

SEMI MF1528-0413 (Reapproved 1018) TEST METHOD FOR MEASURING BORON CONTAMINATION IN HEAVILY DOPED *n*-TYPE SILICON SUBSTRATES BY SECONDARY ION MASS SPECTROMETRY

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 August 17, 2018. Available at www.semiviews.org and www.semi.org in October 2018; originally published by ASTM International as F1528-94; previously published April 2013.

1 Purpose

- 1.1 Frequently it is essential to control the boron level in heavily-doped *n*-type substrates used to make epitaxial wafers because the boron contamination can result in autodoping at the epitaxial silicon-substrate interface.
- 1.2 SIMS can measure the boron contamination in heavily-doped *n*-type substrates.
- 1.3 This Test Method can be used for process control, research and development, and materials acceptance purposes.

2 Scope

- 2.1 This Test Method covers the determination of total trace boron contamination in the bulk of single crystal, heavily doped *n*-type silicon substrates using secondary ion mass spectrometry (SIMS).
- 2.2 This Test Method can be used for silicon in which the dopant concentrations are less than 0.2% (1×10^{20} atoms/cm³) for antimony, arsenic or phosphorus doping. This Test Method is especially applicable for silicon where boron is an unintentional *p*-type contaminant at trace levels ($<5 \times 10^{14}$ atoms/cm³).
- 2.3 This Test Method can be used for silicon in which the boron contamination is greater than two times the SIMS detection limits that is approximately between 5×10^{12} atoms/cm³ and 5×10^{13} atoms/cm³ depending upon the instrumentation type.
- 2.4 In principle, different sample surfaces can be used, but the precision estimate was taken from data on polished etched surfaces.

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 Boron adsorbed on the surface can interfere with the boron measurement.
- 3.2 Boron adsorbed from the SIMS instrument chamber to the surface can interfere with the boron measurement.
- 3.3 The specimen surface must be flat in the specimen holder windows so that the inclination of the specimen surface with respect to the ion collection optics is constant from specimen-to-specimen. Otherwise, the accuracy and precision can be degraded.
- 3.4 The accuracy and precision of the measurement degrade significantly as the roughness of the specimen surface increases. This degradation can be avoided by using polished etched surfaces.
- 3.5 Variability of boron in the calibration standards can limit the measurement precision.
- 3.6 Bias in the assigned boron concentration of the calibration standard can introduce bias into the SIMS measured boron.

4 Referenced Standards and Documents

- 4.1 *SEMI Standards and Safety Guidelines*

SEMI M59 — Terminology for Silicon Technology

4.2 *ASTM Standard*¹

ASTM E122 — Standard Practice for Choice of Sample Size to Estimate a Measure of Quality of a Lot or Process

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

5 Terminology

5.1 General terms, acronyms, and symbols associated with silicon technology and used in this Standard are listed and defined in SEMI M59.

6 Summary of Test Method

6.1 SIMS is utilized to determine the bulk contamination of boron in single crystal, heavily doped *n*-type silicon substrates.

6.1.1 Specimens of single crystal silicon (one silicon specimen with very low boron concentration, such as a high resistivity *n*-type float-zone silicon specimen, to be used as an instrumental BLANK; one calibration specimen made of a bulk-doped boron silicon wafer; and the test specimens) are loaded into a sample holder.

6.1.2 An oxygen primary ion beam is used to bombard each specimen.

6.1.3 The positive secondary ions are mass analyzed.

6.1.4 The BLANK silicon sample is sputtered to determine instrumental background.

6.1.5 The samples are then analyzed for boron and silicon in a sequential manner throughout the holder.

6.1.6 The ratio of the measured boron and silicon secondary ion intensities (B^+/S^+) is calculated for each specimen.

6.1.7 The (B^+/Si^+) ratios of the test specimens are then converted to boron concentrations by linear scaling from the (B^+/Si^+) ratio of the calibration specimen that has a known boron concentration.

6.1.8 No crater measurement is required.

7 Apparatus

7.1 *Magnetic Sector SIMS Instrument* — Equipped with an oxygen primary ion source, electron multiplier detector, and Faraday cup detector or Daley detector capable of measuring positive secondary ions. The SIMS instrument should be adequately prepared (i.e., baked) so as to provide the lowest possible instrumental background.

7.2 *Liquid Nitrogen or Liquid Helium Cooled Cryopanel* — To surround the test specimen holder in the analysis chamber if the analysis chamber vacuum is 10^{-8} torr or higher. For instruments with vacuum less than 10^{-8} torr the cooling is not required.

7.3 *Test Specimen Holder* — To keep the specimen(s) analysis surface planar and perpendicular to the several kV extraction field, depending on the instrument type.

8 Sampling

8.1 Since this procedure is destructive in nature, a sampling procedure must be used to evaluate the characteristics of a group of silicon wafers.

8.1.1 No general sampling procedure is included as part of this Test Method, because the most suitable sampling plan varies considerably depending upon individual conditions. See ASTM E122 for suggested choices of sampling plans.

8.1.2 For referee purposes, a sampling plan shall be agreed upon between the parties to the test before conducting the test.

9 Specimen Requirements

9.1 Sample specimens must be flat and smooth on the side used for analysis. The surface shall have a polish etch surface or better (i.e., chem-mechanically polished).

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