

SEMI F75-1102 (Reapproved 0309) GUIDE FOR QUALITY MONITORING OF ULTRAPURE WATER USED IN SEMICONDUCTOR MANUFACTURING

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1 Purpose

1.1 These guides provide recommendations for facility engineers and other manufacturing and quality professionals who may be responsible for establishing programs to monitor and control the quality of their ultrapure water (UPW) systems through to point-of-use (POU). These guides may be used to help determine the parameters that should be monitored for UPW that is produced, distributed and used throughout the manufacturing facility, and the frequency and location of testing.

NOTE 1: These suggested guides 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. Ultrapure water systems need to be tested and monitored to ensure that the UPW being produced matches the specifications established by the manufacturing process. The purity of the UPW may affect device yield unless a wide range of parameters is closely controlled at the point of distribution (POD). Semiconductor devices are currently being designed with smaller linewidths (<0.13 to $0.18\ \mu\text{m}$) and are more susceptible to low level impurities.

2.2 UPW systems are monitored for continuous performance for desired and achievable levels of quality. Action limits are generally set to determine when system performance data warrants that corrective action is needed. Table 1, Parameters and Range of Performance, in SEMI F63 may be a useful reference for establishing quality levels.

2.3 In more critical processes, the quality of the UPW also needs to be monitored at the POU where the UPW is in contact with the wafer. The quality of the UPW should not be expected to be identical to the quality of the UPW being produced at final filter (FF), which is not subject to conditions within the tool or distribution system.

2.4 These guides logically follow the series of SEMI guides developed for UPW, which include a standard defining the performance of a UPW system, and a standard defining the quality of UPW (see reference section). The 'Schematic of a Typical Ultrapure Water System' in Figure 1 of SEMI F61 may be a useful reference for determining sampling points.

2.5 Guides are provided concerning the frequency and location of sampling for those parameters that are not available from on-line analyzers. Frequency of sampling should be based on the specifications set by manufacturing for the quality of the POD UPW, the number and locations of on-line analyzers, the stability of the incoming feed water to the system, and the historical performance of the UPW system over time.

2.6 These guides may also be used to establish process control criteria for the incoming feedwater, performance of UPW system components and POU rinse baths.

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 These guides have been developed with consideration of various other sources deemed to be relevant for this purpose. However this Guide was not intended to be identical to or consistent with any other industry document or standard.

3.2 Monitoring and testing of recycled or reclaimed water systems are not specifically addressed in these guides. Additional test parameters, such as quantification and identification of organic species in reclaim water, should be added to monitoring programs for reclaim and reuse waters.

3.3 Measuring the purity of UPW can prove challenging. Many online instruments (sodium analyzers, TOC analyzers, silica analyzers, optical particle counters, non-volatile residue analyzers) provide very low limits of detection but may not be capable of being calibrated in the range of detection or may have very poor accuracy at low levels. Online analyzers should primarily be used for trend analysis. Many tests can still be performed more accurately and reproducibly in a laboratory environment but taking batch samples can prove time-consuming and be prone to sampling error.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

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

SEMI F63 — Guide for Ultrapure Water Used in Semiconductor Processing

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

5 Terminology

5.1 Abbreviations and Acronyms

NOTE 2: All other abbreviations and acronyms are defined in the SEMI International Standards: Compilation of Terms available at Web site, <http://www.semi.org/>.

5.1.1 CFU — colony-forming units

5.1.2 DO — dissolved oxygen

5.1.3 EDI — electrodeionization

5.1.4 EDX — energy dispersive x-ray microanalysis

5.1.5 FF — final filter

5.1.6 IC — ion chromatography

5.1.7 NDIR — non-dispersive infrared analysis

5.1.8 OPC — optical particle counters

5.1.9 POD — point of distribution

5.1.10 RO — reverse osmosis

5.1.11 TDS — total dissolved solid

5.1.12 THM — trihalomethanes

6 Units

6.1 Parts per million (ppm) is equivalent to $\mu\text{g/mL}$ or mg/L .

6.2 Parts per billion (ppb) is equivalent to ng/mL or $\mu\text{g/L}$.

6.3 Parts per trillion (ppt) is equivalent to pg/mL or ng/L .

7 Use of the Guides

7.1 Monitoring programs should reflect the age and complexity of the UPW equipment and the needs of the manufacturing process.

7.2 The quality of UPW at the POU may be negatively impacted by, (1) contamination sources within a tool, (2) the design of the tool, (3) the materials of construction of the tool and piping distribution, and (4) contamination loading in the bath from build-up after multiple rinse cycles.

7.3 Sampling methods and contamination control are of paramount importance when attempting to measure the listed parameters at very low levels of sensitivity.

7.4 The quality of the data measured may depend on which testing methods and calibration techniques are used. Consequently, trends observed in the values may be more meaningful than absolute values, especially for certain on-line monitors calibrated for ultrasensitive detection. In addition, online and offline measurements may not correlate depending on the measurement technique and level of sensitivity of the measurement.

8 Tests For Monitoring UPW Production and Distribution

NOTE 3: Since SEMI Guides do not require analytical data or methods to support them, the recommendation of specific analytical methods are only for informational purposes. Alternative methods may also be applicable.

NOTE 4: See Table 1 at the end of this Document for summary of recommended testing frequency and sampling points.

8.1 Resistivity (*megohm-centimeters [mΩ·cm]*)

8.1.1 Resistivity (the inverse of conductivity) is a general measure of ionic activity and is measured by an online meter. The resistivity of UPW should be approximately 18.2 mΩ·cm depending on the resolution of the instrument.

NOTE 5: 18.25 mΩ·cm is the theoretical upper limit for pure water at 25°C.

8.2 Total Oxidizable (Organic) Carbon (TOC) (*ppb*)

8.2.1 Carbon Sources in Water Supplies

8.2.1.1 Incoming feed water contains both inorganic and organic carbon. Inorganic carbon as dissolved carbon dioxide (CO₂), bicarbonate, and carbonate can be present at high ppm levels according to the geology of the water supply. Organic carbon reflects biological input and man-made contaminants such as oils, pesticides, and fertilizers. Ground and well waters normally have significantly lower organic content than surface waters. To remove the majority of organics, most UPW systems employ reverse osmosis; anion exchange resin and ultraviolet (UV) destruction are also employed to remove organics. Some volatile organics, such as trihalomethanes (THM), may be controlled by the use of vacuum degasification. The control of organics is essential for preventing organic fouling and maintaining resin beds at high efficiency. In addition, reduced organic matter will limit the nutrients available for bacteria growth and thus biofilm development. Increasing TOC values at the FF can indicate degradation and/or fouling of system components, contamination from routine operational maintenance, or return contamination from the factory. Changes in the incoming feed water due to seasonal or extreme weather conditions can also cause increases in TOC readings.

8.2.2 Method of TOC Measurement for Source Water

8.2.2.1 There are various methods for measuring TOC, and several TOC analyzers are available. TOC measurement generally involves the oxidation of organic materials by means of temperature, UV radiation, and/or chemicals. The CO₂ produced by these reactions can then be measured by non-dispersive infrared analysis (NDIR) or conductivity (resistivity) differential. The exact method utilized will vary depending on the TOC instrumentation employed and the method may also affect the TOC readings as different methods have different recoveries of various organics. Some instruments will also require the use of a carrier gas such as air or nitrogen, while others measure TOC directly.

8.2.3 Monitoring TOC in the UPW System

8.2.3.1 TOC is a useful test to measure the organic removal effectiveness of the UPW system components including carbon, reverse osmosis (RO), degasification, and ion exchange. Suggested measurement points are city feed, pre and post RO membrane, and FF, with a minimum frequency that reflects possible changes in organics from the feed source or UPW components. After the RO, TOC drops from low ppm levels in the source water to mid ppb range, and to single digit ppb levels after the mixed resin beds and UV TOC reduction units.

8.2.4 Monitoring TOC at the POU

8.2.4.1 TOC may be measured at the POU to determine quality changes from the distribution system and the manufacturing tool. Short wavelength UV (185 nm) is capable of breaking up residual organics into charged organic molecules. TOC which survives to the point of use in a UPW system are typically either 'light' molecules or small fragments of larger molecules such as acetate and formate. While low TOC means that the UPW system is working effectively to eliminate the source water organic load, this test is not an accurate measure of sterility of a UPW system. In addition, TOC levels at POU can also reflect carryover from chemical baths and contaminants in cleanroom air.