

SEMI F57-0312

SPECIFICATION FOR POLYMER MATERIALS AND COMPONENTS USED IN ULTRAPURE WATER AND LIQUID CHEMICAL DISTRIBUTION SYSTEMS

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NOTICE: This Document was completely rewritten in 2011.

1 Purpose

1.1 This Document specifies minimum performance requirements for ultra high purity (UHP) polymer materials and components suitable for conveying ultrapure water (UPW) in UPW distribution systems. Further information regarding UPW systems can be found in SEMI F61.

1.2 It also provides recommendations for the use of polymer materials and components used in UHP liquid chemical distribution systems (LCDS). Such distribution systems covered in this Document include bulk supply, facility distribution, and process equipment applications.

1.3 Although the requirements of this Document focus on testing materials and components with UPW at elevated temperatures, there could be other applicable chemicals, such as caustics and oxidizers, which users of this Document might like to consider. However, defining the vast number of testing parameters for each possible liquid chemistry stream is beyond the scope of this Document. Nevertheless, this Document intends neither to exclude nor to limit the possibility that suppliers and end-users might test with chemicals other than UPW or with other temperature conditions and, at the same time, set their own internal limits separate from the requirements within this Document.

2 Scope

2.1 This Specification focuses on polymer material and component performance and validation. Operational requirements to ensure polymer materials and components meet the intent of this Document are provided where appropriate. A summary list follows:

2.1.1 *Quantitative Measures of Compliance*

- Particle Contribution Limits
- Metallic Contribution Limits
- Ionic Contribution Limits
- Total Organic (Oxidizable) Carbon Contribution Limits
- Surface Roughness Limits

2.1.2 *Qualitative Measures of Compliance*

- Mechanical Properties
- Physical Properties
- Chemical Resistance
- Reliability
- Traceability Requirements
- Packaging Requirements
- Certification

2.2 Polymer materials and components consisting of but not limited to the items shown in Table 1 are designed to contain and supply the following types of liquid chemicals:

- UPW
- Acids, bases and oxidizers
- Aqueous salt solutions
- Solvents

2.3 Polymer materials and components that meet the requirements specified in this Document shall be considered suitable for UPW and LCDS as described in ¶ 1.3.

NOTE 1: The following materials have shown the potential to comply with the requirements of this Specification: perfluoroalkoxy (PFA), polytetrafluoroethylene (PTFE), ethylene-tetrafluoroethylene copolymer (ETFE), polychlorotrifluoroethylene (PCTFE), polyvinylidene fluoride (PVDF), and copolymers, and ethylene-chlorotrifluoroethylene copolymer (ECTFE). However, unique design specifications or new materials may result in instances where significant efficiencies may be achieved while maintaining substantially equivalent performance. These scenarios could result in the use of new or existing materials such as polyether-etherketone (PEEK), polypropylene (PP), acetal resin, polyvinyl chloride (PVC), and polyethylene as examples. Care must be taken to ensure that the materials are compatible with the liquid streams (as shown in § 2.2) for long-term applications. Additionally, it is important that the materials used be compatible with the application temperature or methods for bacterial reduction such as ozone, UV light or other sanitizing agents.

2.4 Unless purchased separately, polymer components constructed of sub-pieces, such as o-rings, gaskets, and diaphragms, must meet the requirements of this Document at the functional component level, not as individual sub-pieces. For example an o-ring in a union must not degrade the overall quality of the union such that it fails to meet the requirements of this Document. Alternative spare parts used in direct fluid contact and purchased separately, such as gaskets and o-rings, must meet this Standard, if applicable.

2.5 Leach out tests and associated requirements referenced within this Document provide values from static conditions.

NOTE 2: A flowing stream concentration can be estimated for a component if the static leach out value, fluid velocity and component inner diameter are known. This value is known as the theoretical dynamic concentration (TDC) and is expressed in parts per billion (µg/liter). Information on how to determine the TDC can be found in the Related Information 1 section of this Document.

2.6 This Document and associated tests specify wetted stream performance requirements for polymer components in an as supplied, native state and reflect the current process on record for the polymer component manufacturers.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This Document applies solely to polymer materials and components.

NOTE 3: Performance specifications for subassemblies or process equipment may be found in other SEMI Standards (see Related Documents, § 12.1).

3.2 This Document does not include specifications for filter elements, UV sterilization systems, reverse osmosis systems sensors (nondirect fluid contact), monitors (sampling devices with no return stream), ultra-filtration equipment or other ancillary equipment.

3.3 Polymer materials and components described within this Document are intended for use in UHP service only. Their specified performance requirements may exceed the needs of materials and components used in drainage and other lesser quality liquids.

3.4 The tests referenced in this Document are designed to assess contamination from the polymer materials and components in an as received state. Assembly steps, such as welding and cleaning, may add some contaminants. The effects of the assembly are beyond the scope of this Document, but should be considered by the supplier or user (see SEMI E49).

3.5 Component types considered within this Document ultimately are joined together to form a piping system. Therefore, the nature of the materials dictate that a variety of connection practices ranging from mechanical to fusion techniques will be used. Laboratories typically find it easier to achieve representative particle data of mechanically joined components (such as flared tubing, connectors and valves) using clean mechanical connections. However, in the case of components needing fusion welding (such as rigid polymer pipes, fittings and valves) adaptors transitioning to clean mechanical connections must be used. The surface area of these adaptors should not exceed 10% of the surface area of the component being tested.

NOTE 4: Pipes, fittings, valves and other components made of thermally fusible polymers, like PVDF, ECTFE and PP will require flare adapters welded to the ends to provide a clean connection to the particle counter. The end-user should be aware that the flare adapters or welding process will add to the background and similar spool pieces should be constructed that can be used as correction blanks.

3.6 The tests for determining leach out values as shown in Tables 3, 4, and 5 are specified to be performed at $85 \pm 5^\circ\text{C}$.

NOTE 5: A review of the rationale for defining the $85 \pm 5^\circ\text{C}$ temperature requirements in SEMI F57 and guidelines for how to structure alternative testing protocols can be found in Related Information 2, Surface Extractable Contamination at 85°C .

3.7 Leach out values listed in Tables 3, 4, and 5 reflect testing in UPW only. The relative leach out performance of polymer materials and components in use with other chemicals (e.g., acids and bases) cannot be directly derived using this data. It is incumbent upon the user to determine if a component is suitable for use based on these requirements (see ¶ 1.3).

3.8 Particle contribution as defined in Table 2 shows typical values and limits that have been witnessed in the historical testing of several components from a variety of manufacturers.

3.9 This Document is not intended to supersede international, national or local codes, regulations, and laws. Each should be consulted to ensure that the manufactured polymer components meet regulatory requirements in each location.

NOTE 6: Organic flammable solvents can pose a safety risk when being transported in nonconductive polymer components due to static discharge. Care must be taken when using polymeric components with flammable solvents.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI E49 — Guide for High Purity and Ultrahigh Purity Piping Performance, Subassemblies, and Final Assemblies

SEMI F40 — Practice For Preparing Liquid Chemical Distribution Components for Chemical Testing

SEMI F61 — Guide for Ultrapure Water Systems Used in Semiconductor Processing

SEMI F104 — Particle Test Method Guidelines for Evaluation of Components Used in Ultrapure Water and Liquid Chemical Distribution Systems

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

4.2 ASTM Standards¹

ASTM D4327 — Anions in Water by Chemically Suppressed Ion Chromatography

ASTM D4779 — Total, Organic, and Inorganic Carbon in High Purity Water by Ultraviolet (UV) or Persulfate Oxidation, or Both, and Infrared Detection

ASTM D5904 — Standard Test Method of Total Carbon, Inorganic Carbon, and Organic Carbon in Water by UV, Persulfate Oxidation and Membrane Conductivity Detection

¹ American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: 610.832.9585, Fax: 610.832.9555, <http://www.astm.org>

4.3 ISO Standards²

ISO 4287 — Geometrical Product Specifications (GPS) – Surface texture: Profile method – Terms, definitions and surface texture parameters

4.4 SEMATECH Documents³

SEMASPEC 92010936B-STD — Provisional Test Method for Determining Leachable Trace Inorganics in Ultra Pure Water Distribution System Components

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 Abbreviations and Acronyms

- 5.1.1 *ALD* — atomic layer deposition
- 5.1.2 *ECTFE* — ethylene-chlorotrifluoroethylene copolymer
- 5.1.3 *ETFE* — ethylene-tetrafluoroethylene copolymer
- 5.1.4 *ICP-MS* — inductively coupled plasma mass spectrometry
- 5.1.5 *LCDS* — liquid chemical distribution systems
- 5.1.6 *PEEK* — polyether-etherketone
- 5.1.7 *PFA* — perfluoroalkoxy
- 5.1.8 *PCTFE* — polychlorotri-fluoroethylene
- 5.1.9 *PP* — polypropylene
- 5.1.10 *PVC* — polyvinyl chloride
- 5.1.11 *PVDF* — polyvinylidene fluoride
- 5.1.12 *PTFE* — polytetrafluoroethylene
- 5.1.13 *TDC* — theoretical dynamic concentration
- 5.1.14 *TOC* — total organic carbon
- 5.1.15 *UHP* — ultra high purity
- 5.1.16 *UPW* — ultrapure water

5.2 General terms for UPW systems can be found in SEMI F61.

5.3 Definitions

5.3.1 *liquid chemical distribution system (LCDS)* — the collection of components and subsystems used to control and deliver liquid process chemicals from a source location to a point of use in a semiconductor manufacturing facility.

5.3.2 *microelectronic devices* — extremely small electronic devices that consume very little electric power and encompass a variety of components used in normal electronic design. They are available individually or, in some cases, combined on a single substrate as transistors, capacitors, inductors, resistors, diodes, insulators, conductors, digital and analog integrated circuits, and microelectronic machines (MEMS), to name a few. Examples of such electronic components are found in computers, cell phones, televisions, photovoltaic solar panels, etc.

5.3.3 *ultrapure water distribution system* — the collection of components and subsystems used to deliver ultrapure water from a source location to a point of use.

² International Organization for Standardization, ISO Central Secretariat, 1 rue de Varembe, Case postale 56, CH-1211 Geneva 20, Switzerland; Telephone: 41.22.749.01.11, Fax: 41.22.733.34.30, <http://www.iso.ch>

³ SEMATECH, 257 Fuller Road, Suite 2200, Albany, NY 12203, USA; Telephone: 518.649.1000, <http://www.semitech.org>

6 Purity Requirements

6.1 The required testing by material and component type can be found in Table 1.

Table 1 Required Testing by Material and Component Type^{#1, #2}

Type	Particles ^{#3, #4} (see § 6.7)		Ionic Contamination (see § 6.8)	Metallic Contamination (see § 6.9)	TOC (see § 6.10)	Surface Roughness (see § 6.11)
	Rinse Test	Cycle Test				
Pellets			-	-	-	
Pneumatic Valves	√	√	√	√	√	√
Electronic Valves	√	√	√	√	√	√
Manual Valves	√	-	√	√	√	√
Check Valves	√	√	√	√	√	√
Flow Meters: No moving parts	-		√	√	√	√
Flow Meters: With moving parts	-	-	√	√	√	√
Flow Controllers	-	-	√	√	√	√
Pneumatic Pilot Regulators	-	-	√	√	√	√
Manual Regulators	-	-	√	√	√	√
Tubing	-		√	√	√	√
Filter Housings	-		√	√	√	√
Degas Modules	-		√	√	√	√
Gauge Guards	-		√	√	√	√
Fittings	-		√	√	√	√
Piping	-		√	√	√	√
Tank /Vessels/Drums ^{#5}	-		√	√	√	
Sensors: With moving parts	-	-	√	√	√	√
Sensors: No moving parts	-	-	√	√	√	√
Pumps	-	-	√	√	√	√

#1 A '√' in Table 1 means the test is required whereas a blank space indicates that the test is not required.

#2 A '-' in Table 1 means the test is currently not required because a test method does not yet exist.

#3 SEMI F104 testing is currently limited to testing of products with orifice size of 1/8 inch minimum to 1 inch maximum.

#4 See ¶ 3.5.

#5 The surface area to volume ratio for some large vessels may prevent obtaining meaningful static leach out testing results. Some dynamic testing has been done, but is not covered within this Document. Surface testing, such as determining ionic, metallic or organic contamination can be performed on tanks/vessels/drums if the need, limits and method are agreed between the supplier and end user.

6.2 The values found in Tables 3 through 6 were constructed from existing databases of high purity grades of PVDF and PFA. They represent characteristics of piping system polymer materials and components which are currently providing end-users with satisfactory results. Other materials with other particle leach out or surface roughness characteristics may or may not be acceptable. The end-user may need to test such materials to determine if they will meet both the static values of this Document as well as any final delivered fluid requirements.

6.3 To prevent the possibility that the results of a leached component or polymer material might become diluted beyond detection limits of the instrument, where possible, the component or material surface area to volume ratio of the leaching solution should provide a detection limit less than or equal to 50% of the specification value.

6.4 In the event the geometry of the material results in the detection limit exceeding 50% but under 100% of the specification value, the data can be used provided no other option exists at the time to improve the detection limits. At no time will a detection limit exceeding 100% of the specification value be considered. In the event the part

geometry is such that the detection limit cannot be reduced below 100% of the specification value, testing a part of similar construction and manufacturing practices can be considered as an alternative solution. This 'similar part' should be of a similar geometry, while still meeting the detection limit requirements of less than 100% of the specification value.

6.5 When testing small components, if the solution volume is insufficient to perform the required tests, multiple components can be used to obtain the required solution volume.

6.6 The components selected for testing should be supplied in the packaging used in normal production and reflect the current manufacturing capabilities of the supplier.

6.7 Particle Contribution

6.7.1 *Importance of Test* — Particles released from within polymer components can come into direct contact with microelectronic devices and other critical surfaces causing unwanted surface contamination or disrupting the photolithography process, thereby decreasing yields.

6.7.2 Particle contribution testing uses methods for measuring particle contribution from components while using UPW as the test medium. These methods use an in situ optical particle measurement instrument to quantify performance.

6.7.3 Particle contribution testing is restricted to polymer components as shown in Table 1.

6.7.4 Polymer components shall conform to the particle contribution specifications appearing in Table 2.

NOTE 7: The performance values in Table 2 for the Rinse Test and Cycle Test represent geometric and arithmetic averages, respectfully, from a minimum of four representative components after subtracting an initial system particle background level.

Table 2 Particle Contribution^{#1}

Description	Units	Particle Size	Value (by Material Type) ^{#2, #3, #4}	
			PTFE or PFA	Other Materials
Rinse Test	Volume Required to Achieve <0.1 Particles/ml	Particle Size $\geq 0.1 \mu\text{m}$	≤ 300 Liters	-
Cycle Testing: Automatically cycled regulators and components	Cycles Required to Achieve <100 Particles per Actuation	Particle Size $\geq 0.1 \mu\text{m}$	≤ 500 Cycles	-
	Cycles Required to Achieve <10 Particles per Actuation	Particle Size $\geq 0.1 \mu\text{m}$	$\leq 10,000$ Cycles	-

#1 A '-' in Table 2 means that the test is currently not required as the limits of acceptance have not been established.

#2 The polymer component test method for particle contribution is SEMI F104 (see ¶ 6.7.5).

#3 SEMI F104 is currently limited to testing of products with orifice size of 1/8 inch minimum to 1 inch maximum.

#4 See § 6.7 for more information about particle contribution.

6.7.5 SEMI F104 defines the test method to be used when conducting particle contribution testing.

6.7.6 Rinse Test evaluates particle contribution performance in a flushing mode while the component is in a static state. It provides an indication of the volume of UPW required to bring particle levels to the guidelines defined in Table 2.

6.7.7 Cycle Test evaluates particle contribution performance during cycling and provides an indication of the steady state particle contribution in a dynamic mode.

6.8 Ionic Contamination

6.8.1 *Importance of Test* — Ionic contamination can have a corrosive or etching effect on microelectronic devices and other critical surfaces during fabrication, causing immediate or future device failure. Evaporation of solutions containing ionic contamination may leave surface residue.

6.8.2 Ionic contamination specifications and testing are required for polymer materials and components as shown in Table 1.

6.8.3 Polymer materials and components shall conform to the ionic contamination specifications appearing in Table 3. Use SEMI F40 to prepare the material or component type for analysis and ASTM D4327 or equivalent to analyze the leachate.

Table 3 Surface Extractable Ionic Contamination Requirements

<i>Description^{#1}</i>	<i>Static Value at 85 ± 5°C for 7 days (µg/m²)^{#2, #3}</i>
Bromide	≤100
Chloride	≤3000
Fluoride	≤60,000
Nitrate	≤100
Nitrite	≤100
Phosphate	≤300
Sulfate	≤300

#1 Optional testing may be considered by the end user for the ammonium ion.

#2 The polymer material and component preparation practice for surface extractable testing is SEMI F40. The polymer material and component test method for extractable ionic contamination is ASTM D4327 (see ¶ 6.8.3).

#3 See § 6.8 for more information about Ionic Contamination.

6.8.4 The Static Value is derived from a static leach out test, using UPW as the test medium and lasting for 7 days.

6.8.5 When reporting ionic contamination, the measured values and detection limits are to be reported in micrograms of contamination per unit surface area in meters squared (µg/m²).

6.8.6 The measured values are reported provided they are above their respective detection limits as described in § 6.3. In the case where the measured value is below the detection limit, less than (<) the detection limit is reported.

6.8.7 Testing temperature of polymer materials and components shall be 85 ± 5°C. The testing temperature is specified to achieve comparable data for polymer materials and components and is not indicative of service temperatures.

6.9 Metallic Contamination

6.9.1 *Importance of Test* — Metallic contamination can alter the electrical properties of microelectronic devices and can have a corrosive or etching effect on microelectronic devices and other critical surfaces during fabrication, causing immediate or future device failure.

6.9.2 Metallic contamination specifications and testing are required for polymer materials and components as shown in Table 1.

6.9.3 Polymer materials and components shall conform to the metallic contamination specifications appearing in Table 4.

6.9.4 Use SEMI F40 to prepare the component type for analysis and analyze polymer materials and components using inductively coupled plasma mass spectrometry (ICP-MS). Calibrate the sample elements with matrix matched blank and external standards.