

SEMI M91-0622

TEST METHOD FOR DETERMINATION OF THREADING SCREW DISLOCATION DENSITY IN 4H-SiC BY X-RAY TOPOGRAPHY

This Standard was technically approved by the Compound Semiconductor Materials Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on January 4, 2022. Available at www.semiviews.org and www.semi.org in June 2022.

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 Threading screw dislocations (TSDs) are detrimental to several types of electronic devices manufactured from 4H-SiC.
- 1.2 Most TSDs are transferred from a substrate into an epitaxial layer and may cause pits in the epi layer, which can be problematic for certain processing steps.
- 1.3 The density and distribution of TSDs is a critical parameter for evaluating the wafer quality and for failure analysis of errant device structures. X-ray topography (XRT) is able to accomplish this task. This Test Method provides information on the measurement procedure and can be used for acceptance testing.

2 Scope

- 2.1 This Test Method covers the determination of TSD density on round test slices and commercial 4H-SiC wafers using XRT for identification and registration of TSDs.
- 2.2 The TSD density is used as a measure for the crystallographic perfection of a crystal.
- 2.3 This Test Method describes the requirements of the sample quality and the procedure to obtain a topogram suitable for TSD identification.
- 2.4 This Test Method is applicable to material with TSD densities up to 5000 cm^{-2} . The resistivity, conductivity type and polarity of the analyzed side of the material is irrelevant.

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 Improper identification of defects is possible during the counting process. The accuracy may be limited by the classification process.
- 3.2 The method requires a surface condition free of sub-surface damage and is not applicable if sub-surface damage is present. Surface defects like scratches or grinding marks may affect the identification and counting of threading screw dislocations.
- 3.3 The information depth is limited by x-ray absorption to $20 \mu\text{m}$ (Cu $K\alpha$ radiation, (0008)-reflex).
- 3.4 The presence of other defects like stacking faults may affect the dislocation detection.
- 3.5 Clustering of threading screw dislocations limits the reliability of defect detection and counting.
- 3.6 Only TSD densities up to 5000 cm^{-2} can be detected.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI M20 — Practice for Establishing a Wafer Coordinate System

SEMI M52 — Guide for Specifying Scanning Surface Inspection Systems for Silicon Wafers for the 130 nm to 11 nm Technology Generations

SEMI M55 — Specification for Polished Monocrystalline Silicon Carbide Wafers

SEMI M59 — Terminology for Silicon Technology

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

5 Terminology

NOTE 1: Refer to the SEMI Standards Compilation of Terms (COTs) for a list of the current Abbreviations, Acronyms, Definitions, and Symbols.

5.1 Terms, acronyms, and symbols relating to compound semiconductor material technology are defined in SEMI M10, SEMI M55, and SEMI M59.

5.2 Other Definitions Used in this Test Method

5.2.1 *classification accuracy* — the ratio of the total number of machine-classified defects for which human and machine classification results agree to the total quantity of human-classified defects.

5.2.2 *classification purity* — the ratio of the total number of machine-classified defects for which human and machine classification results agree to the total quantity of defects classified as a specific class by the machine.

5.2.3 *edge exclusion Δd* — region within a certain distance Δd from the edge of the wafer is excluded from defect counting.

5.2.4 *threading screw dislocations (TSD)* — dislocation with a Burgers vector parallel to the [0001] crystallographic direction and a dislocation propagation parallel to that.

5.2.5 *x-ray topography (XRT)* — imaging of the intensity of a diffracted x-ray beam

6 Summary of Test Method

6.1 Samples for this test should comply with the specification for surface defects according to SEMI M55.

6.2 The wafer is placed on the sample stage of the x-ray topograph.

6.3 The goniometer angles are adjusted for the reflex to be measured and aligned for the sample.

6.4 A topogram of the full wafer is recorded.

6.5 The TSDs are recognized by size, shape and/or intensity and counted.

7 Apparatus

7.1 *X-Ray Topograph* — Able to generate wafer mappings by scanning over the sample area.

7.1.1 *Detector* — Digital detector with a pixel pitch below 10 μm .

7.1.2 *Goniometer* — Able to set detector and source angle such that a suitable reflex can be measured.

7.1.3 *Motorized Sample Stage* — Featuring a scan range covering the full wafer area.

8 Safety Precautions

8.1 X-Radiation

8.1.1 It is absolutely necessary to avoid personal exposure to x-rays.

8.1.2 It is the responsibility of the user to make sure that the equipment and the conditions under which it is used meet all applicable regulations.

9 Procedure

9.1 *Sample Preparation* — For reliable identification and registration of TSDs, the sample surface on which the measurement is carried out, needs to be free of surface defects. This is typically achieved by applying a chemical-mechanical polishing process.

9.2 XRT Measurement

9.2.1 Goniometer angles of source and detector must be adjusted for the (0008)-reflex of Cu K α radiation in reflection geometry on the wafer surface of interest (Si-face, if not agreed otherwise), taking into account the offcut angle, if applicable.

9.2.2 A homogeneous x-ray beam intensity and thus a homogeneous intensity distribution on the detector must be ensured.

9.2.3 The wafer needs to be rotated in such a way that the offcut direction is parallel to the beam direction.

9.2.4 The alignment procedure must ensure a homogeneous contrast over the wafer surface or over the measurement fields, compensating for a potential wafer bow by adjusting the rocking angle if necessary.

9.2.5 The measurement parameters need to be chosen to obtain a sufficient intensity over the full measurement area. The definition of a sufficient intensity is detailed in Appendix 2.

9.3 Measurement Location Plans

9.3.1 *Measurement Location Plan A: Full Wafer Measurement* — The full area of the wafer is mapped. The field size for analysis of the TSD density is selected after the measurement.

9.3.2 *Measurement Location Plan B: Regular Quadratic Grid* — The quadratic measurement locations with width a_F are arranged on a regular quadratic grid with spacing a_G . The grid lines have to be aligned with the x - and y -axes of the coordinate system defined according to SEMI M20. If this coordinate system is not applicable, for example, because the test specimen has no primary flat or notch, the grid lines should be aligned with the $\langle 11-20 \rangle$ -direction as horizontal direction and $\langle 10-10 \rangle$ -direction as vertical direction. The center of the test specimen is a measurement location. The grid spacing a_G has to be smaller than $d/10$.

9.3.3 *Measurement Location Plan C: Centrosymmetric Stripe* — A stripe with height (h) is measured through the center of the sample. The field size for analysis of the TSD density is selected after the measurement.

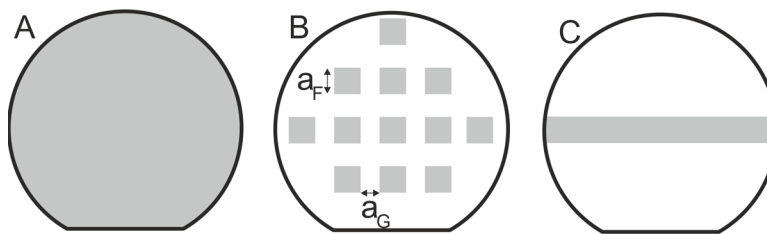


Figure 1
Illustration of the Measurement Plans, Regions to be Analyzed Are Highlighted in Grey

9.4 TSD Detection

9.4.1 TSDs can be recognized by size and shape. Typically, they appear as oval spots with approximate dimensions of $50\ \mu\text{m} \times 30\ \mu\text{m}$ (refer to Figure 1) in the topogram of the (0008) reflex of Cu K α radiation, more generally dimensions between $30\ \mu\text{m} \times 20\ \mu\text{m}$ and $80\ \mu\text{m} \times 50\ \mu\text{m}$, depending on reflex and measurement conditions.

9.4.2 The coordinates of each recognized TSD are registered.