

SEMI C30-0301

SPECIFICATIONS AND GUIDELINES FOR HYDROGEN PEROXIDE

These specifications and guidelines were technically approved by the Global Process Chemicals Committee and are the direct responsibility of the North American Process Chemicals Committee. Current edition approved by the North American Regional Standards Committee on October 17, 1999. Initially available on SEMI OnLine February 2001; to be published March 2001. This document replaces SEMI C1.9, C7.5, C8.5, C11.4, and C12.4 in their entirety. Originally published in 1978, 1990, 1992, 1994, and 1995 respectively; previously published June 2000.

1 Purpose

1.1 The purpose of this document is to standardize requirements for hydrogen peroxide used in the semiconductor industry and testing procedures to support those standards. Test methods have been shown to give statistically valid results. This document also provides guidelines for grades of hydrogen peroxide for which a need has been identified. In the case of the guidelines, the test methods may not have been statistically validated yet.

2 Scope

2.1 The scope of this document is all grades of hydrogen peroxide used in the semiconductor industry.

2.2 The VLSI grade purity level is typically required by semiconductor devices with geometries of 0.8 – 1.2 microns.

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

3 Limitations

3.1 The specification for VLSI grade hydrogen peroxide is only applicable for materials that remain below 25°C during transport and storage.

4 Referenced Documents

4.1 SEMI Standards

SEMI C1 — Specifications for Reagents

4.2 ASTM Standards¹

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

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

¹ American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555. Website: www.astm.org

5 Terminology

5.1 None.

6 Physical Property (for information only)

Density at 25°C	1.11 g/mL
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7 Requirements

7.1 The requirements for hydrogen peroxide for Grades 1, 2, and 3, VLSI Grade, and Tier C are listed in Table 1.

8 Grade 1 Procedures

NOTE 2: When hydrogen peroxide is added to water, there is no spattering. This happens only when the order of addition is reversed.

NOTE 3: Each laboratory is responsible for verifying the validity of the method within its own operation.

8.1 *Assay* — Accurately weigh about 1 mL of sample in a tared 100 mL volumetric flask, dilute to volume with water, and mix thoroughly. Transfer exactly 20.0 mL of this solution to a 250 mL conical flask, add 20 mL of dilute sulfuric acid (1 + 15), and titrate with standardized 0.1 N (0.02 M) potassium permanganate to a pink color that persists for 15 seconds.

$$\% \text{Assay} = \frac{\text{mL} \times \text{N of KMnO}_4 \times 8.500}{\text{Weight of sample (g)}}$$

8.2 *Color* — Dilute 2.0 mL of platinum-cobalt stock solution (APHA No. 500) to 100 mL with water. Compare this standard (APHA No. 10) with 100 mL of sample in Nessler tubes. View vertically over a white background. The sample must be no darker than the standard.

8.3 *Free Acid* — Dilute 9 mL (10 g) of sample with 90 mL of freshly boiled and cooled carbon dioxide-free water. Add 0.15 mL of methyl red indicator solution and titrate with 0.01 N sodium hydroxide. The volume of sodium hydroxide solution consumed should not be more than 0.6 mL greater than the volume required for a blank test on 90 mL of the water used for dilution.

8.4 TOC

8.4.1 Equipment

8.4.1.1 TOC analyzer capable of analyzing total organic carbon in water.

8.4.1.2 Platinum sheet 1 × 1 inch, heated in a muffle oven at 800°C for 15 minutes.

8.4.2 Special Reagents

8.4.2.1 *Water* — The water used for all of the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127 in regard to TOC analysis.

8.4.2.2 *1000 mg/mL TOC Standard (prepare fresh weekly)* — Weigh accurately 0.2128 g of potassium acid phthalate into a 100 mL volumetric flask, add water, shake to dissolve, dilute to volume, and mix well. Lower standards (prepare fresh daily) can be made by diluting an aliquot of the 1000 mg/mL to the appropriate volume.

8.4.3 *Sample Preparation* — Weigh 50 g of hydrogen peroxide, to the nearest 0.01 g, into a 400 mL beaker. Add the platinum sheet to the sample, cover the beaker with a Teflon watch glass, and allow the reaction to go overnight (12 hours minimum). Transfer the solution to a 50 mL volumetric flask, and dilute with water meeting the criteria for Type E1.1 in ASTM D5127 to a final volume of 50 mL.

8.4.4 *Analysis* — Using the prepared solutions, analyze TOC by the total organic carbon analyzer after the instrument has been calibrated with 0, 4, 10, and 20 µg/mL of TOC standards.

8.5 *Chloride* — Dilute 4.5 mL (5 g) of sample with 15 mL of water. Filter, if necessary, through a chloride-free filter. Add 1 mL of nitric acid and 1 mL of silver nitrate reagent solution. Any turbidity produced should be no greater than that produced when 0.01 mg of chloride ion (Cl) is treated as the sample.

8.6 *Sulfate* — To 9 mL (10 g) of sample, add 10 mL of sodium carbonate reagent solution and evaporate to dryness in a hood. Dissolve the residue in 10 mL of water and 1 mL of dilute hydrochloric acid (1 + 19); filter if necessary. Add 1 mL of barium chloride reagent solution, mix, and allow to stand for 10 minutes. Any turbidity developed should be no greater than that produced when 0.05 mg of sulfate ion (SO₄) is treated as the sample.

8.7 *Phosphate* — Evaporate 4.5 mL (5 g) of sample to dryness on the steam bath and dissolve the residue in 25 mL of 0.5 N sulfuric acid. Add 1 mL of ammonium molybdate reagent solution and 1 mL of p-(methylamino)phenol sulfate reagent solution. Allow to

stand for 2 hours at room temperature. Any blue color should not exceed that produced in a standard of equal volume containing 0.01 mg of phosphate ion (PO₄) and the quantities of reagents used in the sample.

8.8 *Arsenic and Antimony (as As)* — To 180 mL (200 g) of sample in a 400 mL beaker, add 5 mL of sulfuric acid and evaporate to dense fumes of sulfur trioxide in a hood. Cool, cautiously add 10 mL of water, and again evaporate to dense fumes of sulfur trioxide. Cool, and cautiously wash into a generator flask with water to make a volume of 35 mL. Proceed as described in General Method for Arsenic (and Antimony) under SEMI C1, Section 3.4.5, starting with the first sentence which begins: "Swirl the flask...." Any red color in the silver diethyldithiocarbamate solution from the sample should be no greater than that of the standard containing 0.002 mg of arsenic (As).

8.9 *Trace Metal Analysis* — The following method has given satisfactory results in determining trace metal impurities at the value specified for each of the following trace metals: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), gold (Au), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), sodium (Na), tin (Sn), titanium (Ti), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate recovery between 75–125% of a known sample spike for half of the value of each specified element.

8.9.1 Special Reagents

8.9.1.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for ultra low metal ion content.

8.9.1.2 *Hydrochloric Acid, Ultra Pure* — Use hydrochloric acid specified for ultra low metal ion content.

8.9.2 Sample Preparation

8.9.2.1 *Sodium and Potassium* — In a clean environment, place 10.0 mL of water in a clean platinum crucible. Slowly add 5.0 mL of hydrogen peroxide. Allow to stand at room temperature until the effervescence ceases (approximately 20 minutes). Swirl. If swirling does not produce any more bubbles, proceed with analysis. If bubbles remain, allow to stand for 5 minutes and repeat the swirl until no bubbles are produced. Run a water blank.

8.9.2.2 *Other Elements* — Two separate samples of hydrogen peroxide are acidified to 2% with hydrochloric acid for the analysis of tin and to 2% with nitric acid for the analysis of (specified elements). Standard additions of tin to the matrix acidified with hydrochloric acid and standard additions of other specified elements to the matrix acidified with nitric acid are added to determine the response for each

element in the peroxide matrix. Aqueous acidified standards for tin in 2% hydrochloric acid and other specified elements in 2% nitric acid should be used to determine instrument responses.

8.9.3 Analysis

8.9.3.1 Using the solution from Section 8.9.2.1, analyze for specified group 1 elements by flame atomic absorption spectroscopy. All other elements analyzed by plasma emission spectroscopy.

9 Grade 2 Procedures

NOTE 4: Each laboratory is responsible for verifying the validity of the method within its own operation.

9.1 Non-Metal Impurities

9.1.1 See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Free Acid

9.2 TOC

9.2.1 Equipment

9.2.1.1 TOC analyzer capable of analyzing total organic carbon in water.

9.2.1.2 Platinum sheet 1 × 1 inch, heated in a muffle oven at 800°C for 15 minutes.

9.2.2 Special Reagents

9.2.2.1 *Water* — The water used for all of the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127 in regard to TOC analysis.

9.2.2.2 *1000 mg/mL TOC Standard (prepare fresh weekly)* — Weigh accurately 0.2128 g of potassium acid phthalate into a 100 mL volumetric flask, add water, shake to dissolve, dilute to volume, and mix well. Lower standards (prepare fresh daily) can be made by diluting an aliquot of the 1000 mg/mL to the appropriate volume.

9.2.3 Sample Preparation

9.2.3.1 Weigh 50 g of hydrogen peroxide, to the nearest 0.01 g, into a 400 mL beaker. Add the platinum sheet to the sample, cover the beaker with a Teflon watch glass, and allow the reaction to go overnight (12 hours minimum). Transfer the solution to a 50 mL volumetric flask, dilute with water, meeting the criteria for Type E1.1 in ASTM D5127, to a final volume of 50 mL.

9.2.4 Analysis

9.2.4.1 Using the prepared solutions, analyze TOC by the total organic carbon analyzer after the instrument has been calibrated with 0, 4, 10, and 20 µg/mL of TOC standards.

9.3 Anions

9.3.1 The following method has given satisfactory results in determining anion impurities at the values specified for each of the following anions: chloride (Cl), phosphate (PO₄), nitrate (NO₃), and sulfate (SO₄). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75 - 125% of a known sample spike for half of the value of each specified anion.

9.3.2 Special Reagents

9.3.2.1 *Eluent* — Prepare an eluent solution that is 2.2 mM sodium carbonate (Na₂CO₃) and 0.75 mM sodium bicarbonate (NaHCO₃) in deionized water meeting the criteria for Type E1.1 in ASTM D5127. Store eluent under a helium gas blanket.

9.3.2.2 *Regenerant* — Prepare a 0.025 N sulfuric acid (H₂SO₄) in deionized water meeting the criteria for Type E1.1 in ASTM D5127.

9.3.2.3 *Potassium Carbonate Solution* — Prepare a solution containing 500 mg of reagent grade potassium carbonate (K₂CO₃) into 100 mL of water meeting the criteria for Type E1.1 in ASTM D5127.

9.3.3 Sample Preparation

9.3.3.1 In a clean environment, place 40 g of sample into a clean beaker. Add 1 mL of a 5 mg/mL potassium carbonate solution and evaporate carefully (at 100°C) to a volume of 0.5 mL. Dilute with water meeting the criteria for Type E1.1 in ASTM D5127 to a final volume of 20 mL.

NOTE 5: For safety purposes, a decomposition aid such as a platinum strip should be used.

9.3.4 Analysis

9.3.4.1 Using the prepared solutions and blanks, analyze chloride, nitrate, phosphate, and sulfate by ion chromatography. Run a reagent blank. Samples and reagent blanks should be prepared and analyzed in triplicate.

9.3.4.2 *Columns* — Precolumn should be AG4-A (Dionex) or equivalent and Separation column should be AS4-A (Dionex) or equivalent.

9.4 Trace Metals Analysis

9.4.1 The following method has given satisfactory results in determining metal ion impurities at the values

specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), bismuth (Bi), boron (B), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gallium (Ga), germanium (Ge), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), niobium (Nb), potassium (K), silver (Ag), sodium (Na), strontium (Sr), tantalum (Ta), tin (Sn), titanium (Ti), vanadium (V), zinc (Zn), and zirconium (Zr). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75 - 125% of a known sample spike for half of the value of each specified element.

9.4.2 Special Reagents

9.4.2.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for low metal ion content.

9.4.2.2 *1% Nitric Acid Solution* — Dilute 10 mL of ultrapure nitric acid to 1 L of water meeting the criteria for Type E1.1 in ASTM D5127.

9.4.2.3 *Water* — The water used for all the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

9.4.2.4 *Indium Internal Standard* — Make up the indium internal standard solution to a concentration of 20 µg/mL (ppm) from the appropriate concentrated indium standard solution.

9.4.3 Sample Preparation

9.4.3.1 In a clean environment, place 20 g of sample in a tared FEP bottle, add 20 µL of the indium internal standard.

9.4.4 Analysis

9.4.4.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium, and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up with the 1% nitric acid solution and the indium internal standard such that the final concentration is 20 ng/g of indium. Run a reagent blank.

10 Grade 3 Procedures

NOTE 6: The analytical procedures associated with this standard are not intended to be the only acceptable procedure or the best procedure available. The published procedures have been found to meet the required criteria for acceptance of an analytical procedure. Alternate procedures may be used if they meet the same criteria as the published procedures.

NOTE 7: Each laboratory is responsible for verifying the validity of each method within its own operation.

10.1 Non-Metal Impurities

10.1.1 See Section 8, which contains procedures for the following tests:

Assay

Color (APHA)

Free Acid

10.2 TOC

10.2.1 Equipment

10.2.1.1 TOC analyzer capable of analyzing total organic carbon in water.

10.2.1.2 Platinum sheet 1 × 1 inch, heated in a muffle oven at 800°C for 15 minutes.

10.2.2 Special Reagents

10.2.2.1 *Water* — The water used for all of the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127 in regard to TOC analysis.

10.2.2.2 *1000 µg/mL TOC Standard (prepare fresh weekly)* — Weigh accurately 0.2128 g of potassium acid phthalate into a 100 mL volumetric flask, add water, shake to dissolve, dilute to volume, and mix well. Lower standards (prepare fresh daily) can be made by diluting an aliquot of the 1000 µg/mL to the appropriate volume.

10.2.3 Sample Preparation

10.2.3.1 Weigh 50 g of hydrogen peroxide, to the nearest 0.01 g, into a 400 mL beaker. Add the platinum sheet to the sample, cover the beaker with a Teflon watch glass, and allow the reaction to go overnight (12 hours minimum). Transfer the solution to a 50 mL volumetric flask, dilute with water, meeting the criteria for Type E1.1 in ASTM D5127 to a final volume of 50 mL.

10.2.4 Analysis

10.2.4.1 Using the prepared solutions, analyze TOC by the total organic carbon analyzer after the instrument has been calibrated with 0, 4, 10, and 20 µg/mL of TOC standards.

10.3 Anions

10.3.1 The following method has given satisfactory results in determining anion impurities at the values specified for each of the following anions: chloride (Cl), phosphate (PO₄), nitrate (NO₃), and sulfate (SO₄). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75 - 125% of a known sample spike for half of the value of each specified anion.

10.3.2 *Special Reagents*

10.3.2.1 *Eluent* — Prepare an eluent solution that is 2.2 mM sodium carbonate (Na_2CO_3) and 0.75 mM sodium bicarbonate (NaHCO_3) in deionized water meeting the criteria for Type E1.1 in ASTM D5127. Store eluent under a helium gas blanket.

10.3.2.2 *Regenerant* — Prepare a 0.025 N sulfuric acid (H_2SO_4) in deionized water meeting the criteria for Type E1.1 in ASTM D5127.

10.3.2.3 *Potassium Carbonate Solution* — Prepare a solution containing 500 mg of reagent grade potassium carbonate (K_2CO_3) in 100 mL of water meeting the criteria for Type E1.1 in ASTM D5127.

10.3.3 *Sample Preparation*

10.3.3.1 In a clean environment, place 40 g of sample into a clean beaker. Add 1 mL of a 5 mg/mL potassium carbonate solution and evaporate carefully (at 100°C) to a volume of 0.5 mL. Dilute with water meeting the criteria for Type E1.1 in ASTM D5127 to a final volume of 20 mL.

NOTE 8: For safety purposes, a decomposition aid such as a platinum strip should be used.

10.3.4 *Analysis*

10.3.4.1 Using the prepared solutions and blanks, analyze chloride, nitrate, phosphate, and sulfate by ion chromatography. Run a reagent blank. Samples and reagent blanks should be prepared and analyzed in triplicate.

10.3.4.2 *Columns* — Precolumn should be AG4-A (Dionex) or equivalent, and separation column should be AS4-A (Dionex) or equivalent.

10.4 *Trace Metals Analysis*

10.4.1 The following method has given satisfactory results in determining metal ion impurities at the values specified for each of the following metals: aluminum (Al), antimony (Sb), arsenic (As), boron (B), cadmium (Cd), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), potassium (K), silver (Ag), sodium (Na), strontium (Sr), tin (Sn), titanium (Ti), vanadium (V), and zinc (Zn). Alternate methods may be used as long as appropriate studies demonstrate a recovery between 75–125% of a known sample spike for half of the value of each specified element.

10.4.2 *Special Reagents*

10.4.2.1 *Nitric Acid, Ultra Pure* — Use nitric acid specified for low metal ion content.

10.4.2.2 *1% Nitric Acid Solution* — Dilute 10 mL of ultrapure nitric acid to 1 L of water meeting the criteria for Type E1.1 in ASTM D5127.

10.4.2.3 *Water* — The water used for all the dilution, calibration, and standards should meet, at a minimum, the criteria for Type E1.1 in ASTM D5127 in regard to cation analysis.

10.4.2.4 *Indium Internal Standard* — Make up the indium internal standard solution to a concentration of 20 $\mu\text{g/mL}$ (ppm) from the appropriate concentrated indium standard solution.

10.4.3 *Sample Preparation*

10.4.3.1 In a clean environment, place 20 g of sample into a tared FEP bottle and add 20 μL of the indium internal standard.

10.4.4 *Analysis*

10.4.4.1 Using the prepared solutions and blanks, analyze sodium, potassium, calcium, and iron by graphite furnace atomic absorption (GFAA) and the remaining elements by inductively coupled plasma mass spectrometry (ICP/MS). For calibration, the standards are made up with the 1% nitric acid solution and the indium internal standard such that the final concentration is 20 ng/g of indium. Run a reagent blank.

11 **Grade 4 Procedures**

11.1 This section does not apply to this chemical.

12 **Grade 5 Procedures**

12.1 This section does not apply to this chemical.

13 **VLSI Grade Procedures**

13.1 Specific procedures for this grade do not exist. Refer to Sections 8 and 9 for available procedures.

14 **Tier A Procedures**

14.1 This section does not apply to this chemical.

15 **Tier B Procedures**

15.1 This section does not apply to this chemical.

16 **Tier C Procedures**

16.1 Standardized test methods are being developed for all parameters at the purity levels indicated. Until standardized test methods are published, test methodology shall be determined by user and producer. The Process Chemicals Committee considers a test method to be valid if there is a documented recovery

study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

Process Chemicals Committee considers a test method to be valid if there is a documented recovery study showing a recovery of 75–125%. Recovery is for a known sample spike at 50% of the specified level.

17 Tier D Procedures

17.1 Standardized test methods are being developed for all parameters at the purity levels indicated. The

Table 1 Impurity Limits and Other Requirements for Hydrogen Peroxide

Previous SEMI Reference #	C1.9-96	C7.5-95	C8.5-0298	C11.4-94	C12.4-95	--
	Grade 1	Grade 2	Grade 3	VLSI Grade	Tier C	Tier D
	(Specification)	(Specification)	(Specification)	(Guideline)	(Guideline)	(Guideline)
Assay (H ₂ O ₂)	30.0–32.0%	30.0–32.0%	30.0–32.0%	30.0–32.0% or 34.0–36.0%	30.0–32.0%	30.0–32.0%
Color (APHA)	10 max	10 max	10 max	10 max	--	--
Residue after Evaporation	--	--	--	20 ppm max	--	--
Chloride (Cl)	2 ppm max	200 ppb max	200 ppb max	0.5 ppm max	30 ppb max	30 ppb max
Nitrate (NO ₃)	--	400 ppb max	400 ppb max	--	30 ppb max	30 ppb max
Phosphate (PO ₄)	2 ppm max	200 ppb max	200 ppb max	1 ppm max	30 ppb max	30 ppb max
Sulfate (SO ₄)	5 ppm max	200 ppb max	200 ppb max	1 ppm max	30 ppb max	30 ppb max
Total Nitrogen (N)	--	--	--	2 ppm max	--	--
Total Organic Carbon (TOC)	20 ppm max	20,000 ppb max	20 ppm max	--	10,000 ppb max	10 ppm max
Free Acid	0.6 µeq/g max	0.6 µeq/g max	0.6 µeq/g max	0.6 µeq/g max	0.6 µeq/g max	--
Aluminum (Al)	1 ppm max	10 ppb max	1 ppb max	0.2 ppm max	100 ppt max	10 ppt max
Ammonium (NH ₄)	--	--	--	2 ppm max	--	--
Antimony (Sb)	--	5 ppb max	1 ppb max	--	100 ppt max	10 ppt max
Arsenic (As)	--	5 ppb max	1 ppb max	--	100 ppt max	10 ppt max
Arsenic and Antimony (as As)	0.01 ppm max	--	--	0.01 ppm max	--	--
Barium (Ba)	--	10 ppb max	--	0.05 ppm max	--	10 ppt max
Beryllium (Be)	--	10 ppb max	--	0.01 ppm max	--	--
Bismuth (Bi)	--	10 ppb max	--	0.02 ppm max	--	--
Boron (B)	0.1 ppm max	10 ppb max	1 ppb max	0.02 ppm max	100 ppt max	10 ppt max
Cadmium (Cd)	--	10 ppb max	1 ppb max	0.01 ppm max	--	--
Calcium (Ca)	0.2 ppm max	10 ppb max	1 ppb max	0.05 ppm max	100 ppt max	10 ppt max
Chromium (Cr)	0.05 ppm max	10 ppb max	1 ppb max	0.01 ppm max	100 ppt max	10 ppt max
Cobalt (Co)	--	10 ppb max	1 ppb max	0.01 ppm max	--	10 ppt max
Copper (Cu)	0.05 ppm max	10 ppb max	1 ppb max	0.01 ppm max	100 ppt max	10 ppt max
Gallium (Ga)	--	10 ppb max	--	0.02 ppm max	--	--
Germanium (Ge)	--	10 ppb max	--	0.05 ppm max	--	--
Gold (Au)	0.3 ppm max	10 ppb max	10 ppb max	0.02 ppm max	100 ppt max	--
Indium (In)	--	--	--	0.02 ppm max	--	--
Iron (Fe)	0.1 ppm max	10 ppb max	1 ppb max	0.05 ppm max	100 ppt max	10 ppt max
Lead (Pb)	0.3 ppm max	10 ppb max	1 ppb max	0.01 ppm max	100 ppt max	10 ppt max
Lithium (Li)	--	10 ppb max	1 ppb max	0.01 ppm max	--	10 ppt max
Magnesium (Mg)	0.1 ppm max	10 ppb max	1 ppb max	0.05 ppm max	100 ppt max	10 ppt max
Manganese (Mn)	0.05 ppm max	10 ppb max	1 ppb max	0.01 ppm max	100 ppt max	10 ppt max
Molybdenum (Mo)	--	10 ppb max	1 ppb max	0.01 ppm max	--	--
Nickel (Ni)	0.05 ppm max	10 ppb max	1 ppb max	0.01 ppm max	100 ppt max	10 ppt max
Niobium (Nb)	--	10 ppb max	--	--	--	--

Previous SEMI Reference #	C1.9-96	C7.5-95	C8.5-0298	C11.4-94	C12.4-95	--
	Grade 1	Grade 2	Grade 3	VLSI Grade	Tier C	Tier D
	(Specification)	(Specification)	(Specification)	(Guideline)	(Guideline)	(Guideline)
Platinum (Pt)	--	--	--	0.02 ppm max	--	--
Potassium (K)	1 ppm max	10 ppb max	1 ppb max	0.05 ppm max	100 ppt max	10 ppt max
Silver (Ag)	--	10 ppb max	1 ppb max	0.02 ppm max	--	--
Sodium (Na)	1 ppm max	10 ppb max	1 ppb max	0.05 ppm max	100 ppt max	10 ppt max
Strontium (Sr)	--	10 ppb max	1 ppb max	0.01 ppm max	--	--
Tantalum (Ta)	--	10 ppb max	--	--	--	--
Thallium (Tl)	--	10 ppb max	--	0.02 ppm max	--	--
Tin (Sn)	1 ppm max	10 ppb max	1 ppb max	0.02 ppm max	100 ppt max	10 ppt max
Titanium (Ti)	0.3 ppm max	10 ppb max	1 ppb max	0.01 ppm max	100 ppt max	10 ppt max
Vanadium (V)	--	10 ppb max	1 ppb max	0.01 ppm max	--	10 ppt max
Zinc (Zn)	0.1 ppm max	10 ppb max	1 ppb max	0.05 ppm max	50 ppt max	10 ppt max
Zirconium (Zr)	--	10 ppb max	--	0.01 ppm max	--	--
Particles in bottles (size, #/mL)	≥ 1.0 μm, 25 max	≥ 0.5 μm, 25 max	≥ 0.5 μm, 25 max (see NOTE 1)	≥ 0.5 μm, 250 max	≥ 0.2 μm, TBD	(See NOTE 2.)

NOTE 1: Care must be taken in analyzing particles because of the potential formation of microbubbles.

NOTE 2: Due to the limitations of current particle counters, particle size and number are to be agreed upon between supplier and user. See SEMI C1, Section 3.9 for particle counting methodology.

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

The user's attention is called to the possibility that compliance with this standard may require use of copyrighted material or of an invention covered by patent rights. By publication of this standard, SEMI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.