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Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for GaN crystal surface defects —

Part 1:
Classification of defects

PROOF/ÉPREUVE

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Foreword

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This document was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

A list of all parts in the ISO 5618 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

GaN is a direct transition type of wide-bandgap semiconductor with superior physical properties, including a higher breakdown electric field, saturated electron drift velocity and thermal conductivity, to Si. GaN is expected to be applied not only in light-emitting devices that have been in practical use for a long time, such as ultraviolet and blue laser diodes (LDs) and light-emitting diodes (LEDs), but also in power devices for high-efficiency power conversion. In particular, the characteristics of GaN-based power devices are applied in the fields of photovoltaics, automobiles, railways (electric motors and linear motors), communication base stations and microwave power transmission.

The single-crystal GaN substrate or single-crystal GaN film is the base material used to produce devices. However, the surface of a single-crystal GaN substrate or single-crystal GaN film contains many dislocations that are introduced during crystal growth and defects that are introduced during wafer processing. The dislocations and/or defects cause a decrease in luminous efficiency for a light-emitting device and a degradation in performance and reliability for a power device. In particular, given the practical applications and market expansion of power devices that apply a high voltage and high current, it is important to supply single-crystal GaN substrates and single-crystal GaN films with low densities of dislocation and defects. Therefore, it is essential to have an International Standard that defines and classifies the types of, and further determines the density of, dislocations and process-induced defects that exist on the surface as an index for assessing the quality of a single-crystal GaN substrate or single-crystal GaN film.

This document gives a classification of the dislocations and process-induced defects exposed on the surface of single-crystal GaN substrates and single-crystal GaN films. These single-crystal substrates and films are mainly used for light-emitting devices, such as LDs and LEDs, and power devices that perform high-voltage and high-current power conversion. ISO 5618-2[1] provides a method of determining the etch pit density

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[1] Under preparation. Stage at the time of publication: ISO/DIS 5618-2:2023.

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for GaN crystal surface defects —

Part 1:
Classification of defects

1 Scope

This document gives a classification of the dislocations and process-induced defects, from among the various surface defects, that occur on single-crystal gallium nitride (GaN) substrates or single-crystal GaN films.

It is applicable to the dislocations and process-induced defects exposed on the surface of the following types of GaN substrates or films:

- single-crystal GaN substrate;
- single-crystal GaN film formed by homoepitaxial growth on a single-crystal GaN substrate;
- single-crystal GaN film formed by heteroepitaxial growth on a single-crystal aluminium oxide (Al_2O_3), silicon carbide (SiC) or silicon (Si) substrate.

It is not applicable to defects exposed on the surface if the absolute value of the acute angle between the surface normal and the *c*-axis of GaN is ≥ 8°.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at https://www.electropedia.org/

3.1
gallium nitride
GaN
compound semiconductor crystal material composed of gallium and nitrogen having a wurtzite structure or a zincblende structure

3.2
silicon carbide
SiC
compound semiconductor crystal composed of silicon and carbon, which exhibits a large number of polytypes such as 3C, 4H and 6H

Note 1 to entry: A symbol like 4H gives the number of periodic stacking layers (2, 3, 4,...) and the crystal symmetry (H = hexagonal, C = cubic) of each polytype.

[SOURCE: IEC 63068-1:2019, 3.1]

3.3
aluminium oxide
Al_2O_3
compound crystal material composed of aluminium and oxygen with a corundum structure

3.4
substrate
material on which epitaxial layer is deposited

[SOURCE: IEC 63068-1:2019, 3.9, modified — Definition revised.]

3.5
homoepitaxial growth
single-crystal growth that inherits information concerning the chemical composition, atomic arrangement and crystal orientation of homogeneous *substrates* (3.4)

3.6
heteroepitaxial growth
single-crystal growth that inherits information concerning the atomic arrangement and crystal orientation of heterogeneous *substrates* (3.4)

3.7
Burgers vector
b
vector that represents the magnitude and direction of the lattice distortion of *dislocation* (3.10) in a crystal lattice

[SOURCE: ISO 15932:2013, 6.5.2]

3.8
***c*-axis**
axis with sixfold symmetry in a hexagonal crystal

3.9
basal plane
plane perpendicular to the crystallographic *c-axis* (3.8) in a hexagonal crystal

[SOURCE: IEC 63068-1:2019, 3.13]

3.10
dislocation
linear crystallographic defect in single-crystal material

[SOURCE: IEC 63068-1:2019, 3.22]

3.11
edge dislocation
dislocation (3.10) with *Burgers vector* (3.7) perpendicular to the dislocation line

3.12
screw dislocation
dislocation (3.10) with *Burgers vector* (3.7) parallel to the dislocation line

3.13
mixed dislocation
dislocation (3.10) with *Burgers vector* (3.7) containing components that are both perpendicular and parallel to the dislocation line

3.14

etching

chemical treatment of the GaN crystal surface to detect *dislocations* (3.10)

3.15

etchant

solution or melt used for *etching* (3.14)

4 Classification of defects

4.1 General

The dislocations and process-induced defects exposed on the surface of single-crystal GaN substrates and single-crystal GaN films shall be categorized into the classes of defects given in 4.2.

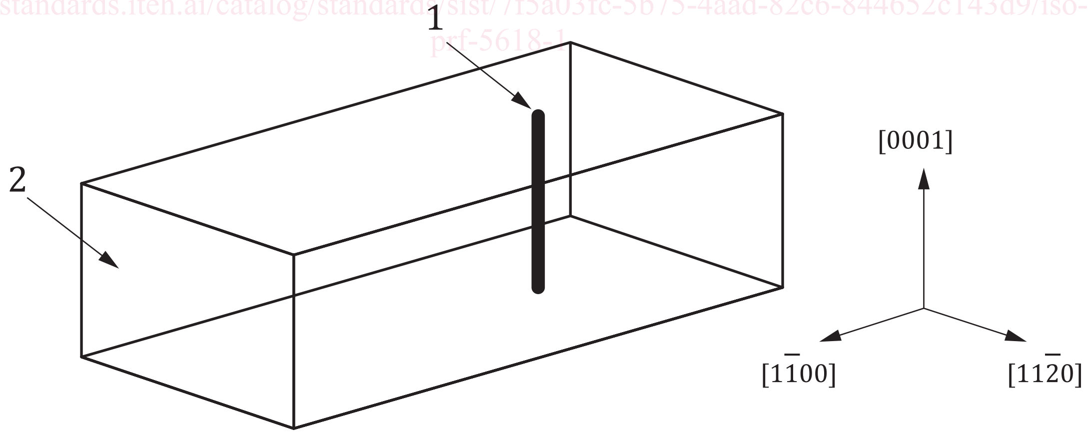
4.2 Description of the defect classes

4.2.1 Dislocation

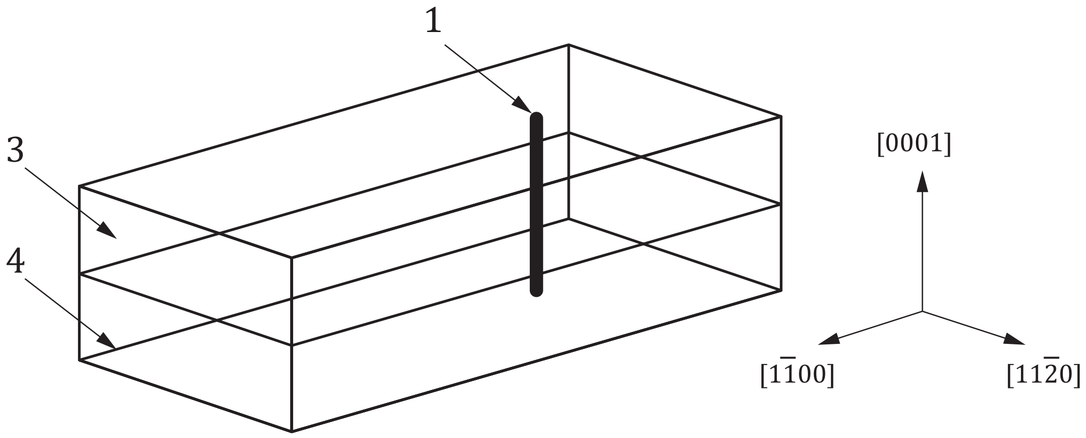
4.2.1.1 Threading dislocation

The class of threading dislocation means a dislocation that reaches the surface from the inside of the single-crystal GaN substrate or the single-crystal GaN film and extends almost parallel to the *c*-axis. Schematic illustrations of threading dislocations are shown in Figure 1. Threading dislocations include tilted dislocations with an angle of up to 80° with respect to the *c*-axis. Threading dislocations include those where the dislocation lines are not straight but have a helical spring shape.

NOTE For the single-crystal GaN substrate, dislocations reach from the inside of the crystal to the surface and extend in the *c*-axis direction; they do not necessarily penetrate from the crystal surface to the back surface.



a) Schematic illustration of a threading dislocation in a GaN single-crystal substrate



b) Schematic illustration of a threading dislocation in a GaN single-crystal film

Key

1	threading dislocation
2	single-crystal GaN substrate
3	single-crystal GaN film
4	single-crystal GaN substrate (including single-crystal substrates such as Al_2O_3, Si, SiC)

Figure 1 — Schematic illustrations of threading dislocations

4.2.1.2 Threading edge dislocation (TED) $\boldsymbol{b} = n\boldsymbol{a}$

The class of threading edge dislocation (TED) means a threading dislocation with a Burgers vector of:

$$\boldsymbol{b} = n \times (|\boldsymbol{a}|/3) <11\bar{2}0>$$

where n is an integer.

When the threading edge dislocation is classified as including the size of the Burgers vector, it is written as: TED $\boldsymbol{b} = n\boldsymbol{a}$.

NOTE In crystallography, a threading edge dislocation is defined as a dislocation line and a Burgers vector that are orthogonal to each other, but it is specified in this document as satisfying the above prescription.

EXAMPLE Where $n = 2$, it is written as TED $\boldsymbol{b} = 2\boldsymbol{a}$.

4.2.1.3 Threading screw dislocation (TSD) $\boldsymbol{b} = n\boldsymbol{c}$

The class of threading screw dislocation (TSD) means a threading dislocation with a Burgers vector of:

$$\boldsymbol{b} = n \times |\boldsymbol{c}| <0001>$$

where n is an integer.

Threading screw dislocations include those in which part of the dislocation core is hollow. When the threading screw dislocation is classified as including the size of the Burgers vector, it is written as: TSD $\boldsymbol{b} = n\boldsymbol{c}$.

NOTE In crystallography, a threading screw dislocation is defined as a dislocation line and a Burgers vector that are parallel to each other, but it is specified in this document as satisfying the above prescription.

EXAMPLE Where $n = 2$, it is written as TSD $\boldsymbol{b} = 2\boldsymbol{c}$.