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INTERNATIONAL STANDARD

Semiconductor devices – Non-destructive recognition criteria of defects in silicon carbide homoepitaxial wafer for power devices –
Part 1: Classification of defects

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Part 1: Classification of defects

FOREWORD

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International Standard IEC 63068-1 has been prepared by IEC technical committee 47: Semiconductor devices.

The text of this International Standard is based on the following documents:

CDV	Report on voting
47/2474/CDV	47/2521A/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 63068 series, published under the general title *Semiconductor devices – Non-destructive recognition criteria of defects in silicon carbide homoepitaxial wafer for power devices*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

Silicon carbide (SiC) is widely used as a semiconductor material for next-generation power semiconductor devices. SiC, as compared with silicon (Si), has superior physical properties such as a higher breakdown electric field, higher thermal conductivity, lower thermal generation rate, higher saturated electron drift velocity, and lower intrinsic carrier concentration. Their attributes realize SiC-based power semiconductor devices with faster switching speeds, lower losses, higher blocking voltages, and higher temperature operation relative to standard Si-based power semiconductor devices.

SiC-based power semiconductor devices are not fully realized due to high costs, low yield, and perceived reliability concerns. One of the serious issues lies in the defects existing in SiC homoepitaxial wafers. Although an effort of decreasing defects in the SiC homoepitaxial layer is actively implemented, there are a number of defects (approximately 1 000 defects/cm^2) in commercially available SiC homoepitaxial wafers. Therefore, it is indispensable to establish an international standard regarding the quality assessment of SiC homoepitaxial wafers.

The IEC 63068 series of standards is planned to comprise Part 1, Part 2, and Part 3, as detailed below. The outline of this Part 1 is to list, illustrate and provide reference for various characteristic features and defects that are observed on SiC homoepitaxial wafers of crystallographic polytype 4H used in high-power semiconductor device manufacturing.

Part 1: Classification of defects

Part 2: Test method for defects using optical inspection

Part 3: Test method for defects using photoluminescence

SEMICONDUCTOR DEVICES – NON-DESTRUCTIVE RECOGNITION CRITERIA OF DEFECTS IN SILICON CARBIDE HOMOEPITAXIAL WAFER FOR POWER DEVICES –

Part 1: Classification of defects

1 Scope

This part of IEC 63068 gives a classification of defects in as-grown 4H-SiC (Silicon Carbide) epitaxial layers. The defects are classified on the basis of their crystallographic structures and recognized by non-destructive detection methods including bright-field OM (optical microscopy), PL (photoluminescence), and XRT (X-ray topography) images.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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 terminological databases for use in standardization at the following addresses:

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

3.1
silicon carbide
SiC
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.

3.2
3C-SiC
SiC crystal with zinc blende structure, in which three Si-C layers are periodically arranged along the <111> direction

3.3
4H-SiC
SiC crystal showing a hexagonal symmetry, in which four Si-C layers are periodically arranged along the crystallographic c-axis

Note 1 to entry: The crystal structure of 4H-SiC is similar to wurtzite with a unit cell having four periodical occupied sites along the <0001> direction.

3.4
6H-SiC
SiC crystal showing a hexagonal symmetry, in which six Si-C layers are periodically arranged along the crystallographic c-axis

Note 1 to entry: The crystal structure of 6H-SiC is similar to wurtzite with a unit cell having six periodical occupied sites along the <0001> direction.

3.5
crystal plane
plane, usually denoted as (hkl), representing the intersection of a plane with the *a*-, *b*- and *c*-axes of the unit cell at distances of 1/h, 1/k and 1/l, where h, k and l are integers

Note 1 to entry: The integers h, k and l are usually referred to as the Miller indices of a crystal plane.

Note 2 to entry: In 4H-SiC showing a hexagonal symmetry, four-digit indices are frequently used for planes ($hkil$).

[SOURCE: ISO 24173:2009, 3.2, modified – Note 2 to entry has been entirely redrafted.]

3.6
crystal direction
direction, denoted as [uvw], representing a vector direction in multiples of the basis vectors describing the *a*–, *b*- and *c*-axes

Note 1 to entry: In 4H-SiC showing a hexagonal symmetry, four-digit indices [$uvtw$] are frequently used for crystal directions.

Note 2 to entry: Families of symmetrically equivalent directions are written by <uvw> and <$uvtw$> for cubic and hexagonal symmetries, respectively.

[SOURCE: ISO 24173:2009, 3.3, modified – Note 1 to entry and Note 2 to entry have been added.]

3.7
polytypism
phenomenon where a material occurs in several structural modifications, each of which can be regarded as built up by stacking layers of identical structure and chemical composition

3.8
polytype
one of the modifications of monocrystalline material which shows polytypism

3.9
substrate
material on which homoepitaxial layer is deposited

3.10
homoepitaxial layer
thin monocrystalline film epitaxially-formed on a substrate of the same material and crystallographic orientation, inheriting the atomic order of the substrate

3.11
crystal
monocrystalline material

3.12
lattice site
arrangement position of the atoms in crystal

3.13
basal plane
plane perpendicular to the crystallographic c-axis in a hexagonal crystal

3.14
prism plane
plane parallel to the crystallographic c-axis in a hexagonal crystal

3.15
crystallographic c-axis
principal axis in a hexagonal crystal

3.16
defect
crystalline imperfection

Note 1 to entry: Defect of SiC homoepitaxial wafers including point defect, extended defects, surface defects, and others.

3.17
crystal defect
local alteration of crystal periodicity

Note 1 to entry: Crystal defect is generally classified into point and extended defects.

3.18
point defect
crystal defect that occurs at or around a single lattice site, such as a vacancy, interstitial, antisite, impurity and complex

3.19
vacancy
lattice site of a lack of atom in crystal

3.20
interstitial
atom that occupies a site in monocrystalline material, at which atoms usually do not exist

3.21
extended defect
crystal defect extended in space in one, two or three-dimension

3.22
dislocation
linear crystallographic defect in monocrystalline material

3.23
micropipe
hollow tube extending approximately normal to the basal plane

3.24
threading screw dislocation
TSD
screw dislocation penetrating through the crystal approximately normal to the basal plane

3.25
threading edge dislocation
TED
edge dislocation penetrating through the crystal approximately normal to the basal plane

3.26
basal plane dislocation
BPD
dislocation lying on the basal plane

3.27
partial dislocation
dislocation encompassing a stacking fault

3.28
Frank partial dislocation
dislocation encompassing a Frank-type stacking fault

3.29
Shockley partial dislocation
dislocation encompassing a Shockley-type stacking fault

3.30
Si-core partial dislocation
partial dislocation having Si-Si bonds at the dislocation core

3.31
C-core partial dislocation
partial dislocation having C-C bonds at the dislocation core

3.32
stacking fault
planar crystallographic defect in monocrystalline material, characterized by an error in the stacking sequence of crystallographic planes

3.33
basal plane stacking fault
stacking fault lying on the basal plane

3.34
prismatic fault
stacking fault lying on the prism plane

3.35
Frank-type stacking fault
stacking fault where atomic displacement occurs in the direction perpendicular to the plane on which the stacking fault lies

3.36
Shockley-type stacking fault
stacking fault where atomic displacement occurs in the direction parallel to the plane on which the stacking fault lies

3.37
surface defect
morphological irregularity on the homoepitaxial layer surface, not associated with extended defects in the underlying layer

3.38
bunched-step
surface steps of multiple height of unit steps, which are formed by coalescing unit steps into a large single step