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INTERNATIONAL STANDARD

Semiconductor devices – Non-destructive recognition criteria of defects in silicon carbide homoepitaxial wafer for power devices –
Part 2: Test method for defects using optical inspection

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International Standard IEC 63068-2 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
47/2475/CDV	47/2522A/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- withdrawn,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. These 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 some issues including high costs, low yield, and low long-term reliability. In particular, one of the serious issues lies in the defects existing in SiC homoepitaxial wafers. Although efforts of decreasing defects in SiC homoepitaxial wafers are actively implemented, there are a number of defects 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. This document provides definitions and guidance in use of optical inspection for detecting defects in commercially available silicon carbide (SiC) homoepitaxial wafers.

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 2: Test method for defects using optical inspection

1 Scope

This part of IEC 63068 provides definitions and guidance in use of optical inspection for detecting as-grown defects in commercially available 4H-SiC (Silicon Carbide) epitaxial wafers. Additionally, this document exemplifies optical images to enable the detection and categorization of the defects for SiC homoepitaxial wafers.

This document deals with a non-destructive test method for the defects so that destructive methods such as preferential etching are out of scope in this document.

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
optical inspection
morphological inspection of wafers using optical imaging where an optical image sensor scans the wafer surface under a non-contact test method for obtaining features of defects, e.g. size and shape of defects

3.2
optical imaging
technique for capturing, processing and analysing images of defects using light source for illumination, optical components, optical image sensor and computer systems

3.3
illumination
application of light to defects and their surroundings so that they can be observed

3.4
reflective illumination
illumination for observing the reflected light from defects by irradiating light onto the wafer surface

3.5
directional lighting
lighting in which the light to the wafer is incident from a particular direction

3.6
diffused lighting
lighting in which the irradiation direction of the light to the wafer is random

3.7
bright-field observation
method of image capturing in which an optical image sensor detects both lights reflected and scattered from defects

3.8
dark-field observation
method of image capturing in which an optical image sensor detects only light scattered from defects

3.9
differential interference contrast observation
method of image capturing in which contrast derives from the difference in optical path between adjacent points on the wafer surface by irradiating two orthogonal polarized lights which are spatially displaced

3.10
polarized light observation
method of image capturing in which an optical image sensor detects a polarized light using polarizing plates in a path from defects by irradiating polarized light

3.11
optical image sensor
device to transform an optical image into digital data

3.12
optical component
lenses, mirrors, filters and other components, which comprise an optical system and are used to capture optical images

3.13
image capturing
process of creating a two-dimensional original digital image of defects on the wafer surface

3.14
original digital image
digitized image taken by an optical image sensor, without performing any image processing

Note 1 to entry: Original digital images are divided into pixels by a grid, and one grey level is assigned to each pixel.

3.15
charge-coupled device
CCD
light-sensitive integrated circuit that stores and displays the data for optical images

Note 1 to entry: CCD chips are subdivided into fine elements, each of which corresponds to a pixel of original digital images.

3.16
pixel
smallest formative element of original digital images, to which a grey level is assigned

3.17
resolution
number of pixels per unit length (or area) of original digital images

Note 1 to entry: If resolutions in the X- and Y- directions are different, both values have to be recorded.

3.18
grey level
shade of grey assigned to each pixel

Note 1 to entry: Shade of grey is usually a positive integer taken from grey scale.

3.19
grey scale
range of grey shades from black to white

EXAMPLE: 8-bit grey scale has two-to-the-eighth-power (= 256) grey levels. Grey level 0 (the 1st level) corresponds to black, grey level 255 (the 256th level) to white.

3.20
image processing
software manipulation of original digital images to prepare for subsequent image analysis

Note 1 to entry: For example, image processing can be used to eliminate mistakes generated during image capturing or to reduce image information to the essential.

3.21
binary image
image in which either 0 (black) or 1 (white) is assigned to each pixel

3.22
brightness
average grey level of a specified part of optical images

3.23
contrast
difference between the grey levels of two specified parts of optical images

3.24
shading correction
software method for correcting non-uniformity of the illumination over the wafer surface

3.25
thresholding
process of creating a binary image out of a grey scale image by setting exactly those pixels whose value is greater than a given threshold to white and setting the other pixels to black.

Note 1 to entry: To make a binary image, grey level 0 (black) or 1 (white) is assigned to each pixel in the grey-scale image, depending on whether the pixel indicates a grey level greater than or less than or equal to a given threshold.

3.25.1
edge detection
method of isolating and locating edges of defects and surface features in a given digital image

3.26
image analysis
extraction of imaging information from processed digital images by software

3.27
image evaluation
process of relating a series of values resulting from image analysis of one or more characteristic images via a classification scheme of defects

3.28
reference wafer
specified wafer used for parameter settings, which has already been evaluated for checking the reproducibility and repeatability of optical inspection process for defects

3.29
test wafer
SiC homoepitaxial wafers provided to evaluate defects

3.30
crystal direction
direction, usually denoted as [uvw], representing a vector direction in multiples of the basis vectors describing the a, b and c crystal axes

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

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

3.31
defect
crystalline imperfection

3.32
micropipe
hollow tube extending approximately normal to the basal plane

3.33

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

3.34
threading edge dislocation
TED
edge dislocation penetrating through the crystal approximately normal to the basal plane

3.35
basal plane dislocation
BPD
dislocation lying on the basal plane

3.36
scratch trace
dense low of dislocations caused by mechanical damages on the substrate surface