

SEMI M90-0821

TEST METHOD FOR BULK MICRO DEFECT DENSITY AND DENUDED ZONE WIDTH IN ANNEALED SILICON WAFERS BY OPTICAL MICROSCOPY AFTER PREFERENTIAL ETCHING

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NOTICE: Paragraphs entitled ‘NOTE:’ are not an official part of this Standard or Safety Guideline and are not intended to modify or supersede the official Standard or Safety Guideline. These have been supplied by the global technical committee to enhance the usage of the Standard or Safety Guideline.

NOTICE: The section symbol (§) is used to reference a numbered section, paragraph, or header and all subordinate paragraphs, headers, and embedded material (i.e., EXCEPTIONs, lists) therein. The paragraph symbol (§§) is used to reference a particular numbered paragraph and embedded material therein. When duplicated (i.e., §§ and §§§) the symbols are used to reference more than one section or paragraph, respectively.

1 Purpose

1.1 This Standard defines the measurement method for bulk micro defect (BMD) densities and denuded zone (DZ) width in annealed silicon wafers.¹ This Standard describes the preferential etching technique to measure BMD density and DZ width. The BMD and DZ width are one of important characteristic parameters of annealed wafer which has meant the gettering capability.

2 Scope

2.1 This Standard defines measurement technique of BMD density and DZ width. BMD and DZ form in silicon wafers after annealing the wafers with heat treatment. The techniques covered in this Standard are intended to measure BMD density over a range of $10^7/\text{cm}^3$ to $10^{10}/\text{cm}^3$ and DZ width up to 150 μm .

2.2 This Standard applies to mirror-finished annealed silicon samples with a specific resistance of 0.01 $\Omega\cdot\text{cm}$ or greater.

2.3 This Standard defines measurement techniques for BMD density and DZ width using a preferential etching technique.

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 *Annealing Process to Create the Test Samples* — Thermal treatment conditions cannot be defined unambiguously because they are tailored to the end use of the silicon wafer. It shall be decided with discussion as the thermal cycle including the insert/withdrawal temperatures, ramp up/ramp down rates, and gas ambient during all steps between customer and vender. A typical BMD growth heat treatment is 3 hours at 780°C in dry oxygen followed by 16 hours at 1000°C in dry oxygen.

3.2 *Etching Process to Decorate the BMD for Observation* — For the etching process one shall follow other standard documents as SEMI MF1809 and JIS H 0609.

3.3 *Human Observed Counting and Automated Counting* — The method of automated counting usually combines microscopy and CCD camera or CMOS image sensor with subsequent image processing. In that case, sensitivity of this system shall be adjusted by applying the standard method which is used for manual counting. And its condition shall be maintained using tool statistical process control method.

¹ This Standard was derived from JEITA EM-3508 with permission from the Japan Electronics and Information Technology Industries Association.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI M59 — Terminology for Silicon Technology

SEMI MF1809 — Guide for Selection and Use of Etching Solutions to Delineate Structural Defects in Silicon

4.2 JIS Standards²

JIS H 0609 — Test Methods of Crystalline Defects in Silicon by Preferential Etch Techniques

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

5 Summary of Test Method

5.1 This Test Method is destructive. The annealed wafer is cleaved to expose the {110} surface.

5.1.1 *Preferential Etching Technique* — The cleavage plane's measurement surface of the annealed silicon wafer is etched with a solution which exposes BMD as etch pits. These etch pits are observed, counted, and sequenced by depth from the polished surface using an optical microscope or possibly by other means.

6 Terminology

6.1 Most definitions of terms and acronyms used in silicon technology can be found in SEMI M59.

6.2 Additional terms are defined below.

NOTE 1: Similar but not identical definitions for these terms appear in JIS H 0609.

6.2.1 *bulk micro defects (BMD)* — defects within the wafer such as dislocations, stacking faults, and oxide precipitates, that may be observable as etch pits by this test method.

6.2.2 *oxide precipitates* — silicon oxide deposits in Czochralski-grown silicon arising from the reaction of oxygen atoms, existing between lattice sites, with silicon. Oxide precipitate growth occurs, based on thermal history, during crystal growth or during later thermal processing stages of the silicon. Oxide precipitates account for most of the BMD in silicon crystals and annealed silicon wafers.

7 Apparatus

7.1 *Preferential Etching Method* — An optical microscope or an automatic measuring device consisting, for example, of an optical microscope and CCD camera, is used to measure the locations of etch pits due to BMD on the cleaved facet of a preferentially etched test specimen. The observation is performed in reflection (typically differential interference contrast microscopy (DIC or Nomarski) is used) to enhance the detection of the small pits.

7.1.1 *Eyepiece Observation* — The total magnification, M , of visual observation using a compound microscope is the magnification of the objective lens, M_o , multiplied by the magnification of the eyepiece, M_e :

$$M = M_o \times M_e \quad (1)$$

During observations, the use of a calibrated eyepiece reticle is required to define the measurement area dimensions.

7.1.2 *Using an Image Sensor* — Measurement area dimensions of digital images are required when digitized images are analyzed in this test method.

7.1.2.1 The total magnification, M , of the microscope is determined.

7.1.2.1.1 For microscopes using infinite conjugate objectives the total magnification is the product of the objective magnification, M_o , and the magnification of the photo lens (tube lens), M_p .

$$M = M_o \times M_p \quad (2)$$

² Japanese Standards Association, 4-1-24 Akasaka, Minato-ku, Tokyo 107-8440, Japan; Telephone: +81.3.3583.8005, Fax: +81.3.3586.2014, <http://www.jsa.or.jp>

7.1.2.1.2 For fixed focal length objective microscope there is no tube lens and the total magnification is the objective magnification.

$$M = M_o \quad (3)$$

7.1.2.2 The image pixel pitch is defined as the image sensor array pitch divided by the total magnification. In general, the image sensor may have a different array pitch in the x and y directions, P_x and P_y . For example, an image acquired using an image sensor with 25 μm square array pitch at total magnification $M = 50$ produces an image where adjacent pixels in the image represent physical points on the object that are 0.5 μm apart.

7.1.2.3 The dimensions of the examination area, A_E , within the digital image are defined by the product of the number of effective image pixels in each direction times the pixel pitch in that direction. The examination area is then the product of these two dimensions.

$$A_E = N_x \cdot P_x \cdot N_y \cdot P_y / M^2 \quad (4)$$

8 Reagents and Materials

8.1 Preferential etching reagents that conform to the reagent concentrations and usage practices in JIS H 0609 or SEMI MF1809 are required for the preferential etching method.

NOTE 2: Measurement results are not guaranteed when etchant mixtures are used that are not given in the referenced standards.

9 Test Specimens

9.1 *Heat Treatment* — Determine the thermal treatment conditions to be applied for treating the test specimens prior to measurement with the agreement of all parties to the test.

9.2 Cleave the silicon wafer in the center along a $\langle 110 \rangle$ direction into a rectangular section. A $\langle 110 \rangle$ direction can be identified easily for most (100) wafers because it is either parallel or perpendicular to the orientation flat or notch.

9.3 Carefully handle the cleaved section so the examination surface is free of work damage, contamination, or residues that could cause measurement errors. If contamination or residues stick to the sample, wipe the measurement surface with alcohol or other solvent so measurements can be taken on a clean surface.

10 Procedure

10.1 *Preferential Etching Procedure*

10.1.1 *Measurement Positions* — Measurement positions shall be determined by agreement between the parties to the test because bulk micro defects are not necessarily distributed homogeneously in a radial direction around the silicon wafer, and the radial distribution of defects changes depending on heat treatment conditions.

NOTE 3: Some possible measurement position guidelines are (1) a three-point measurement system, like that illustrated in Figure 1, where measurements are taken at the center, at half the radius, and at a point 10 mm from the wafer edge, and (2) a one-point measurement system, where the measurement taken in the center of the wafer.

10.1.2 At each measurement point, measure the BMD density at the center of the wafer's cross-sectional width, and measure the DZ width just under the surface with an optical differential-interference reflection microscope. Visual examinations shall be made at 100 times to 1000 times total magnification. When the defect density is low, increase the total number of defects counted to reduce statistical error by either examining the defects at an even lower magnification or expanding the examination area.

NOTE 4: If the depth profile of the BMD density plateaus at a shallower wafer depth and this density can be confirmed to be the same as the density at the midpoint, measurements taken at the shallower depth can be regarded as the BMD density at the wafer's center.

10.1.3 Defects shall be counted either from an image recorded through the microscope or directly while observing the sample under the microscope. Figure 2 shows a typical BMD observation. When measurements are taken with an automatic measuring device, take them under conditions complying with the device's specification.

10.1.4 *Measuring DZ Widths* — DZ widths shall be measured visually under a microscope at a total magnification of 100 times to 1000 times. When the defect density is low, reduce the statistical error by either examining the defects at an even lower magnification or expanding the examination area. Figure 3 shows a typical DZ observation).

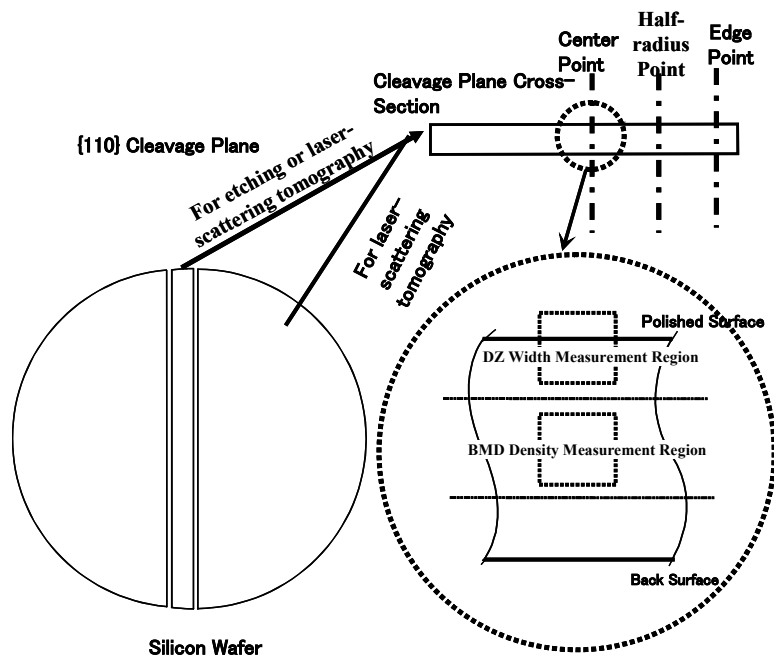


Figure 1
Example Measurement Positions

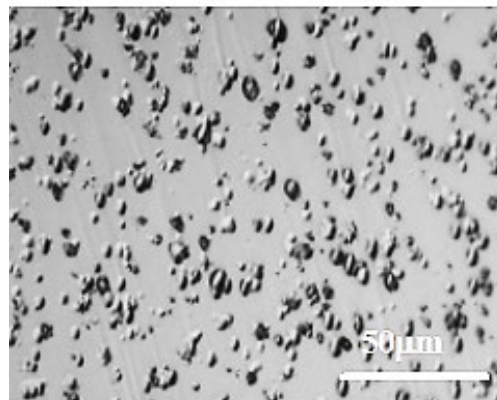


Figure 2
Typical BMD Examination Example