SEMI M65-0306[E]
SPECIFICATIONS FOR SAPPHIRE SUBSTRATES TO USE FOR COMPOUND SEMICONDUCTOR EPITAXIAL WAFERS

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[E] This standard was editorially modified in April 2006 to correct an error. Changes were made to § 12.1.1.

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1 Purpose

1.1 Sapphire substrates are utilized for hetero-epitaxial growth of gallium nitride and related film. The properties of the films depend in part on the properties of the substrates used. These specifications are intended to provide specifications for the criteria necessary to use for growth of films suitable for device production, and to unify the notation method of sapphire substrate.

2 Scope

2.1 These specifications cover requirements for three sizes (50.8 mm, 76.2 mm, and 100 mm) of monocrystalline high-purity polished sapphire substrates. Dimensional and crystallographic orientation characteristics are the only standardized properties set forth herein. A purchase specification may require additional physical properties, which should be defined. Many of these properties are listed, together with test methods suitable for determining their magnitude. Additional information and recommended specification levels for several of these properties are provided in Related Information sections.

2.2 These specifications are directed specifically to sapphire substrates with one polished surface. Substrates polished on both sides, or unpolished, or with epitaxial film, are not covered; however, customers of such substrates will find that these specifications are useful guides in defining their requirements.

2.3 The notations of crystallographic orientation are unified to prevent possible misunderstandings. The symbols written by capital or small letters must be strictly used with distinction for the correct expression of a crystal plane.

2.4 Optical measurement methods are widely used to evaluate flatness of substrate, owing to their precise and easy handling. Therefore the items of Sori, Taper, GBIR and GFLR are introduced, in order to examine strained or unrestrained surface flatness more appropriately.

2.5 For referee purpose, SI (System International commonly called metric) units are used for all substrates.

NOTICE: 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 or other limitations prior to use.

3 Referenced Standards and Documents

3.1 *SEMI Standards*

SEMI M1 — Specifications for Polished Monocrystalline Silicon Wafers

SEMI M3 — Specifications for Polished Monocrystalline Sapphire Substrates

SEMI MF26 — Test Method for Determining the Orientation of a Semi-conductive Single Crystal

SEMI MF523 — Practice for Unaided Visual Inspections of Polished Silicon Wafer Surfaces

SEMI MF533 — Test Method for Thickness and Thickness Variations of Silicon Wafers

SEMI MF671 — Test Method for Measuring Flat Length on Wafers and Other Electronic Materials

SEMI MF847 — Test Method for Measuring Crystalographic Orientation of Flats on Single Crystal Silicon Wafers by X-ray Techniques

SEMI MF928 — Test Method for Edge Contour of Circular Semiconductor Wafers and Rigid Disk Substrates

SEMI MF1810 — Test Method for Counting Preferentially Etched or Decorated Surface Defects in Silicon Wafer

SEMI MF2074 — Guide for Measuring Diameter of Silicon and Other Semiconductor Wafers

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3.2 *ASTM Standard*[1]

E 122 — Practice for Choice of Sample Size to Estimate the Average Quality of a Lot or Process

F2358-04 — Standard Guide for Measuring Characteristics of Sapphire Substrates

3.3 *Other Standard*[2]

ANSI/ASQC Z1.4-1993 — Sampling Procedures and Tables for Inspection by Attributes

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

4 Terminology

4.1 *General Definitions*

4.1.1 *back surface* — the surface opposite the front surface.

4.1.2 *best-fit plane* — the theoretical plane established by using the least squares fit method, based on data obtained from the quality area only.

4.1.3 *front surface* — the preferred surface, as defined by the user.

NOTE 1: If there is no difference between the front and back surfaces, then the surfaces may be determined arbitrarily, and are therefore interchangeable.

4.1.4 *lot* — for the purposes of these specifications, (a) all of the substrates of nominally identical size and characteristics contained in a single shipment, or (b) subdivisions of large shipments consisting of substrates as (a) above which have been identified by the supplier as constituting a lot.

4.1.5 *quality area* — the central area of a wafer surface, defined by a nominal edge exclusion, over which the specified values of parameters are not applied. If the quality area is not circular, the "circle defining the quality area" shall be defined as the minimum diameter circle which contains all of the data within the quality area.

4.1.6 *reference plane* — the plane from which deviations are measured.

4.1.7 *restrained condition* — this refers to the state of the substrate under test, when one side of the substrate is clamped to an ideally flat surface; for example, when pulled down by a vacuum onto an ideally clean flat chuck.

4.1.8 *sapphire* — single crystal aluminum oxide (Al_2O_3) having a definite orientation that allows epitaxial compound semiconductor deposition.

4.1.9 *substrate* — the polished sapphire wafer upon which the epitaxial layer of compound semiconductor is grown.

4.1.10 *thickness* — the distance through the substrate between corresponding points on the front and back surfaces.

NOTE 2: Refer to SEMI M1 on the items of Sori, GBIR and GFLR, and refer to ASTM (F2358-04) on Taper.

4.1.11 *unrestrained condition* — this refers to the state of the substrate under test, when the substrate is in a stress-free condition with minimal deformation due to gravity.

4.2 *Definitions of Unrestrained Parameters*

4.2.1 *Sori* — the maximum distance above, plus the maximum distance below the front surface best-fit plane of a free, unclamped substrate (see Figure 5).

4.3 *Definitions of Restrained Parameters*[3]

4.3.1 *Global-Back-Ideal-Range (GBIR)* — the difference between maximum and minimum values of the thickness of the substrate (see Figure 7).

NOTE 3: GBIR equals Total Thickness Variation (TTV) in ASTM (F2358-04).

4.3.2 *Global-Front-Least Squares-Range (GFLR)* — maximum distance above, plus maximum distance below the front surface best-fit plane of a substrate, measured with the back surface restrained (see Figure 8).

NOTE 4: GFLR equals Front-to-Front Deviation (FFD) in ASTM (F2358-04).

4.3.3 *Taper* — the linear component of the variation in thickness across a substrate, indicated by the angle between the best-fit plane to the front surface and the ideally flat back surface of the substrate (see Figure 6).

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1 ASTM International, 100 Barr Harbor Drive, West Conshohoken. PA 19428-2959, USA. Telephone: 610.832.9585, Fax:610.832.9555, Website: www.astm.org.

2 American Sociaty for Quality Control, 611 East Wisconsin Avenue, Milwaukee, WI 53202; Website: www.asqc.org.

3 Even though the above parameters define the variation of a theoretically restrained substrate, the measurements may be performed in the unrestrained state, with calculations performed to simulate the restrained condition.

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5 Ordering Information

5.1 Purchase orders for sapphire substrates furnished to these specifications shall include the following items:

5.1.1 Nominal Diameter (see Table 2),

5.1.2 Crystal growth method,

5.1.3 Surface orientation (see Figure 2 and 3, and Table 2),

5.1.4 Lot acceptance procedures (see ¶ 9),

5.1.5 Certification (see ¶ 13, if required), and

5.1.6 Packing and marking (see ¶ 14),

5.2 The following items may be specified optionally in addition to those listed in ¶ 5.1 (see NOTE 2):

5.2.1 Crystal perfection,

5.2.2 Surface defect and contaminated levels,

5.2.3 Impurities,

5.2.4 Front surface finish quality level (see Figures R2-1 through R2-4),

5.2.5 Back surface finish,

5.2.6 Secondary flat (see Figure 3),

5.2.7 Flatness (see Table 2), and

5.2.8 Edge Profile.

NOTE 5: The crystal growth method (e.g., Czochralski or EFG ribbon) is difficult to ascertain in the finished substrates. Verification test procedures or certification of these characteristics (see ¶ 13) shall be agreed between the supplier and the customer.

NOTE 6: Items in ¶ 5.2 are less commonly specified than the others but are included for completeness as parameters for which methods of evaluation have been developed.

6 Dimension and Permissible Variations

6.1 The material shall conform to the dimensions and dimensional tolerances as specified in Table 2 for the following parameters.

6.1.1 *Diameter*,

6.1.2 *Thickness*, *Center Point*,

6.1.3 *Primary Flat Length*,

6.1.4 *Secondary Flat Length*,

6.1.5 *Sori*,

6.1.6 *Global-Back-Ideal-Range* (*GBIR*), and

6.1.7 *Global-Front-Least Squares-Range* (*GFLR*).

6.2 The orientation of the substrate material shall be identified by flat systems as defined in ¶ 12.

7 Materials and Manufacture

7.1 The material shall consist of wafers from sapphire grown by the process specified in the purchase order or contract.

8 Physical Requirements

8.1 The material shall conform to the crystallographic orientation details listed in Table 1 (see Figure 1).

8.2 The following items, if included, shall conform to the requirements specified in the purchase order or contract.

8.2.1 Crystal perfection,

8.2.2 Surface defect and contaminant levels (see Related information 1 for surface defect definitions and Table R1-1 for suggested allowable levels of surface defects),

8.3 Amount of impurities,

8.4 Front surface finish quality level (see Related Information 2 and Figures R2-1 through R2-4 for information on recommended front surface finish quality levels), and

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8.5 Back surface finish (see Related Information 2 for recommended back surface finish level).

9 Sampling

9.1 Unless otherwise specified, ASTM Practice E122 shall be used. When so specified, appropriate sample size shall be selected from each lot in accordance with ANSI/ASQC Z1.4-1993. Each quality characteristic shall be assigned an acceptable quality level (AQL) and lot total percent defective (LTPD) value in accordance with ANSI/ASQC Z1.4-1993 definitions for critical, major, and minor classifications. If desired and so specified in the contract or order, each of these classification may alternatively be assigned cumulative AQL and LTPD values. Inspection levels shall be agreed upon between the supplier and the customer.

10 Test Methods

10.1 *Dimensions* — Measure as follows:

10.1.1 *Diameter* — Determine by a method agreed upon between the supplier and the customer at locations specified in Configuration 1 of SEMI MF2074.

NOTE 3: Sapphire substrates are highly susceptible to surface damage. While the mechanical dimensions of a wafer can be measured by use of tools such as micrometer calipers and other conventional techniques, the substrate may be damaged physically in ways that are not immediately evident. Special attentions must therefore be paid in the selection and execution of measurement methods.

10.1.2 *Thickness, Center Point* — Determine at the center of the substrate (Point 2 in Figure 4) in accordance with SEMI MF533.

10.1.3 *Global-Back-Ideal-Range:GBIR (TTV)* — Determine in accordance with ASTM F2358-04.

Calculations: The maximum thickness minus minimum thickness (see Figure 7).

10.1.4 *Taper* — Determine in accordance with ASTM F2358-04.

Calculations: The diameter of the quality area times the tangent of the angle between the best-fit front surface plane and the restrained back surface plane (see Figure 6).

10.1.5 *Global-Front-Least Squares-Range: GFLR (FFD)* — Determine in accordance with ASTM F2358-04.

Calculations: The maximum distance above the best-fit front surface plane plus the maximum distance below the best-fit front surface plane (see Figure 8).

10.1.6 *Flat Length* — Determine in accordance with SEMI MF671.

10.1.7 *Sori* — Determine in accordance with ASTM F2358-04.

Calculations: The maximum distance above the best-fit plane plus the maximum distance below the best-fit plane (see Figure 5).

10.2 *Flat Orientation* — Determine in accordance with SEMI MF847.

10.3 *Surface Orientation* — Determine in accordance with SEMI MF26.

10.4 *Crystal Perfection* — Unless otherwise specified, determine in accordance with SEMI MF1810.

10.5 *Surface Defects and Contamination* — Determine defects in accordance with SEMI MF523.

10.6 *Other Impurities* — Determine by methods agreed upon between the supplier and the customer.

10.7 *Front Surface Finish* — Determine by methods agreed upon between the supplier and the customer.

10.8 *Back Surface Finish* — Determine by methods agreed upon between the supplier and the customer.

10.9 *Edge Profile* — Determine by methods agreed upon between the supplier and the customer. Method B of SEMI MF928 is a non-destructive way of evaluating the shape of the edge profile. If this method is used, the template to be used shall be agreed upon between the supplier and the customer.

11 Crystallographic Notation System

11.1 Sapphire crystals have two indices used to describe the crystal planes: structural indices, and morphological indices. The structural indices result from x-ray diffraction measurements and are more easily determined so morphological index has fallen into disuse. This standard uses only the structural indices. Correct capitalization (or lower case) is necessary for the unambiguous description of a particular crystal plane.

11.2 The relations of symbols, structural and morphological index are described in Table 1. Sapphire crystallographic diagrams by using symbols and structural indexes are shown in Figure 1.

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