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Standard Guide for Ultra-Pure Water Used in the Electronics and Semiconductor Industries[1]

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1. Scope

1.1 This guide provides recommendations for water quality related to electronics and semiconductor-industry manufacturing. Six classifications of water are described, including water for line widths as low as 0.09 micron. In all cases, the recommendations are for water at the point of distribution (POD).

1.2 Water is used for washing and rinsing of semiconductor components during manufacture. Water is also used for cleaning and etching operations, making steam for oxidation of silicon surfaces, preparing photomasks, and depositing luminescent materials. Other applications are in the development and fabrication of solid-state devices, thin-film devices, communication lasers, light-emitting diodes, photo-detectors, printed circuits, memory devices, vacuum-tube devices, or electrolytic devices.

1.3 Users needing water qualities different from those described here should consult other water standards, such as Specification D 1193 and Guide D 5196.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 1129 Terminology Relating to Water
D 1193 Specification for Reagent Water
D 1976 Test Method for Elements in Water by Inductively-Coupled Argon Plasma Atomic Emission Spectroscopy
D 2791 Test Method for On-line Determination of Sodium in Water
D 3919 Practice for Measuring Trace Elements in Water by Graphite Furnace Atomic Absorption Spectrophotometry
D 4191 Test Method for Sodium in Water by Atomic Absorption Spectrophotometry
D 4192 Test Method for Potassium in Water by Atomic Absorption Spectrophotometry
D 4327 Test Method for Anions in Water by Chemically Suppressed Ion Chromatography
D 4453 Practice for Handling of Ultra-Pure Water Samples
D 4517 Test Method for Low-Level Total Silica in High-Purity Water by Flameless Atomic Absorption Spectroscopy
D 5173 Test Method for On-Line Monitoring of Carbon Compounds in Water by Chemical Oxidation, by UV Light Oxidation, by Both, or by High Temperature Combustion Followed by Gas Phase NDIR or by Electrolytic Conductivity
D 5196 Guide for Bio-Applications Grade Water
D 5391 Test Method for Electrical Conductivity and Resistivity of a Flowing High Purity Water Sample
D 5462 Test Method for On-Line Measurement of Low-Level Dissolved Oxygen in Water
D 5542 Test Methods for Trace Anions in High Purity Water by Ion Chromatography
D 5544 Test Method for On-Line Measurement of Residue After Evaporation of High-Purity Water
D 5673 Test Method for Elements in Water by Inductively Coupled Plasma—Mass Spectrometry
D 5996 Test Method for Measuring Anionic Contaminants in High-Purity Water by On-Line Ion Chromatography
D 5997 Test Method for On-Line Monitoring of Total Carbon, Inorganic Carbon in Water by Ultraviolet, Persulfate Oxidation, and Membrane Conductivity Detection
F 1094 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

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide refer to Terminology D 1129.

3.2 *Definitions of Terms Specific to This Standard:*

[1] This guide is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.02 on General Specifications, Technical Resources, and Statistical Methods.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.1 *total bacterial counts*, *n*—total number of cultureable microorganisms present in the named sample, excluding obligate anaerobic organisms, determined in accordance with Test Methods F 1094.

3.2.2 *total organic carbon (TOC)*, *n*—carbon measured after inorganic-carbon response has been eliminated by one of the prescribed ASTM test methods.

4. Significance and Use

4.1 This guide recommends the water quality required for the electronics and microelectronics industries. High-purity water is required to prevent contamination of products during manufacture, since contamination can lead to an unacceptable, low yield of electronic devices.

4.2 The range of water purity is defined in accordance with the manufacturing process. The types of ultra-pure water are defined with respect to device line width. In all cases, the water-quality recommendations apply at the point of distribution.

4.3 The limits on the impurities are related to current contamination specifications and to available analytical methods (either performed in a suitable clean laboratory or by on-line instrumentation). On-line and off-line methods are used in accordance with current industry practice. Concentration of the sample may be required to measure the impurities at the levels indicated in Table 1.

5. Classification

5.1 Six types of electronic-grade water are described in this guide. In all cases, the water-quality recommendations apply at the point of distribution.

5.1.1 *Type E-1*—This water is classified as microelectronic water to be used in the production of devices having line widths between 0.5 and 1.0 µm.

5.1.2 *Type E-1.1*—This water is classified as microelectronic water to be used in the production of devices having line widths between 0.25 and 0.35 µm.

TABLE 1 Requirements for Water at the Point of Distribution in the Electronics and Semiconductor Industries[A]

Parameter	Type E-1	Type E-1.1	Type E-1.2	Type E-2	Type E-3	Type E-4
Linewidth (microns)	1.0–0.5	0.35–0.25	0.18–0.09	5.0–1.0	>5.0	—
Resistivity, 25°C (On-line)	18.1	18.2	18.2	16.5	12	0.5
TOC (µg/L) (on-line for <10 ppb)	5	2	1	50	300	1000
On-line dissolved oxygen (µg/L)	25	10	3	—	—	—
On-Line Residue after evaporation (µg/L)	1	0.5	0.1	—	—	—
On-line particles/L (micron range)						
0.05–0.1		1000	200	—	—	—
0.1–0.2	1000	350	<100	—	—	—
0.2–0.5	500	<100	<10	—	—	—
0.5-1.0	200	<50	<5	—	—	—
1.0	<100	<20	<1	—	—	—
SEM particles/L (micron range)						
0.1–0.2	1000	700	<250	—	—	—
0.2–0.5	500	400	<100	3000	—	—
0.5–1	100	50	<30	—	10 000	—
10	<50	<30	<10	—	—	100 000
Bacteria in CFU/Volume						
100 mL Sample	5	3	1	10	50	100
1 L Sample			10			
Silica – total (µg/L)	5	3	1	10	50	1000
Silica – dissolved (µg/L)	3	1	0.5	—	—	—
Anions and Ammonium by IC (µg/L)						
Ammonium	0.1	0.10	0.05	—	—	—
Bromide	0.1	0.05	0.02	—	—	—
Chloride	0.1	0.05	0.02	1	10	1000
Fluoride	0.1	0.05	0.03	—	—	—
Nitrate	0.1	0.05	0.02	1	5	500
Nitrite	0.1	0.05	0.02	—	—	—
Phosphate	0.1	0.05	0.02	1	5	500
Sulfate	0.1	0.05	0.02	1	5	500
Metals by ICP/MS (µg/L)						
Aluminum	0.05	0.02	0.005	—	—	—
Barium	0.05	0.02	0.001	—	—	—
Boron[B]	0.3	0.1	0.05	—	—	—
Calcium	0.05	0.02	0.002	—	—	—
Chromium	0.05	0.02	0.002	—	—	—
Copper	0.05	0.02	0.002	1	2	500
Iron	0.05	0.02	0.002	—	—	—
Lead	0.05	0.02	0.005	—	—	—
Lithium	0.05	0.02	0.003	—	—	—
Magnesium	0.05	0.02	0.002	—	—	—
Manganese	0.05	0.02	0.002	—	—	—
Nickel	0.05	0.02	0.002	1	2	500
Potassium	0.05	0.02	0.005	2	5	500
Sodium	0.05	0.02	0.005	1	5	1000
Strontium	0.05	0.02	0.001	—	—	—
Zinc	0.05	0.02	0.002	1	5	500

[A] The user should be advised that analytical data often are instrument dependent and technique dependent. Thus, the numbers in Table 1 are only guidelines.
[B] Boron is monitored only as an operational parameter for monitoring the ion-exchange beds.