanned Mass (AMU)	Scan Speed (ms/AMU)	Repeat Scan every seconds
1	150	32	30

#	Disabled	Type	Target	Rate (°C/min)/Duration (min)	Scanning	Duration (min)			
1	<input type="checkbox"/>	Background		10 scans		0.0	I	I	Add Step +
2	<input type="checkbox"/>	Ramp	50 °C	2		12.5	I	I	Add Step +
3	<input type="checkbox"/>	Ramp	250 °C	15		13.3	I	I	Add Step +
4	<input type="checkbox"/>	Dwell		30		30.0	I	I	Add Step +
						55.8	Delete Procedure		

Buttons: Save, Clone, Convert to v2

Fig. 1: A screen capture of the UI in EVACS™ used to define heating protocol for the IC samples. MAX initial system pressure (Torr) defines the maximum value for system pressure required to start the analysis. This means pressure has to below 5E-8 torr to initiate the analysis. During analysis the max system pressure allowed defines the value over which MS will shut off the filament and stop the analysis. This limit is essential to protect ion source filament from high gas pressure. First and last scanned mass gives the mass range over which the analysis will be performed. For example, 1 to 150 amu scan were taken for this study. Scan speed is scan time per amu. For example, when a scan is done at 32 ms/amu speed, to complete the scan over 1-150 amu, the total scan time will be 32 ms * 150 = 4,800 ms = 4.8 s. Scans were repeated every 30 seconds.

Table lists steps for heating schedule. The first step is for collecting 10 background scans without any change in the temperature. Second step is a ramp type step, where heating is started from standby heater temperature (i.e., 30°C) value to 50°C, at the rate of 2°C/min. “Duration” lists the time estimated to achieve this step. The next step is set with higher heating rate (i.e., 15°C/min) to heat up to 250°C. The fourth step is dwell type, where the temperature of 150°C is maintained for 120 mins. The analysis will be stopped after completing all the four steps, which is estimated to completed in 154.5 mins.

Results

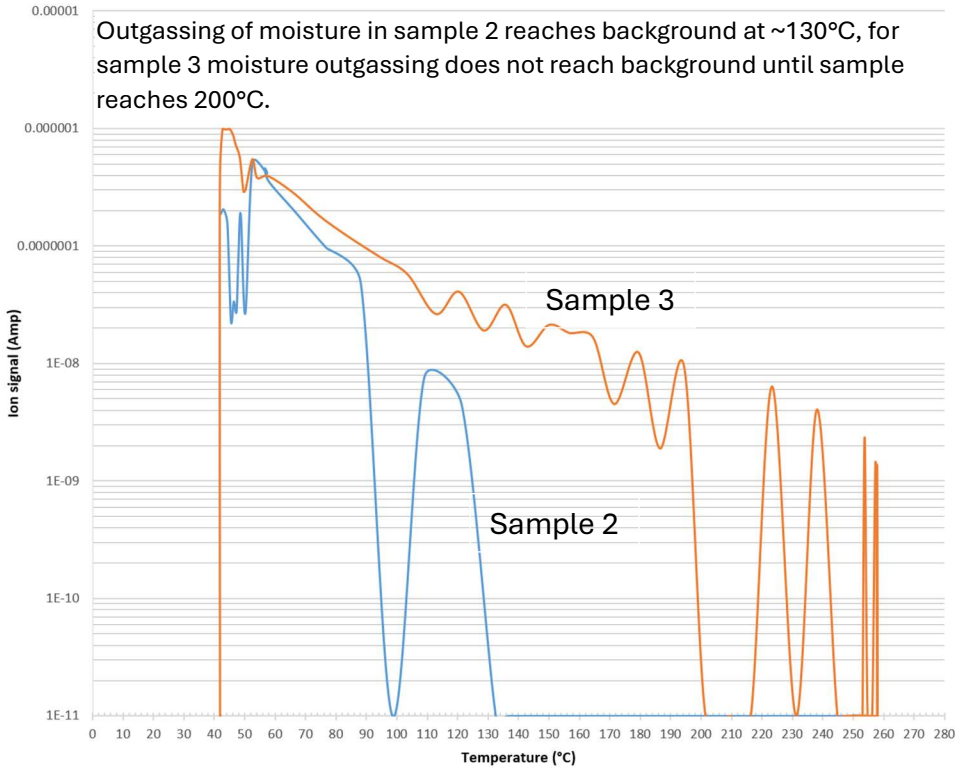


Fig. 2. Plot comparing ion signal for mass 18 for sample 2 and sample 3 to understand moisture outgassing from the samples.

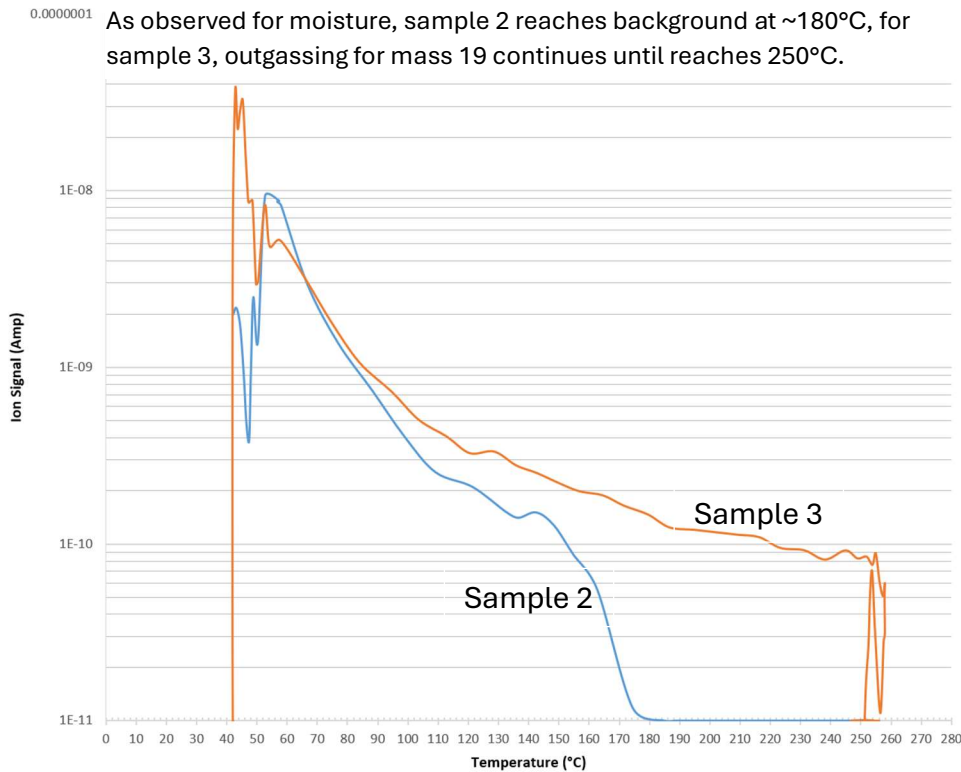


Fig. 3. Plot comparing ion signal for mass 19 for sample 2 and sample 3 to understand additional outgassing from the samples.

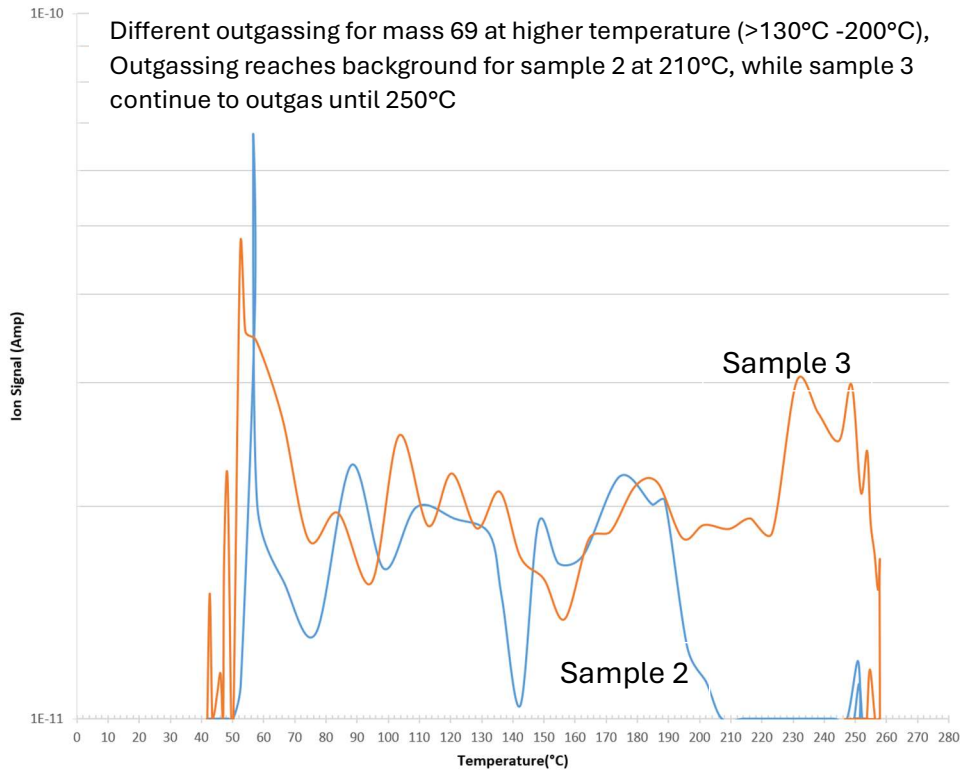


Fig. 4. Plot comparing ion signal for mass 69 for sample 2 and sample 3 to understand additional outgassing from the samples.

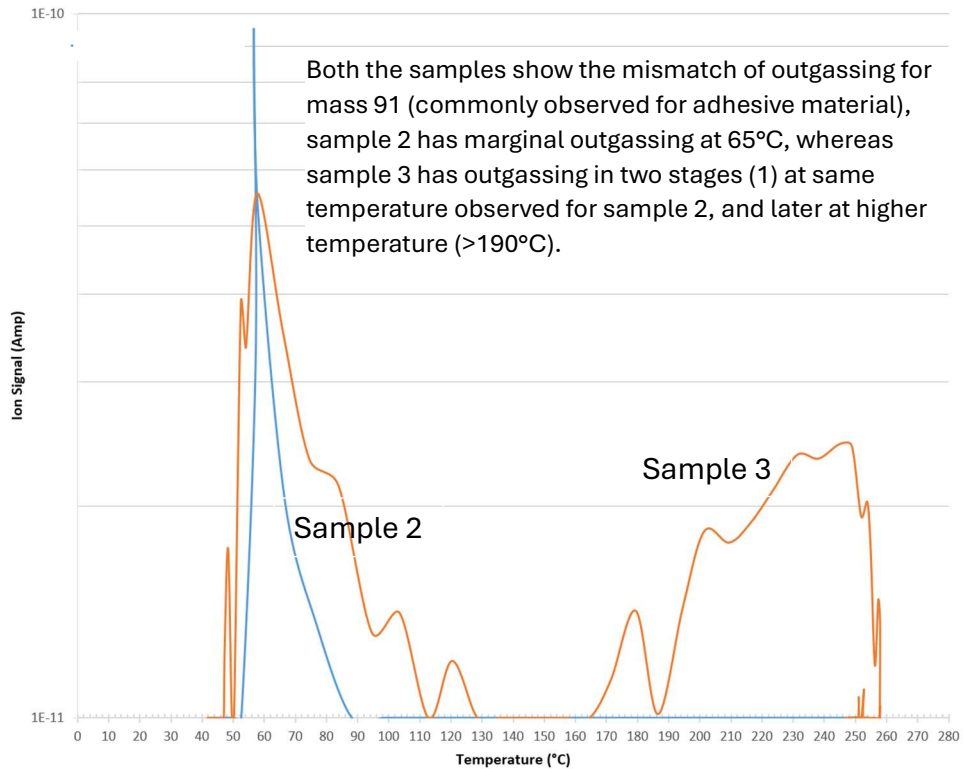


Fig. 5. Plot comparing ion signal for mass 91 for sample 2 and sample 3 to understand additional outgassing from the samples.

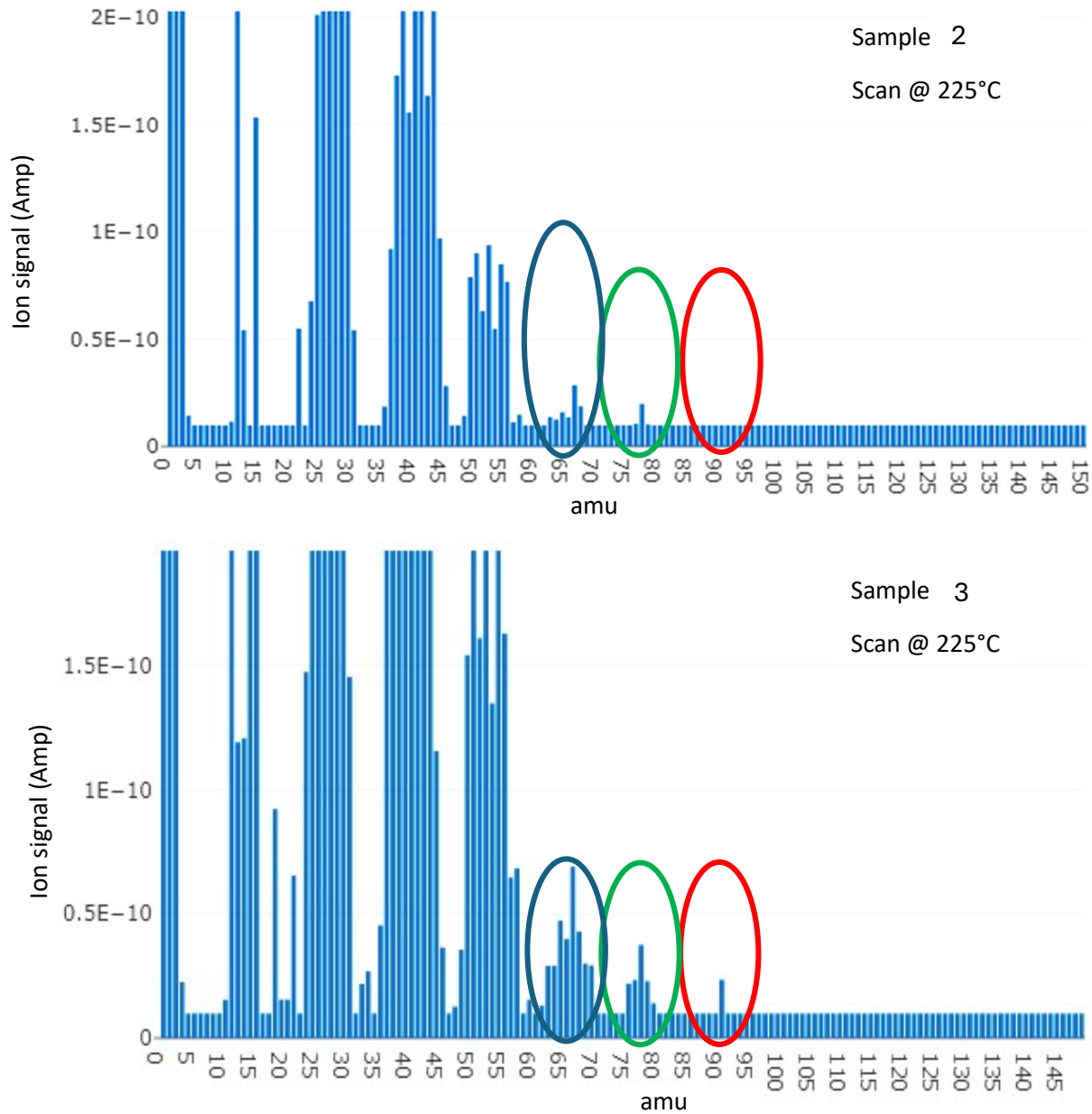


Fig. 6: The plot above compares single scan for the 1-150 amu at 225°C for both the samples. As evident in the plot, masses that are generally contributed by outgassing of adhesive material is higher in sample 3.

Conclusion

- A UHV-EGA comparative study was conducted on samples 2 and sample 3 to investigate the significant difference in their moisture content determined by MIL-STD 883 TM 1018.
- The UHV-EGA analysis identified the presence of unknown gases (i.e., masses 19, 55, 56, 68, and 78) in sample 3. Although these masses were also detected in sample 2, their relative abundance was lower.

- The UHV-EGA findings for mass 18, which corresponds to the main peak for moisture, revealed that moisture in sample 3 continued to outgas until the sample reached 200°C. In contrast, for sample 2, moisture outgassing reduced to background levels at approximately 132°C. This suggests that sample 3 retains moisture attached to the lattice structure in its inner volume—likely originating from adhesive material—manifesting at higher temperatures.
- Observations for masses 19, 69 and 91 (and other masses) emphasized the differences between samples 2 and 3. For sample 2, outgassing of these masses remained low or reduced to background levels, whereas for sample 3, the outgassing persisted and continued above 200°C. These findings align with moisture-related observations and suggest that adhesive material in sample 3 is still outgassing, indicating inadequate baking. Despite the same date code for both samples, this highlights heterogeneity in baking and sealing processes.
- The prolonged outgassing at higher temperatures observed in sample 3 further supports the conclusion of insufficient baking for this sample. If adhesive curing is carried out during or before baking, UHV-EGA analysis should be used to confirm that the cured adhesive does not outgas, as seen in sample 3.

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