Solution White Paper (Full): REALMETER® Standard Leak Sources for Semiconductor Material Outgassing Analysis Systems

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Executive Summary (Fab Review Release)

Document status: This version is a **Fab Review Release** prepared for fab/OEM technical review, tool-qualification discussions, and material-approval evaluation. It is not a conceptual or lab-demo note.

- **Unified reference platform:** The REALMETER® standard-leak portfolio covers **single-gas, mixed-gas, and liquid (or saturated-vapor) media** within one traceable metrology framework.
- **Same Leak Core, Different Actuation:** PSOZV™ and MDZV™ share the same calibrated metrology core; only valve actuation differs (pneumatic NC vs manual NC). Actuation does not define metrology or media coverage.
- **Fab-critical closure:** traceable I↔Q, consistent coverage across the full mass range (including the high-mass m/z=131 anchor), and engineering equivalence for quantifiable organic outgassing.
- **Direct adoption:** Mass Coverage Map, m/z=131 alignment criteria, C12-EOR example, uncertainty budget, and Fab audit checklist are provided for SOP/audit packages.

Fab-grade thesis: RGA outgassing data becomes decision-grade only when it is (1) traceable (I↔Q), (2) consistent across the mass range, and (3) engineering-relevant to organic contamination. REALMETER® achieves this through a complete chain: single-gas + mixed-gas + C12 organic reference leaks.

1. Background

Advanced nodes and EUV tighten contamination margins. Fabs require decision-grade, comparable, auditable chains—not just “nice spectra”.

2. Three inherent breaks (must be closed)

- **Traceability break:** RGA outputs ion current, not flow. Without known-flow reference, absolute scaling can drift.
- **Coverage break:** single-point calibration cannot prove high-mass credibility.
- **Relevance break:** organic outgassing involves adsorption/condensation and time decay; inert gases cannot emulate it.

3. Architecture

Fig. 1 | Reference stack from anchoring to engineering decisions.

4. Why single-gas / mixed-gas / organic are all mandatory

- **Single-gas:** establishes S=I/Q as the measurement ruler.
- **Mixed-gas:** validates low/mid/high mass response consistency and detects aging.
- **C12 organic:** provides organic fingerprint & scaling to compute C12-equivalent outgassing.

5. Method-critical boundary conditions

- Normally-closed pneumatic valve (0.4–0.6 MPa) for repeatable on/off injection.

- Vacuum boundary at outlet (<0.1 Pa class or lower) for stable baseline.
- For hydrocarbons: keep lines short & large-diameter to reduce conductance/wall effects.
- Exponential temperature sensitivity (~8–12%/°C order): define stability & correction rules.
- Medium-dependent pre-pump time; after venting, re-conditioning is required and must be logged.

6. Audit package minimum

Include before/after single-gas & mixed-gas checks, sample time-series and spectra, C12-EOR with uncertainty notes, and traceability fields.

7. Add-on A | Mass Coverage Map (H_2 → Xe → C_{12} → PFTBA)

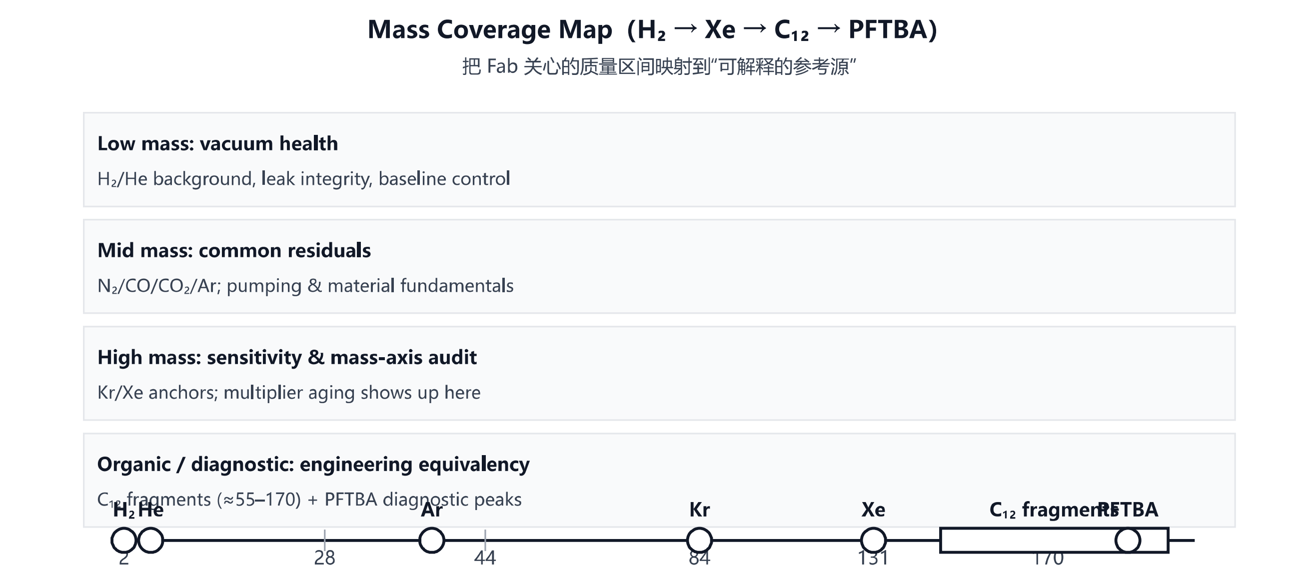

Fig. 3 | Mass Coverage Map: linking fab-critical mass regions to interpretable references.

Fabs audit whether each critical mass region has a defensible anchor and interpretation path. H_2/He support vacuum health and baseline. Xe (m/z 131) audits high-mass sensitivity where aging is visible. C_{12} fragments (≈55–170) provide an organic-equivalency scale for contamination risk. PFTBA serves as a mass-axis and high-mass diagnostic ruler (a ruler, not a sample).

8. Add-on B | C12-EOR calculation example (full chain)

Example (illustrative numbers): Q_{C12}=2.00e-06 Pa·m³/s; I_{C12}^{Σ}=1.20e-09 A → S_{C12}=6.00e-04. If I_{sample}^{Σ}=3.60e-10 A, then $Q_{sample}^{C12\text{-}EOR}$=6.00e-07 Pa·m³/s.

Temperature sensitivity (~10%/°C order) must be logged and controlled; $\Delta T=0.8°C$ implies a scale factor $\approx\times1.080$.

9. Add-on C | Uncertainty budget (how it enters Pass/Fail)

Fabs do not demand perfection; they demand you know the dominant error terms and control them. A typical relative uncertainty budget includes leak nominal/traceability, temperature term, line conductance/wall effects, RGA gain drift, and fragment-window definition. An illustrative RSS combination yields $u_{rel}\approx34.6\%$.

10. Add-on D | Fab audit Q&A (field version)

- **Why not use N_2/Ar as organic proxy?** Inert gases do not emulate organic adsorption/condensation and fragmentation; the decision target is contamination risk.
- **Why C_{12} over C_{16}?** C_{16} is stickier, slower, and more plumbing-sensitive; C_{12} is a practical balance for repeatable SOPs.
- **Is mixed-gas optional?** No. It validates full-range consistency, especially high-mass credibility.
- **Why include PFTBA?** As a mass-axis and high-mass diagnostic ruler for audit confidence.
- **How prove no drift?** Include before/after single-gas and mixed-gas checks; out-of-threshold runs are flagged for review.

Appendix B | RGA Health & Mass Axis Verification (for audit)

B.2 Mass-axis alignment at m/z = 131: Xe vs PFTBA

Fabs use **m/z = 131** as a high-mass audit point: Xe(131) is an atomic peak while PFTBA provides a stable fragment at 131. Agreement supports mass-axis correctness and high-mass health.

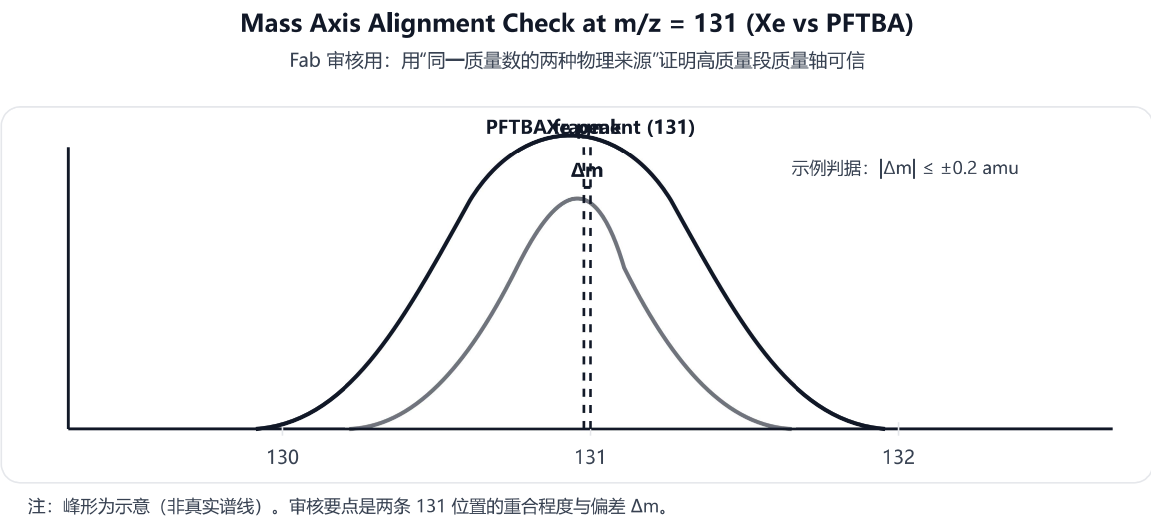

Fig. B-1 | Alignment concept: compare Xe(131) and PFTBA(131) positions and compute Δm.

B.3 PFTBA Mass-Point Checklist (Fab Audit One-pager)

Purpose: use selected PFTBA fragment peaks as audit points across low/mid/high masses to verify **mass-axis correctness, resolution, sensitivity trend, and high-mass health**. This page can be attached directly to a fab audit package.

Set	Mass points (m/z)	Intent & interpretation
Minimal	**69**, **131**, **219**	69 visibility; 131 alignment with Xe (Δm, see B.2); 219 mid-high sensitivity anchor (aging trend).
Recommended	**69**, **100**, **131**, **169**, **219**, **264**	100 energy/fragmentation sensitivity; 169/264 high-mass health; common for qualification audits.
Extended	**69**, **131**, **219**, **264**, **414** (±502)	414+ capability check for instruments with sufficient upper mass and sensitivity (FAT/SAT, annual deep checks).

Suggested acceptance criteria

Item	Recommended	Notes
Mass-axis alignment	|Δm| ≤ ±0.2 amu	Use m/z=131 (Xe vs PFTBA) as the key point; add multi-point checks if required.

Peak shape / resolution	Symmetric, no strong tailing	Tailing may indicate source contamination or ion-optics/settings issues.
High-mass sensitivity	219/264 within control limits	Trend against the same tool's baseline rather than cross-tool absolute values.
Repeatability	Within threshold	Run 2–3 repeats; instability often indicates valve/plumbing/stabilization issues.

Required audit fields

- Injection method/duration/stabilization time, base pressure & background spectrum.
- Scan range/step/dwell, resolution, electron energy, source settings, multiplier voltage.
- Peak position/intensity at each point; peak-shape notes.
- Computed Δm at 131 and trending of relative intensities (219/264/414).

B.4 Application Origin & Reference Implementation

The methodologies presented in this white paper—including **RGA calibration, mass-axis verification, organic outgassing quantification, and uncertainty budgeting**—are not theoretical constructs or lab demonstrations. They are derived from the engineering implementation and long-term application of the **REALMETER® standard leak platform covering single-gas, mixed-gas, and liquid (or saturated-vapor) media**.

- **REALMETER® PSOZV™ / MDZV™ — Liquid (or Saturated-Vapor) Media Standard Leaks:** provide stable, traceable delivery of liquid/organic species (e.g., $C_{12}H_{26}$, PFTBA, H_2O, DMC) for high-mass calibration, organic fragment-region validation, and quantitative material outgassing analysis.
- **REALMETER® PSOZV™ / MDZV™ — Single- and Mixed-Gas Standard Leaks:** provide inert gases including He, N_2, Ar, Kr, Xe and their mixtures for mass-axis anchoring, sensitivity consistency verification, and instrument health diagnostics.

Note: PSOZV™ and MDZV™ share the same calibrated metrology core. The only difference is valve actuation (pneumatic NC vs manual NC); actuation does not define metrology or media coverage.

References

1. REALMETER® PSOZV™/RGA Liquid-media Standard Leak Product Manual: appearance/interface, media specs, operating environment and conductance guidance, operating steps and pre-pump notes.

说明 / Notes：本 v1.1.6.3.2 在 v1.0 基础上新增：Mass Coverage Map、C12-EOR 计算示例页、不确定度预算表、Fab Audit Q&A，并保持推理/论证不删减。