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INTERNATIONAL STANDARD

colour inside

Printed electronics – Part 402-3: Printability – Measurement of qualities – Voids in printed pattern using a two-dimensional optical image

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FOREWORD

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International Standard IEC 62899-402-3 has been prepared by IEC technical committee 119: Printed Electronics.

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

FDIS	Report on voting
119/346/FDIS	119/350/RVD

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

A list of all parts in the IEC 62899 series, published under the general title *Printed electronics*, can be found on the IEC website.

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

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- withdrawn,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

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INTRODUCTION

This document contains fundamental information on the measurement of voids in a printed pattern in printed electronics. Void in this document is defined as a very small non-patterned part of a printed pattern, caused by the printing condition and ink properties, and treated as two-dimensional on a substrate. It can be seen that the terms void and pinhole used in the electronics and graphic printing industries, and the term void used in this document are different. There can be three kinds of absence of materials in the pattern. First, an absence of material inside the solid pattern, which is generally called void in the electronics industry. In this case, there is a vacancy inside the pattern but no imperfection area observed from a two-dimensional (2D) top-view. Therefore, it cannot be defined in the graphic printing industry where only two-dimensional (2D) images are meaningful. Second, there can be a hole penetrating from the surface of the printing layer to the substrate. This case can be observed as a hole in the printing area, and is called a pinhole in the electronics industry and a void in the graphic printing industry, respectively. The third one is a deep hole that does not penetrate into the substrate, therefore it is observed as a hollow in a 2D top-view of a printing image. In the electronics industry, this case is called hollow or pit, and in the graphic printing industry, it is called hollow or void in general. This document deals with the second and third cases, and focuses on the 2D image of the printed pattern; therefore, the term void is used in this document according to the generally used definition in the graphic printing industry. Voids should not exist in the printed patterns which constitute the printed electronics devices to be commercialized for the stable and reliable performance of the devices. The detection and analysis of voids in the pattern can provide guidelines to evaluate the printability of the process, inks, and equipment, therefore, it is possible to manage and control the performance of the printed electronics devices by measuring and analysing the voids at the patterning process from the point of view of printability. An easy way to detect voids in the printed pattern can be to use a three-dimensional (3D) profiler, however, it is too expensive to install in small-sized manufacturing facilities. Therefore, this document provides a measurement method of voids using a 2D image obtained by a conventional optical microscope or camera. This document includes the measurement procedures of voids and related attributes such as numbers, size, and ratio of voids within the pattern. In the area of the void, the thickness of the pattern changes gradually: the pattern thickness decreases gradually and finally becomes zero at the void, which is a three-dimensional characteristic of the void. The boundary of the void can be different depending on the definition of the meaningful thickness of the pattern near the void area. This document offers a method to determine the boundary between the void and the pattern. Although this document offers a measurement method of voids from the two-dimensional image of the printed pattern, it gives a proper method that can capture the voids considering their three-dimensional structure even from the two-dimensional photo image of the pattern. This simple cost-effective measurement method can offer an easy way to check the voids in the printed pattern in the manufacturing process, and can be useful way for the printed electronics industry to manage the quality of the products at lower cost.

This document excludes the standardization of the measurement system. It specifies the properties related to the voids such as numbers, areas, sizes, etc., in the printed pattern obtained from the optical measurement system.

Operators should avoid misdetection of voids from deeply rough surfaces on the thick pattern such as printed by screen-printing. It is recommended that surface roughness be measured as well for these cases.

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1 Scope

This part of IEC 62899 specifies the optical measurement method for acquiring two-dimensional images of voids and obtaining the void-related attributes in the dried or cured printed patterns which are part of the electronic products in the field of printed electronics. The measurable voids using this document are limited to those that are distinguishable by the optical image measurement.

NOTE In this document, void means an imperfection of pattern observed from a two-dimensional (2D) top-view.

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.

ISO 291, *Plastics – Standard atmospheres for conditioning and testing*

3 Terms, definitions and abbreviated terms

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:

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

3.1
region of interest
ROI
area, inside defined boundaries, to be analysed

3.2
background area
part of the area in the ROI that contains the background, excluding the patterned part

3.3
pattern area
part of the area in the ROI that contains the patterned part, and which may include voids, excluding the background

3.4
void
absence of ink in an area that should be inked

3.5
ratio of void
ratio of the total void area to the area of the pattern

3.6
void threshold
B_{ref}
brightness level of the pattern which separates voids and non-voids

3.7
void threshold index
Z
weight factor that determines the value of the void threshold

Note 1 to entry: The void threshold index Z is used for $B_{ref} = B_{back} + (B_{pattern} - B_{back}) \times Z$, where B_{ref} is the void threshold, and B_{back} and $B_{pattern}$ are brightness levels of the background and the pattern, respectively.

3.8
B_{back}
brightness level of the background

3.9
$B_{pattern}$
brightness level of the pattern

4 Atmospheric conditions for evaluation and conditioning

The standard atmosphere for evaluation (test and measurement) and storage of the specimen shall be a temperature of (23 ± 2) °C and relative humidity of (50 ± 10) %, conforming to standard atmosphere class 2 specified in ISO 291. For a plastic test piece which is a substrate with printed patterns, the standard atmosphere for evaluation (test and measurement) and storage of the specimen shall be a temperature of (23 ± 1) °C and relative humidity of (50 ± 5) %, conforming to standard atmosphere class 1 specified in ISO 291.

Unless otherwise specified, the conditions shall be reported.

If conditioning is necessary, the same standard atmosphere specified above shall apply.

5 Measuring methods and instruments

5.1 Measuring instrument

The measurement of voids in the pattern shall be carried out with an instrument that can obtain the image of the pattern. The repeatability and accuracy of the measuring instrument should be less than 10 % of the tolerance specification of the smallest dimension of the voids that the measurer wants to measure. In the measurement system, the image of the pattern should be converted to an image file. The image should include the pixel information without loss due to compression (e.g. causes of jpeg compression). The pixel dimension or resolution of the image is determined by agreement between the user and supplier; if not, the pixel dimension of the image should be less than half of the smallest dimension of the void that the measurer wants to measure. If working with the resolution instead of the pixel dimension, this requirement should be fulfilled accordingly.

5.2 Preparation of specimen

The measuring area of the specimen is determined by agreement between the user and supplier. The specimen should be kept flat during the measurement. The specimen to measure voids in the pattern necessarily contains the background area which does not have the pattern.

5.3 Measuring method

The printed pattern has the form of a line or solid area and can have voids. For the measurement of voids in the pattern, the boundary between the printed area and the void is recognized and the number and area of the void are calculated using an appropriate software. The size information on every measurable void of interest is required. The measurement steps are as follows:

a) Find a region of interest (ROI)

The ROI shall be set to include a whole pattern or a part of the pattern to be measured depending on the size of the pattern. The ROI shall contain both the pattern with voids (measuring area) and the background without the pattern as shown in Figure 1.

b) Define the pattern area

The pattern area shall include only the printed pattern excluding the background area without the pattern as shown in Figure 1.

c) Define the background area

The background area in the ROI shall include only the background area excluding the printed pattern as shown in Figure 1. The brightness of the background area is used to define the void threshold (refer to Annex A).

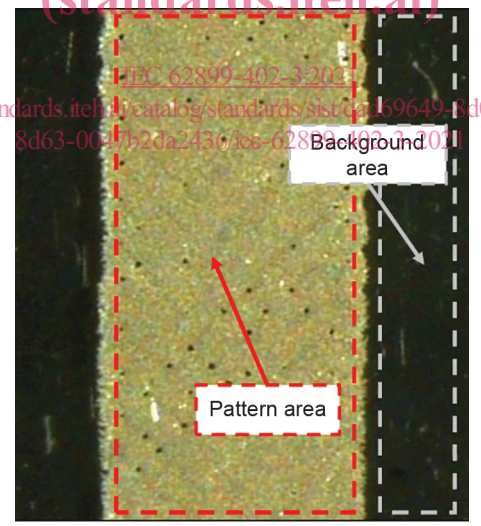

Figure 1 – Definition of pattern area and background area in the ROI of the captured image

d) Measure the mean brightness of the pattern area and the mean brightness of the background area

Using a suitable software that can provide the value of the brightness of a pixel, measure the brightness of all the pixels of the image of the pattern area and calculate their mean value, B_{pattern}. The value of the brightness ranges from 0 (darkest) to 255 (brightest). The description is given based on an 8-bit pixel depth. If the pixel depth is different, the numerical value for the brightest value can vary. Also measure the brightness of all the pixels of the image of the background area and calculate their mean value, B_{back}. Figure 2 shows examples of the distribution of the brightness of the pixels of the pattern area and the distribution of the brightness of the pixels of the background area.

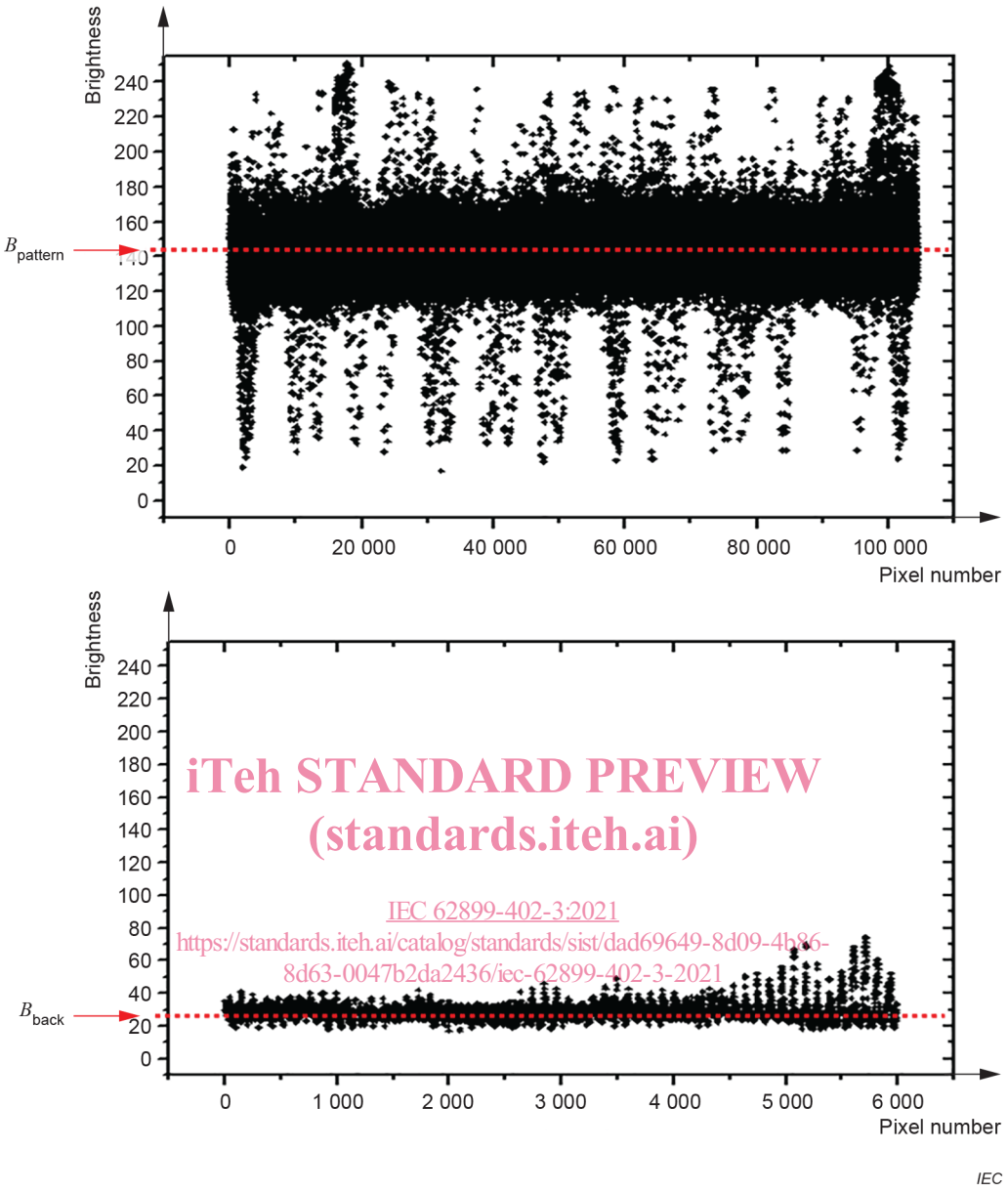

Figure 2 – Distribution of the brightness of the pixels of the pattern area and mean value, and distribution of the brightness of the pixels of the background area and mean value

e) Specification of the void threshold

Define the void threshold B_{ref} which is given by Formula (1):

$$B_{ref} = B_{back} + (B_{pattern} - B_{back}) \times Z \quad (1)$$

where Z, the void threshold index, is the value that the measurer can select depending on the degree of detection of voids ranging from 0 to 1. More details on the void threshold are given in Annex A. The measurer reports the value of Z as shown in Table 1, because Z determines the degree of detection of the voids as described in Annex A.