1 Purpose
1.1 This document specifies guidelines for high purity (HP) gas distribution systems in semiconductor production equipment.

2 Scope
2.1 Gas distribution systems consist of stainless steel (SS) piping designed to supply the following types of gases to the process chamber:

2.1.1 Specialty Gases — Corrosive, flammable, pyrophoric, oxidizer, toxic, inert, and mixtures.

2.1.2 Bulk Gases — Nitrogen, oxygen, argon, hydrogen, and helium.

2.2 Typical processes include diffusion, anneal, plasma etch, chemical vapor deposition, physical vapor deposition, and ash.

3 Referenced Documents
3.1 SEMI Standards


SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures - Stainless Steel Systems

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

3.2 ASM Document

ASM UNS S31603 — Composition of Standard Stainless Steels

3.3 ASTM Standards

See Section 3.3 of SEMI E49.

3.4 NFPA Documents

NFPA 49 — Hazardous Chemicals Data

NFPA 704 — Standard System for the Identification of the Fire Hazards of Materials

4 Terminology

See Section 4 of SEMI E49.

5 Performance Guidelines

5.1 Purity Indices

- Particle Count (ptc), at ≥ 0.1 µm
  - ≤ 0.18 ptc/L (5 ptc/ft³) average single count
  - ≤ 1.8 ptc/L (50 ptc/ft³) maximum single count

- Moisture Level — ≤ 100 ppb

- Oxygen Level — ≤ 100 ppb

- Total Hydrocarbon (THC) — ≤ 100 ppb

- Inboard Helium Leak Rate — ≤ 10⁻⁹ atm. cc/sec.

5.2 All performance measures are absolute values, relative to respective test instrument background level.

5.3 See SEMI E49.6 for recommended gas system testing procedures.

5.4 Reliability and Maintainability Indices — Equipment supplier should provide actual gas system performance data and/or component reliability data, accompanied by the associated failure analysis method.

<table>
<thead>
<tr>
<th>Indices</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean time between failure (MTBF)</td>
<td></td>
</tr>
<tr>
<td>Mean time between assists (MTBA)</td>
<td></td>
</tr>
<tr>
<td>Mean time to repair (MTTR)</td>
<td></td>
</tr>
<tr>
<td>Start-up time (Initial)</td>
<td></td>
</tr>
</tbody>
</table>

6 Design Guidelines

6.1 All weld joints should be automatically orbital butt welded.

6.2 Directional changes in the process bww path should be minimized. Required directional changes should be accomplished by butt weld elbows or block...
components. Tube bends may be used up to sizes of ≤ 1/2 in. O.D., with a minimum of 8 × tube diameter.

6.3 Metal face seal type mechanical fittings should be used where required for component removal/replace-

ment.

6.4 Dead volumes and system internal volume should be minimized by use of miniature type weld fittings. Multi-valve arrangements are optional.

6.5 Purge and vent connections to process gas stream should be accomplished by tee fittings and branch valves. Flow through branch valves or multivalue block arrangements are optional.

6.6 All corrosive, toxic, and flammable gases (i.e., reactive) should have upstream and downstream purge/ vacuum capability for MFC maintenance. A gas should be defined to be reactive if it has a Hazardous Production Material (HPM) rating of 3 or 4 per NFPA 49 and NFPA 704.

6.7 All inert gases should have downstream purge capability as a minimum. Atmospheric gas services (e.g., N₂, Ar) can use the process gas as a purge gas.

6.8 For low pressure equipment, the vacuum path from the MFC manifold to the pump should be through the process chamber as a minimum. Piping for chamber bypass to vacuum pump foreline is optional.

6.9 For atmospheric pressure equipment, a vacuum venturi to vent/exhaust method should be required for reactive gases.

6.10 Design should include a means of flow-through purging for removable components or component sticks for reactive gases and should include a means of flow-through purging for all removable components.

6.11 Backflow/back pressure protection should be included for all gases in the system.

6.12 All incoming gas lines should have filters included. Filters for process gases should be located downstream of any regulator or check valve and upstream of any MFC. Screen filters (e.g., wire mesh) should not be used.

6.13 Any additional filters for reactive gases, located at point of use before a process chamber or loadlock, should have a means of isolation from atmosphere.

6.14 For processes requiring pressure control, regulators should be included in the gas system and located upstream of MFCs. Pressure gauges or transducers, with a display, should be used for process measure-

ment.

6.15 The gas system should have a means of mani-
folding supply lines onboard, so that there is a single point connection for each individual gas (consisting of the same chemical composition and purity level).

7 Materials Guidelines

7.1 Material Mechanical Characteristics - Stainless Steel

7.1.1 All tubing greater than or equal to 1.27 cm (1/2 in.) diameter should conform to ASTM A 269.

7.1.2 Tubing less than 1.27 cm (1/2 in.) diameter should conform to ASTM A 632.

7.1.3 All bar stock should conform to ASTM A 479.

7.1.4 All steel should conform to ASM UNS S31603 for chemical composition with the following exceptions:

- Sulfur as reported by the SMTR ≤ 0.030%
- Carbon as reported by the SMTR ≤ 0.030%

7.2 Stainless steel should be 316L electropolished for gas system wetted flow streams and/or as specified by the customer.

7.3 Materials for valve seals, diaphragms, gaskets, and O-rings should be chemically compatible with the process gas.

7.4 Material Performance Guidelines

7.4.1 The performance guidelines below are SS qualification values to be demonstrated by the original com-

ponent manufacturer. Semiconductor equipment suppliers should provide proof that their components con-

form to these requirements.

7.4.2 The performance tests should be considered pro-
duction qualification tests. It is the responsibility of the component manufacturer to provide statistically signif-

icant data which correlates their production tests to these qualification tests (e.g., Statistical Process Con-

trol, MIL-STD-105D).

7.4.3 The equipment supplier should be responsible for maintaining and supplying, upon request, docu-
mentation that proves their components meet the user's materials performance requirements.
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal Surface Chemistry (AUGER)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface chromium oxide enhanced layer thickness at 1/2 peak height of measured oxygen signal level</td>
<td>≥ 15</td>
<td>Å</td>
</tr>
<tr>
<td>For an example of a test method, see SEMASPEC 90120573B (AUGER)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Internal Surface Chemistry (ESCA)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total chromium to iron ratio including both reduced and oxidized states</td>
<td>≥ 1.25:1</td>
<td>value</td>
</tr>
<tr>
<td>For an example of a test method, see SEMASPEC 90120403B (ESCA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Internal Surface Chemistry (EDX)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface foreign elements, those elements not in the Smelter’s Test Report (SMTR)</td>
<td>0</td>
<td>value</td>
</tr>
<tr>
<td>Test procedures per ASTM F 1375 (EDX)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Internal Surface Defects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photos per test method</td>
<td>5</td>
<td>value</td>
</tr>
<tr>
<td>Counts per photo</td>
<td>≤ 50</td>
<td>value</td>
</tr>
<tr>
<td>Test procedures per ASTM F 1372 (SEM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Internal Surface Roughness</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average surface roughness</td>
<td>≤ 0.25</td>
<td>µm</td>
</tr>
<tr>
<td>Roughness average (Rₐ)</td>
<td>(≤ 10)</td>
<td>(µin.)</td>
</tr>
<tr>
<td>Maximum surface Rₐ (individual reading)</td>
<td>≤ 0.33</td>
<td>µm</td>
</tr>
<tr>
<td>(≤ 15) (µin.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For an example of a test method, see SEMASPEC 90120400B (Contact Profilometry)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Particulate Contribution</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at ≥ 0.1 µm size</td>
<td>≤ 0.71 (20)</td>
<td>ptc/L (ptc/ft²)</td>
</tr>
<tr>
<td>Test procedures per ASTM F 1394 (Particles)</td>
<td>≤ 2.6 (75)</td>
<td>ptc/L (ptc/ft²)</td>
</tr>
<tr>
<td>at ≥ 0.02 µm size</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Internal Absorbed Moisture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to recover to baseline from a 2 ppm spike for low surface area component (valve, regulator)</td>
<td>≤ 4</td>
<td>hour</td>
</tr>
<tr>
<td>Time to recover to baseline from a 2 ppm spike for high surface area component (filters, tubing)</td>
<td>≤ 6</td>
<td>hour</td>
</tr>
<tr>
<td>Test procedures per ASTM F 1397</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Anionic Contamination</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total anionic contamination added to test water</td>
<td>≤ 1</td>
<td>ppm</td>
</tr>
<tr>
<td>Individual anionic contaminant</td>
<td>≤ 0.2</td>
<td>ppm</td>
</tr>
<tr>
<td>Test procedures per ASTM D 4327 (Total Anions)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Leak Rate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inboard leak rates for He</td>
<td>≤ 1 x 10⁻⁹</td>
<td>scc/s</td>
</tr>
<tr>
<td>Outboard leak rates for He</td>
<td>≤ 1 x 10⁻⁵</td>
<td>scc/s</td>
</tr>
<tr>
<td>Cross-seat leak rates for He</td>
<td>≤ 4 x 10⁻⁸</td>
<td>scc/s</td>
</tr>
<tr>
<td>Test procedures per SEMI F1 (Leak Rate)</td>
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<td></td>
</tr>
<tr>
<td><strong>Cycle Life</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual valves pressure automatic valves</td>
<td>≥ 25 K</td>
<td>cycles</td>
</tr>
<tr>
<td>High pressure automatic valves</td>
<td>≥ 25 K</td>
<td>cycles</td>
</tr>
<tr>
<td>Low pressure automatic valves</td>
<td>≥ 500 K</td>
<td>cycles</td>
</tr>
<tr>
<td>Test procedures per ASTM F 1373 (Cycle Life)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8 Component Guidelines

8.1 For component leak rate and cycle life requirements, see Section 7.

8.2 Valves should be springless and packless inverted bellows type with all metal bonnet seals. Springless diaphragm type valves are optional.

8.3 Regulators should be a threadless type (wetted stream) with all metal bonnet seals and should meet the following minimum requirements:

- Supply Pressure Effect — \( \leq 0.021 \text{ kg/cm}^2 \) rise/7 kg/cm\(^2\) drop (\( \leq 0.3 \text{ psi rise/100 psi drop} \))
- Repeatability — \( \pm 0.5\% \) of outlet pressure range
- Setpoint Sensitivity — \( \leq 0.0175 \text{ kg/cm}^2 \) (\( \leq 0.25 \text{ psi} \))
- Setpoint Stability — \( \pm 1\% \) of setpoint

For an example of a test method, see SEMASPEC 90120392B.

8.4 Regulators and valve flow coefficient \((C_v)\) should be selected based on gas flow requirements and gas characteristics. For an example of a test method, see SEMASPEC 90120394B.

8.5 Filter performance should be 9-LOG retention value at most penetrating particle size and should meet the following minimum requirements:

- Media-rated at 0.01 \( \mu \text{m} \) pore size
- PTFE or stainless steel media for noncorrosive gases
- PTFE or nickel media for corrosive gases
- Sized for 0.35 kg/cm\(^2\) (5 psi) maximum pressure drop at design flow conditions

For an example of a test method, see SEMASPEC 90120393B.

8.6 MFC's should have as a minimum:

- Metal seals and seats for reactive gases.
- Optional soft start feature.
- High flow purge capability of \( \geq 50 \) times full scale flow for range for MFC's sized for \( \leq 200 \text{ sccm} \) in reactive gas service. High flow purge feature is optional for all other gases and flow rates.

8.7 All mechanical fittings should be a metal face seal type with solid nickel gaskets.

8.8 Pressure gauges should be a compound type and have metal face seal connections. Pressure gauges or transducers should be used for process measurement.

8.9 Pressure transducers should be flow-through or flush-mount, with digital displays. No deadleg-type transducers or pressure gauges should be used for process gas streams. Pressure transducers should meet the following minimum requirements.

- Accuracy (combined linearity, hysteresis, and repeatability) — \( \pm 0.25\% \) of full scale maximum
- Repeatability — \( \pm 0.08\% \) of full scale maximum
- Span Shift — \( \pm 0.1\% \) of full scale maximum due to change in ambient conditions
- Functionally unaffected by RFI/EMI (radio frequency interference/electromagnetic interference) in frequency ranges up to 350 – 950 Mhz, at a distance of 0.61 m (2 ft.) from a 2W source.

8.10 Check valves should be a disk poppet type.

9 Subsystem Assembly Guidelines

See SEMI E49.6 for recommended SS system assembly procedures.

10 Controls Guidelines

10.1 The cycle purge and flow-through purge sequences may be operated by manual means such as toggle switches and push buttons. Automatic controllers for gas system maintenance are optional.

10.2 Detailed instructions for purge sequence operation should be included with equipment.

11 Related Documents

11.1 SEMATECH Documents \(^4\)

SEMASPEC 90120392B — Test Method for Determination of Regulator Performance Characteristics for Gas Distribution System Components

SEMASPEC 90120393B — Test Method for Determination of Filter Flow Pressure Drop Curves for Gas Distribution System Components

\(^4\) SEMATECH, Technology Transfer Department, 2706 Montopolis Drive, Austin, TX 78741
SEMASPEC 90120394B — Test Method for Determination of Valve Flow Coefficients for Gas Distribution System Components

SEMASPEC 90120400B — Test Method for Determination of Surface Roughness by Contact Profilometry for Gas Distribution System Components

SEMASPEC 90120403B — Test Method for XPS Analysis of Surface Composition and Chemistry of Electropolished Stainless Steel Tubing for Gas Distribution System Components

SEMASPEC 90120573B — Test Method for AES Analysis of Surface and Oxide Composition of Electropolished Stainless Steel Tubing for Gas Distribution System Components

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