

SEMI F63-1016

GUIDE FOR ULTRAPURE WATER USED IN SEMICONDUCTOR PROCESSING

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1 Purpose

1.1 This Guide may be used:

- To establish performance criteria when purchasing ultrapure water (UPW) purification equipment.
- To set the process control parameters for UPW-system operation.
- To establish quality expectations for the supplied UPW.

NOTE 1: These suggested guidelines are published as technical information and are intended for informational purposes only.

2 Scope

2.1 UPW is used extensively in the production of semiconductor devices for all wet-processing steps (including wafer rinsing). UPW purity is therefore critical to the manufacture of semiconductors. This Guide provides UPW quality parameters and background information for the decision-making process related to new or retrofit facilities that manufacture semiconductors with line widths of 65 nm and smaller.

2.2 The goal of members of the International Technology Roadmap for Semiconductors (ITRS) UPW committee is to look years ahead on a continual basis to assess the semiconductor industry's future UPW technology requirements. In addition to ITRS input, the SEMI committee contributed its knowledge of the feasibility and cost viability of the technical solutions required to support UPW quality values specified in this Guide.

2.3 The information in this Guide has been developed from the following sources:

- ITRS risk assessment with input from facility- and manufacturing-experts and technology providers in the semiconductor manufacturing industry.
- The results of UPW testing at semiconductor manufacturing sites as measured by independent laboratories that test high purity water for the semiconductor industry.
- Specifications from water-system equipment manufacturers.
- Input from UPW producers and users at SEMI Standards committee meetings, and also through the balloting process.

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 Guide is not intended to define UPW system performance requirements. It only provides a reference set of parameters and their values, considered to be satisfactory for the advanced semiconductor manufacturing needs. In some cases, the values are limited by the feasibility of the available treatment technology or metrology. It is expected that semiconductor company experts will define the performance requirements for the UPW system based on specific manufacturing process sensitivities, with reference to the information provided in this Guide.

3.2 The purity of water generated in water systems differs. These guidelines were developed for properly maintained, state-of-the-art UPW systems as found in high-end semiconductor manufacturing plants and may not reflect the needs of lesser demanding end-users.

3.3 This Guide is not intended to be used to define the criteria needed for selecting process tools.

3.4 This Guide defines parameters that apply to the quality of UPW required in semiconductor processing when proper analytical hookup and tool installation is made.

3.5 This Guide may include suggested values that are at the detection limit of today's available, cost-viable, analytical instrumentation or techniques. UPW system owners, engineers, and technicians are expected to decide whether the benefits of meeting the suggested values outweigh the associated time and costs. The quality of the data measured will depend on which testing method and calibration techniques are used. Laboratory or metrology vendors may be requested to provide additional analytical validation data to confirm detection limits before internal specification values are set.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI C1 — Guide for the Analysis of Liquid Chemicals

SEMI C10 — Guide for the Determination of Method Detection Limits

SEMI C79 — Guide to Evaluate the Efficacy of Sub-15 nm Filters Used in Ultrapure Water (UPW) Distribution Systems

SEMI C93 — Guide for Determining the Quality of Ion Exchange Resin Used in Polish Applications of Ultrapure Water System (Preliminary)

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

4.2 ASTM Standards¹

ASTM D859 — Standard Test Method for Silica in Water

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

ASTM D4517 — Standard Test Method for Low-Level Total Silica in High-Purity Water by Flameless Atomic Absorption Spectroscopy

ASTM D5127 — Standard Guide for Ultra Pure Water Used in the Electronics and Semiconductor Industries

ASTM D5173 — Standard Guide for On-Line Monitoring of Total Organic Carbon in Water by Oxidation and Detection of Resulting Carbon Dioxide

ASTM D5391 — Standard Test Method for Electrical Conductivity and Resistivity of a Flowing High Purity Water Sample

ASTM D5544 — Standard Test Method for On-Line Measurement of Residue After Evaporation of High-Purity Water

ASTM D6317 — Standard Test Method for Low Level Determination of Total Carbon, Inorganic Carbon and Organic Carbon in Water by Ultraviolet, Persulfate Oxidation, and Membrane Conductivity Detection

ASTM D7126 — Standard Test Method for On-Line Colorimetric Measurement of Silica

ASTM F1094 — Standard Test Methods for Microbiological Monitoring of Water Used for Processing Electron and Microelectronic Devices by Direct Pressure Tap Sampling Valve and by the Presterilized Plastic Bag Method

4.3 Other Documents

International Technology Roadmap for Semiconductors (ITRS)²

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

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 <http://www.itrs.net>

5 Terminology

5.1 General terms and acronyms used in this standard are listed and defined in SEMI F61.

5.2 Abbreviations and Acronyms

5.2.1 *LPC* — laser particle counter

5.2.2 *POC* — point of connection

5.2.3 *POD* — point of distribution

5.2.4 *POE* — point of entry

5.2.5 *POM* — point of measurement

5.2.6 *POP* — point of process

5.2.7 *POU* — point of use

5.3 Definitions

5.3.1 *points of measurement (POM)* — of the specified parameters follow commonly accepted terminology in semiconductor industry (UPW ITRS 2015, Table YE1):

5.3.1.1 *point of connection (POC)* — is at Outlet of lateral take off valve.

5.3.1.2 *point of distribution (POD)* — is at Outlet of final filtration in UPW system.

5.3.1.3 *point of entry (POE)* — is at Inlet of wet bench or sub-equipment.

5.3.1.4 *point of process (POP)* — is at Wafer in production.

5.3.1.5 *point of use (POU)* — is at Inlet of wet bench bath, spray nozzle, or connection point to piping, which is also used for other chemicals.

6 Use of the Guidelines

6.1 Supplemental information, including recommendations on how to use this Document, is provided at the end of this Guide. The supplemental information is critical to understanding the intent of this Guide.

6.2 The supplemental information should be considered when making decisions on UPW performance requirements. Any additional data about manufacturing process sensitivities should also be considered when making a final decision about appropriate UPW quality.

7 Units

7.1 Parts per million (ppm) is equivalent to $\mu\text{g/mL}$ or mg/L , where 1 L approximately equals 1 kg.

7.2 Parts per billion (ppb) is equivalent to ng/mL or $\mu\text{g/L}$, where 1 L approximately equals 1 kg.

7.3 Parts per trillion (ppt) is equivalent to pg/mL or ng/L , where 1 L approximately equals 1 kg.

7.4 Micrometer (μ) is a unit of length equal to one millionth of a meter, or one thousandth of a millimeter.

7.5 Colony forming units (CFU) is a measurement of bacteria organisms as referred to in ASTM F1094.

8 Description of Parameter Tests

NOTE 2: SEMI Guides do not require analytical data to support analytical methods, therefore the recommendations of specific analytical methods are only for informational purposes. Alternative methods may also be applicable (see SEMI C1 for analytical validation methodology).

8.1 Resistivity (*megohm-centimeters or $M\Omega\cdot\text{cm}$*)

8.1.1 Resistivity (reciprocal of electrical conductivity) is measured accurately with on-line instrumentation only. 18.18 $M\Omega\cdot\text{cm}$ is the theoretical upper limit for pure water at 25°C.

8.2 Temperature

8.2.1 Temperature stability (K) is defined as a range of the temperature deviation from the facility-specified temperature target. The temperature is measured with an on-line sensor installed inline.

8.2.2 Temperature gradient (K per interval) is defined as the rate of change of temperature within a specific interval of time.

8.3 Nonvolatile Residue (NVR)

8.3.1 NVR or a residue after evaporation (usually expressed in units of ppt) is measured using an online, NVR monitor.

8.4 Total Organic Carbon (TOC) (usually expressed in units of ppb) also known as Total Oxidizable Carbon

8.4.1 Conductivity cells or infrared photometry can be used to measure the carbon dioxide created by the oxidation of organic materials.

8.5 Dissolved oxygen (usually expressed in units of ppb) is measured accurately with only on-line instrumentation.

8.6 Particulate Matter (Particles/L)

8.6.1 Currently, accurate trend analysis requires online methods using particle counters. Since no method is currently available (although several promising methods are under development) for accurately monitoring particles at the target size (see Table 1), no specific recommendation for the metrology is provided (see also additional clarification in § 10).

8.7 Bacteria (CFU/L)

8.7.1 Triplicate samples are cultured based on ASTM F1094.

8.8 Silica

8.8.1 Total Silica (usually expressed in units of ppb) is measured by graphite furnace atomic absorption spectrophotometry (GFAAS), inductively-coupled plasma atomic emission spectroscopy (ICP-AES), or high resolution-inductively coupled plasma-mass spectroscopy (HR-ICP-MS).

8.8.2 Dissolved silica (usually expressed in units of ppb as SiO₂) is measured by heteropoly blue photometry, or by ion chromatography.

8.9 Ions and Metals (usually expressed in units of ppt)

8.9.1 Anions and cations such as ammonium, bromide, chloride, fluoride, nitrate, nitrite, phosphate, and sulfate, can be detected using ion chromatography.

8.9.2 The 21 elements included in this Guide are listed in Table 1.

NOTE 3: Up to 68 elements, including the 21 of interest can be determined by GFAAS, ICP-AES, or ICP-MS.

9 Recommended Ultrapure Water Quality

9.1 Table 1 lists each parameter with its range of performance.

9.2 Table 1 should be considered together with the supplemental information (§ 10).

Table 1 Recommended Ultrapure Water Quality

PARAMETER	Point of Measurement of the Specified Parameters	Typical Linewidth <0.065 MICRONS	
		PERFORMANCE	Limit of Detection (RL) ^{#1}
On-line Particles (#/L)^{#3} , see § 10.7	TBD	TBD	TBD
Silica			
Silica – Total (ppb), § 10.9	Feed to the Final Filters	<0.5	<0.5
Silica – Dissolved or Reactive (ppb as SiO ₂), § 10.9	Feed to the Final Filters	<0.5	<0.5
On-line TOC (ppb) , see § 10.3	POD	<1	0.05