SEMI MF1239-0305 (Reapproved 0211)
TEST METHOD FOR OXYGEN PRECIPITATION CHARACTERISTICS OF SILICON WAFERS BY MEASUREMENT OF INTERSTITIAL OXYGEN REDUCTION

This Standard was technically approved by the Silicon Wafer Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on December 21, 2010. Available at www.semiviews.org and www.semi.org in February 2011; originally published by ASTM International as ASTM F1239-89; previously published March 2005.

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1 Purpose

1.1 Oxide precipitates in the bulk of a silicon wafer can act as gettering sites for contamination that may be introduced during manufacture of circuits and devices. This contamination (usually metallic impurities), if not gettered, can reduce device manufacturing yields and degrade device or circuit performance. Thus, the oxygen precipitation characteristics of the silicon wafer can significantly affect both yields and performance.

1.2 Although interstitial oxygen concentration is an important factor in affecting the amount of oxygen precipitation that occurs in silicon during a specific thermal cycle, the presence of other impurities such as carbon or nitrogen, and differences in dopant type and density, thermal history, or defect properties of the crystal can also affect the precipitation characteristics. Thus, it is frequently necessary to choose particular material properties and preparation techniques to obtain the desired precipitation characteristics for a particular application.

1.3 This Test Method may be used to compare the oxygen reduction of two or more groups of silicon wafers. This Test Method is based on thermal cycles that simulate certain common device processing cycles.

1.3.1 *Cycle A* — A one-step precipitation cycle, provides an indication of the native nucleation sites present in the as-received wafers.

1.3.2 *Cycle B* — A two-step nucleation-precipitation cycle, simulates the precipitation that occurs in normal *n*-MOS device processing.

1.4 These test methods may be used to compare qualitatively the precipitation characteristics of two or more groups of wafers.

1.5 These test methods may also be used to determine the uniformity of oxygen reduction across a wafer (in conjunction with SEMI MF951) or from wafer to wafer within a lot.

2 Scope

2.1 These test methods cover complementary procedures for testing the oxygen precipitation characteristics of silicon wafers. It is assumed that the precipitation characteristics are related to the amount of interstitial oxygen lost during specified thermal cycles.

2.2 These test methods may be applied to any *n*- or *p*-type Czochralski silicon wafers of any orientation whose thickness, resistivity, and surface finish are such as to permit the oxygen concentration to be determined by infrared absorption and whose oxygen concentration is such as to produce measurable oxygen loss.

2.3 These test methods are not suitable for determining the width or characteristics of a ‘denuded zone’, a region near the surface of a wafer that is essentially free of oxide precipitates.

2.4 Because these test methods are destructive, suitable sampling techniques must be employed.

2.5 Determination of material performance in actual device fabrication situations is beyond the scope of these methods. However, by comparing the results of these tests with actual device yields and performance, criteria for selection of specific material characteristics may be established.

2.6 The values stated in SI units are regarded as standard.

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3 Limitations

3.1 All factors that affect the infrared absorption measurement (including differences in back surface condition, instrumental characteristics, and wafer resistivity) may cause errors in the determination of oxygen reduction.

3.2 If significant quantities of oxygen are out-diffused during the thermal cycles, the measured oxygen reduction may not be representative of the amount of oxygen precipitation.

3.3 If precipitate size varies from sample to sample, the variations in measured oxygen reduction may not be representative of variations in the number of oxide precipitates that are formed.

3.4 The specified thermal cycles may or may not provide adequate simulation of the cycles used in a particular device processing sequence. The results obtained in these test methods can serve as predictors of those expected in actual device processing only to the extent that the simulation is representative of the device process.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI C28 — Specifications for Hydrofluoric Acid

SEMI C29 — Specifications and Guide for 4.9% Hydrofluoric Acid 10:1 v/v

SEMI C54 — Specifications and Guidelines for Oxygen

SEMI C59 — Specifications and Guidelines for Nitrogen

SEMI M59 — Terminology for Silicon Technology

SEMI MF951 — Test Method for Determination of Radial Interstitial Oxygen Variation Silicon Wafers

SEMI MF1188 — Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption with Short Baseline

SEMI MF1619 — Test Method for Measurement of Interstitial Oxygen Content of Silicon Wafers by Infrared Absorption Spectroscopy with *p*-Polarized Radiation Incident at the Brewster Angle

4.2 *ASTM Standards*[1]

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

4.3 *DIN Standards*[2]

DIN 50438-1 — Determination of Impurity Content in Silicon by Infrared Absorption: Oxygen

4.4 *JEITA Standards*[3]

JEITA EM-3504 — Standard Test Method for Interstitial Atomic Oxygen Content of Silicon by Infrared Absorption

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

5 Terminology

5.1 For definitions of terms relating to silicon technology, refer to SEMI M59.

[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] Deutsches Institut für Normung e.V., Available from Beuth Verlag GmbH, Burggrafenstrasse 6, D-10787 Berlin, Germany; Telephone: +49.30.2601.0; Fax: +49.30.2601.1260; http://www.din.de

[3] Japan Electronics and Information Technology Industries Association, Ote Center Building, 1-1-3, Otemachi, Chiyoda-ku, Tokyo 100-0004, Japan; http://www.jeita.or.jp

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6 Summary of Test Method

6.1 A representative sample is selected from each group of wafers to be tested.

6.2 The initial value of interstitial oxygen concentration is measured by the infrared absorption method at the desired points on each wafer.

6.3 The wafers are passed through one of two simulation thermal cycles. Cycle A consists solely of a precipitation step. Cycle B consists of a nucleation step followed by a precipitation step.

6.4 After the thermal cycle, the oxide film is stripped and the final value of oxygen concentration is measured at the same points on each wafer using the same technique and instrumentation as was used to determine the initial value.

6.5 The oxygen reduction is determined for each wafer (or for each point on each wafer) tested as the difference between the initial and final values.

6.6 If all samples have the same initial oxygen concentration (within a narrow range), the average oxygen reduction for each test condition (such as, group or position on wafer) is computed, and the appropriate comparisons made.

6.7 If the samples have initial oxygen concentrations that cover a relatively wide range, a plot of oxygen reduction against initial oxygen concentration is made for each group or position. Again appropriate comparisons can be made.

7 Apparatus

7.1 *Infrared Absorption Spectrophotometer* — As specified in SEMI MF1188 or DIN 50438-1.

7.2 *Resistance Heated Tube Furnace* — Capable of providing temperatures in the range from 750°C to 1050°C to ±2°C over the length required to contain the load of wafers to be tested. The furnace shall be fitted with the following:

7.2.1 *Gas Manifold* — That allows dry oxygen and nitrogen to be mixed at the required ratios and flows (see Table1);

Table 1 Thermal Cycle Tests for Oxygen Precipitation in Silicon

Parameter	*Value*
Test A	1050°C for 16 hours
Test B	750°C for 4 hours, followed by 1050°C for 16 hours
Furnace Ambient	Nitrogen plus 5% dry oxygen
Gas Flow Rate	4.2 ± 0.2 L/min[#1]
Push/Pull Temperature	750°C
Push/Pull Rate	25 cm/min.
Ramp Up Rate	10°C/min.
Ramp Down Rate	5°C/min.

#1 For 155 mm diameter tube; for other diameters flow rate should be proportional to the cross sectional area of the tube.

7.2.2 *Quartz, Polysilicon, or Silicon Carbide Tube* — Of diameter appropriate for the wafers to be tested to isolate the wafers from external contamination;

7.2.3 *Quartz Boats* — To hold the wafers during processing;

7.2.4 *Loader* — To allow controlled insertion of the quartz boat into the hot zone, (see Table 1); and

7.2.5 *Laminar Flow Load Station* — To permit loading of the wafers without adding contamination to the surfaces.

7.3 Facilities for processing wafers through chem-mechanical polishing, or bright acid etching to provide smooth, flat surfaces.

7.4 Facilities for dipping the wafers in hydrofluoric acid prior to the oxygen determination in order to remove the surface oxide film grown during thermal cycling. Suitable protective clothing, acid disposal facilities, and ventilation shall be provided.

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