

SEMI F57-0622

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

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NOTICE: Paragraphs entitled ‘NOTE:’ are not an official part of this Standard or Safety Guideline and are not intended to modify or supersede the official Standard or Safety Guideline. These have been supplied by the global technical committee to enhance the usage of the Standard or Safety Guideline.

NOTICE: The section symbol (§) is used to reference a numbered section, paragraph, or header and all subordinate paragraphs, headers, and embedded material (i.e., EXCEPTIONs, lists) therein. The paragraph symbol (§) is used to reference a particular numbered paragraph and embedded material therein. When duplicated (i.e., §§ and §§) the symbols are used to reference more than one section or paragraph, respectively.

1 Purpose

1.1 This Standard 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, SEMI F63.

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 Specification include bulk supply, facility distribution, and process equipment applications.

1.3 Although the requirements of this Specification 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 Specification might like to consider. However, defining the vast number of testing parameters for each possible liquid chemistry stream is beyond the scope of this Specification. Nevertheless, this Specification 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 Specification.

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 Specification are provided where appropriate. A summary list follows:

2.1.1 *Quantitative Measures of Compliance*

- 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 This Specification pertains to polymer materials and components consisting of but not limited to the items shown in Table 1 are designed to contain and supply the following, but not limited to, the types of liquid chemicals listed below:

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

2.3 Polymer materials and components that meet the requirements specified in this Standard shall be considered suitable for UPW and LCDS as described in ¶ 1.3. Refer to SEMI C90 for additional requirements for the use of polymers in LCDS.

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. 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 Specification 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 Specification. Alternative spare parts used in direct fluid contact and purchased separately, such as gaskets and O-rings, must meet this Standard, if applicable.

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 Specification.

2.5 This Specification 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 Specification applies solely to polymer materials and components.

NOTE 3: Performance specifications for subassemblies or process equipment may be found in other SEMI Standards (refer to Referenced Documents, § 4.1).

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

3.3 This Specification can apply to polymers used in chemical delivery systems. Note that SEMI F57 only considers extraction in UPW. Polymers used in UHP chemical systems may require further investigation.

3.4 Polymer materials and components described within this Specification 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.

3.5 The tests referenced in this Specification 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 Specification but should be considered by the supplier or user (refer to SEMI E49).

3.6 Components considered within this Specification 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.

3.7 Leach out values listed in Tables 2, through 4 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 (refer to ¶ 1.3).

3.8 Testing of Pellets as described in Table 1 requires an estimate of pellet surface area (refer to SEMI C69) in order to calculate extraction results in units of $\mu\text{g}/\text{m}^2$. As results are based on surface area (reported in $\mu\text{g}/\text{m}^2$), the accuracy of these measurements are dependent on the accuracy of the surface area estimates. The accuracy of pellet surface area estimates can vary with pellet geometry, and as such, can affect reported test result accuracy. Per SEMI C69 the pellet surface finish can also affect the results. The normalized surface area calculation for pellets has more variability than components and therefore can have more impact on calculated results.

3.9 This Specification 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 4: 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 C69 — Test Method for the Determination of Surface Areas of Polymer Pellets

SEMI C90 — Test Method and Specification for Testing Perfluoroalkoxy (PFA) Materials Used in Liquid Chemical Distribution Systems

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

SEMI F40 — Practice for Preparing Liquid Chemical Distribution Components and Neat Polymers for Chemical Testing

SEMI F61 — Guide to Design and Operation of a Semiconductor Ultrapure Water System

SEMI F63 — Guide for Ultrapure Water used in Semiconductor Processing

4.2 ASTM Standards¹

ASTM D4327 — Standard Test Method for Anions in Water by Chemically Suppressed Ion Chromatography

ASTM D4779 — Standard Test Method for Total, Organic, and Inorganic Carbon in High Purity Water by Ultraviolet (UV) or Persulfate Oxidation, or Both, and Infrared Detection (Withdrawn 2002)

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

4.3 ISO Standards²

ISO 4287 — Geometrical Product Specifications (GPS) – Surface Texture: Profile Method – Terms, Definitions and Surface Texture Parameters

¹ ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: +1.610.832.9585, Fax: +1.610.832.9555, <http://www.astm.org>

² International Organization for Standardization, ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland; Telephone: +41.22.749.01.11, <http://www.iso.org>

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 *PCTFE* — polychlorotri-fluoroethylene
- 5.1.7 *PEEK* — polyether-etherketone
- 5.1.8 *PFA* — perfluoroalkoxy
- 5.1.9 *PP* — polypropylene
- 5.1.10 *PTFE* — polytetrafluoroethylene
- 5.1.11 *PVC* — polyvinyl chloride
- 5.1.12 *PVDF* — polyvinylidene fluoride
- 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 Definitions

5.2.1 *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.

5.2.2 *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.

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

6 Purity Requirements

6.1 High purity testing is performed per SEMI F40 with purity requirements defined in Tables 2 through 4 within the SEMI F57 Standard. Material and components required to be tested for purity can be found in Table 1.

NOTE 5: For other components which have significantly smaller surface area and whose values may differ from those in the table please refer to the Related Information 1 and Related Information 2 for guidance on how to evaluate the effect of the contamination.

6.2 Testing of raw materials in the form of pellets as described in Table 1 below shall be done per SEMI F40 and in a manner negotiated and agreed to by the raw material suppliers and component manufacturers. The primary goal of performing and sharing such information is to assist the component manufacturer in producing products that meet the requirements of SEMI F57. Pellet testing frequency, form of the material, surface area calculation methods, contamination limits and units reported shall all be part of this negotiated agreement (between the raw material suppliers and component manufacturers).

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

<i>Type</i>	<i>Ionic Contamination (refer to § 6.8)</i>	<i>Metallic Contamination (refer to § 6.9)</i>	<i>TOC (refer to § 6.10)</i>
Pellets ^{#2, #4}	√	√	√
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	√	√	√
Filters	√	√	√
Piping	√	√	√
Tank/Vessels/Drums ^{#3}			
Sensors: With moving parts	√	√	√
Sensors: No moving parts	√	√	√
Pumps	√	√	√

#1 A '√' in Table 1 means testing is required.

#2 Pellet Surface area can be determined following the procedures defined in SEMI C69.

#3 Testing of these components for extractables is currently not covered by SEMI F40.

#4 Refer to ¶ 6.2 in § 6 "Purity Requirements"

#5 It should be noted that differences between pellet and component data values are expected.

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

6.4 In the event the geometry of the material results in the reporting 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 reporting limits. At no time will a reporting limit exceeding 100% of the specification value be considered. In the event the part geometry is such that the reporting 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 reporting 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 When reporting contamination (ionic, metals and TOC), the measured values are reported if above the respective reporting limits as described in § 6.4. In the case where the measured value is below the reporting limit, a less than

the reporting limit (<RL) is reported. All measured values and reporting limits when reported will be in the units of micrograms of contamination per unit surface area in meters squared ($\mu\text{g}/\text{m}^2$).

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 testing is required for high purity 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 2 when prepared per SEMI F40 and analyzed following the procedures defined in ASTM D4327 or equivalent.

Table 2 Surface Extractable Ionic Contamination Requirements

<i>Ionic Contamination Limits^{#1}</i>	
<i>Ionic Contaminant</i>	<i>Ionic Extraction Limits ($\mu\text{g}/\text{m}^2$)</i>
Ammonium	≤ 100
Bromide	≤ 100
Chloride	≤ 100
Fluoride	≤ 20000
Nitrate	≤ 100
Nitrite	≤ 100
Phosphate	≤ 100
Sulfate	≤ 100

^{#1} Refer to ¶ 6.2 in § 6 “Purity Requirements” when testing materials in the form of pellets as described in Table 1.

6.8.4 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 testing is required for high purity 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 3 when prepared per SEMI F40 and analyzed using inductively coupled plasma mass spectrometry (ICP-MS).

Table 3 Surface Extractable Metallic Contamination Requirements^{#1}

<i>Metallic Contaminant</i>	<i>Metallic Extraction Limits ($\mu\text{g}/\text{m}^2$)</i>
Aluminum	≤ 5
Arsenic	≤ 2
Antimony	≤ 2
Barium	≤ 15
Boron	≤ 30
Cadmium	≤ 2
Calcium	≤ 10

<i>Metallic Contaminant</i>	<i>Metallic Extraction Limits ($\mu\text{g}/\text{m}^2$)</i>
Chromium	≤ 1
Copper	≤ 10
Iron	≤ 5
Lead	≤ 1
Lithium	≤ 2
Magnesium	≤ 2
Manganese	≤ 5
Nickel	≤ 1
Potassium	≤ 10
Sodium	≤ 10
Strontium	≤ 0.5
Titanium	≤ 2
Tin	≤ 2
Vanadium	≤ 2
Zinc	≤ 5

#1 Refer to ¶ 6.2 in Section 6 “Purity Requirements” when testing materials in the form of pellets as described in Table 1.

6.10 Total Organic Carbon (TOC)

6.10.1 *Importance of Test* — TOC can have an effect on semiconductor processing including silicon oxidation, uniformity of etching, cleaning (including wafers and masks), adhesion, gate oxide breakdown voltage, epitaxy, atomic layer deposition (ALD), CVD of silicon nitride or other thin film deposition steps. TOC is a screening method, and while low TOC values set a maximum level of TOC in water, the effects of the individual compounds can depend of the structure of the molecules, and the process. Compounds that leave residues may be more detrimental than very water soluble and volatile compounds (e.g., isopropanol). In addition, TOC added to ultrapure water can be a nutrient to increase the growth of bacteria in water systems. As many methods might be required to assess the identification of all organic contaminants, TOC is a practical screening method to assess total organics present, and if low, further testing typically is not needed.

6.10.2 TOC specification and testing are required for polymer materials and components as shown in Table 1.

6.10.3 Polymer materials and components shall conform to the TOC contamination specifications appearing in Table 4 when prepared per SEMI F40 and analyzed following the procedures defined in ASTM D4779 or ASTM D5904 or equivalent.

Table 4 Surface Extractable TOC Contamination Requirements

<i>TOC Contamination Limit^{#1}</i>	
<i>Contaminant</i>	<i>TOC Extraction Limit ($\mu\text{g}/\text{m}^2$)</i>
TOC	≤ 40000

#1 Refer to ¶ 6.2 in § 6 “Purity Requirements” when testing materials in the form of pellets as described in Table 1.

6.11 Surface Roughness

6.11.1 *Importance of Test* — Surface roughness can influence microbial proliferation, provide an entrapment area for microcontamination build-up or promote shedding of the polymer itself within a distribution system.

6.11.2 All components shown in Table 1 with the exception of pellets and tanks, vessels, drums, degas units, gauge guards, sensors (all) and filters will be tested for surface roughness. Only surfaces in direct contact with liquid chemicals as defined in § 2.2 need to be tested for surface roughness.

6.11.3 Polymer components to be tested for surface roughness shall conform to surface roughness specifications appearing in Table 5 as required by the end user. ISO 4287 defines the test method to be used when conducting surface roughness measurements.

6.11.4 The product descriptions found in Table 6 describe the manufacturing processes used to produce plastic components. Extruded products are represented by components such as pipe and tubing. Injection molded products are represented by components such as fittings, valves, housings and pumps. A machined component is one produced by machining plastic stock or by a post-mold machining operation used to define a specific component characteristic, such as a valve seat.

6.11.5 It is understood that surface roughness will vary with the manufacturing process. The surface roughness values are based on what is believed obtainable when good manufacturing methods are being practiced.

Table 5 Surface Roughness Requirements

<i>Description</i>	<i>Ra max. Value^{#1, #2} μm (μin)</i>
Extruded Pipe (<250 mm OD)	≤ 0.25 (≤ 10)
Extruded Pipe (≥ 250 mm OD, ≤ 315 mm OD)	≤ 0.45 (≤ 18)
Injection Molded (<250 mm OD)	≤ 0.35 (≤ 14)
Injection Molded (≥ 250 mm OD, ≤ 315 mm OD)	≤ 0.50 (≤ 20)
Machined (<250 mm OD)	≤ 0.60 (≤ 24)
Machined (≥ 250 mm OD, ≤ 315 mm OD)	≤ 1.00 (≤ 40)

#1 Units in (μin) are rounded approximations.

#2 The polymer component method for surface roughness testing is ISO 4287 (refer to ¶ 6.11.3).

6.11.6 Surface roughness will be calculated as the arithmetic mean Deviation (Ra) with measured values reported in micrometers (μm).

6.11.7 Surface roughness measurements are to be taken in areas that best represent the bulk of the wetted surface of the component. Surface roughness measurements of post machined surfaces are only necessary if the total machined surface area is greater than 25% of the component's total wetted surface area.

7 Analytical Requirements

7.1 Requirements for all of analytical procedures are defined in SEMI F40.

8 Test Methods

8.1 Test methods, including materials preparation, reporting and calculation of results are defined in SEMI F40.

9 General Specifications for Polymer Materials and Components

9.1 Due to purity and traceability issues, reprocessed or regrind materials must not be used by the manufacturer when making polymer components intended to meet this Specification.

9.2 Upon request, suppliers of polymer materials and components shall provide data or information about their products. This information is typically found in product catalogs, component data sheets or other published literature. Where applicable, the end user may request information including the test methods used, component failure analysis, or reliability data that show conformance to the manufacturers' specifications. Tables 6 and 7 show examples of the type of data an end user might request.

Table 6 Typical Specifications for Polymeric Materials

<i>Specification</i>	<i>Examples</i>
Physical and Mechanical Properties	Tensile, flexural, impact, hardness, aging, crystallinity, clarity
Chemical Resistance Properties	Chemical resistance rating (material, media, concentration and temperature)
Thermal Properties	Melting point, Vicat, Tg, Decomposition
Permeability	Permeation rate (time, temperature, pressure, thickness, media)

Table 7 Typical Specifications for Polymeric Components

<i>Specification</i>	<i>Examples</i>
Dimensional Tolerances	Diameter, wall thickness, length, width and height, ovality
Flow Characteristics	Flow coefficient (Cv or Kv), computational fluid dynamics (CFD) analysis, flow rate range
Leak Integrity	Pressure decay, leak across seat, leak to ambient
Mechanical Strength Characteristics	Burst pressure, weld strength, side loading, pull out strength, deflection
Electrical and Optical Characteristics	Current draw, electrical emissions
Temperature and Pressure Rating	Hydrostatic resistance, lower and upper temperature (media) limit, ambient temperature, pressure vs. temperature curve
Chemical Resistance Properties	Chemical resistance rating (material, media, concentration and temperature)
Reliability and Performance Data	Life cycle testing, response time reliability in DIW and chemicals, valve membrane fatigue, membrane deformation, membrane pin pullout

10 Component Performance Validation

10.1 The supplier is responsible for defining, establishing, and executing a testing program for polymer materials and components based on the requirements outlined within this Specification.

10.2 The testing program will specify the frequency of testing, the test material or component(s) or both, and the tests to be conducted.

10.3 The testing program should include a plan that identifies any corrective actions required in the event a test material or component fails to meet these requirements.

10.4 The supplier is not required to test polymer materials or components shipped from each individual lot. The supplier is also not required to test each size component or material grade within the manufacturer's product range. Instead, the supplier shall select materials or components considered representative of product(s) having similar processing or production techniques. Samples shall be randomly selected from a population that reflects current production processes as outlined in the supplier's testing program.

10.5 The supplier is responsible for maintaining and supplying documentation that demonstrates its polymer materials or components consistently meet the requirements of this Specification. A sample summary report form is provided in Appendix 1 to help summarize key information to be included when validating compliance to SEMI F57. The use of this form is optional and may be requested by the customer.

11 Traceability Requirements

11.1 It is the responsibility of the supplier to establish procedures to maintain an incoming raw material certification, inspection, and traceability process that will ensure manufactured polymer materials and components meet the requirements of this Specification.

11.2 Each deliverable item shall have some scheme of identification on the material, component, exterior bag, or box so that traceability is provided from the raw material to the final finished, packaged product.

11.3 In the event that component installation by the purchaser removes or obliterates such identification, it becomes the responsibility of the purchaser to maintain identification records.