

INTERNATIONAL STANDARD



**Printed electronics –
Part 402-2: Printability – Measurement of qualities – Edge waviness**

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CONTENTS

FOREWORD.....	3
INTRODUCTION.....	5
1 Scope.....	6
2 Normative references	6
3 Terms and definitions	6
4 Atmospheric conditions for evaluation and conditioning	7
5 Measuring methods and instruments	8
5.1 Image acquisition.....	8
5.2 Measuring instrument.....	8
5.3 Analysis software.....	8
5.4 Preparation of image (specimen)	9
5.5 Data collection and analysis.....	9
5.6 Obtaining edge waviness and related attributes	12
6 Report of results	12
6.1 Test identification information	12
6.2 Instrument specification	12
6.3 Results	12
Bibliography.....	13
Figure 1 – ROI image of the specimen, and inner edge and test line selection	9
Figure 2 – Distribution graph of pattern edge waviness	10
Figure 3 – Distribution graph of pattern edge waviness of the sample with a spike on the edge	11
Figure 4 – Distribution graph of pattern edge waviness of the sample with a groove on the edge	11
Table 1 – Reporting items (example)	12

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PRINTED ELECTRONICS –

**Part 402-2: Printability –
Measurement of qualities – Edge waviness**

FOREWORD

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International Standard IEC 62899-402-2 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
119/310/FDIS	119/317/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 document 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 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- withdrawn,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.

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INTRODUCTION

This part of IEC 62899-402 describes the measurement methods of printed patterns to evaluate their printability in the field of printed electronics. Printability is defined as both the qualities of printed patterns and the reproducibility of printing designs as the interaction result of printing media, inks and substrates. The qualities of printed patterns are satisfied by accurate measuring of the printed patterns two- and/or three-dimensionally with mechanical, physical and optical apparatus. The reproducibility of printing designs is achieved by estimating the reproducibility of replica. In terms of the business background, the requests from the industry applying the printing technology to the electronics manufacturing concern the guarantees of both the quality and reproducibility of printed patterns and printing designs to facilitate international trade and enhance user value in the field of printed electronics.

This document provides fundamental information on the measurement of printed pattern edge waviness to evaluate the printability in the field of printed electronics. An assurance of printability enhances user value of printed electronics and facilitates international trade. This document includes the measurement procedure, as well as the definition of edge waviness and related attributes such as average edge, touch edge and distribution edge of edge waviness, which are quite different from those that appear in the printing of graphic arts or from etching processes.

This document excludes the standardization of any kind of measurement equipment or system. It focuses on specifying the properties related to edge waviness of the printed patterns obtained by an optical measurement system.

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PRINTED ELECTRONICS –

Part 402-2: Printability – Measurement of qualities – Edge waviness

1 Scope

This part of IEC 62899 describes the measurement methods of the edge waviness of printed patterns in printed electronics.

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 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

inner edge

line drawn in a tangent to the innermost edge point and parallel to the pattern's centre line

3.2

test line

selected line on a sample pattern edge (parallel to the inner edge) to test the edge waviness

3.3

background gray value

gray value of the line which is in the area without any printed patterns and parallel to the inner edge

Note 1 to entry: A centre line between two adjacent printed patterns is recommended.

3.4

average edge

1 σ edge

distance to the inner edge of a gray ratio of more than 0,68 (single standard deviation in Gaussian distribution)

3.5**relative gray value****RGV**

relative gray value of the line to the background gray value

Note 1 to entry: RGV can be obtained by subtracting the background value from the original gray value.

3.6**touch edge****2 σ edge**

distance to the inner edge of an RGV ratio of more than 0,95

Note 1 to entry: This is referred to as the double standard deviation.

3.7**distribution edge****3 σ edge**

distance to the inner edge of an RGV ratio of more than 0,99

Note 1 to entry: This is referred to as the triple standard deviation.

3.8**distribution graph**

curve graph based on the RGV ratio between the test line and inner edge (termed y axis) correlation with the distance to the inner edge (termed x axis)

3.9**region of interest****ROI**

area (inside defined boundaries) that the user wants to analyse

3.10**sampling length**

length along the direction of the edge waviness, containing at least five successive cycles of peak and valley

3.11**edge waviness**

degree to which a pattern edge conforms to a measurement plane

Note 1 to entry: In this document, the edge waviness specifies the amplitude of the edge line.

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 $(23 \pm 2) ^\circ\text{C}$ and relative humidity of $(50 \pm 10) \%$, 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 $(23 \pm 1) ^\circ\text{C}$ and relative humidity of $(50 \pm 5) \%$, conforming to standard atmosphere class 1 specified in ISO 291.

Unless mentioned otherwise, the atmospheric conditions shall be reported.

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

5 Measuring methods and instruments

5.1 Image acquisition

The optics of the image acquisition system shall give a magnification such that the field of view parallel to the edge is sufficient to include a statistically significant sample of the edge. The printed test image shall contain a straight edge of a statistically significant length in comparison to the roughness spectrum or any periodicity of the substrate or printing method.

In some cases, a flatbed scanner can provide resolution that shows a magnified edge image with the variations. In other cases, optical cameras or microscopes working in the transmission or reflection mode can be necessary. The lighting shall be uniform across the field of view.

The numerical aperture of the optics shall be sufficient to provide a depth of field adequate to observe the topography of the sample.

The electronic imaging device shall provide a sampling resolution that is sufficient to acquire the edge waviness.

5.2 Measuring instrument

The optical microscope shall have at least 20 times magnification.

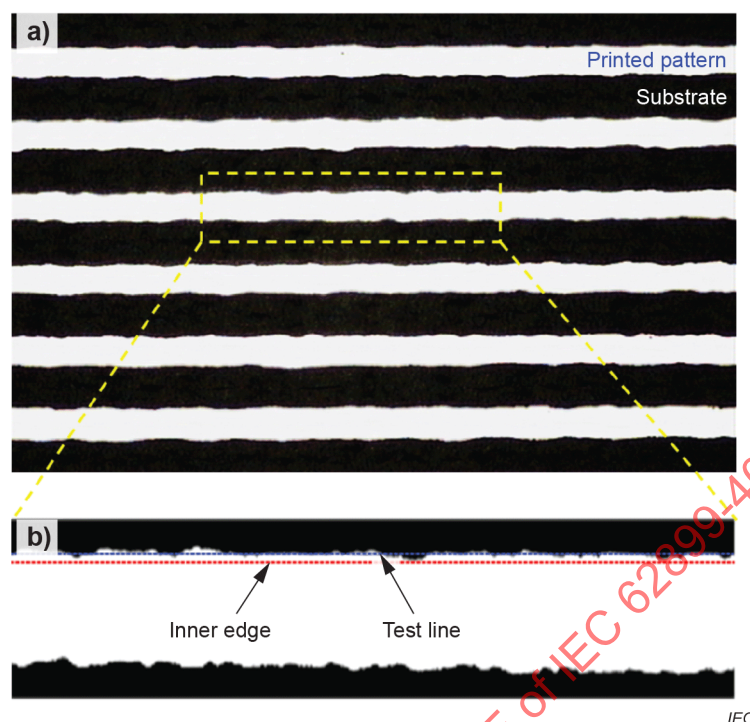
The optical microscope shall have as its light source a halogen lamp, LED light or other visible light sources.

A charge coupled device (CCD) and complementary metal-oxide semiconductor (CMOS) imaging device with 8 mega or advanced pixels are suggested.

5.3 Analysis software

Image processing software shall have a gray value readout function.

5.4 Preparation of image (specimen)



a) A measurement of the printed silver ink parallel linear array sample is performed.

b) An amplified segment line pattern of Figure 1a) is selected as the ROI.

Figure 1 – ROI image of the specimen, and inner edge and test line selection

Figure 1 shows how to capture the area of the specimen to measure the pattern edge waviness. The images were taken via a reflective microscope for Ag nanoparticle ink printed patterns on a transparent polymer substrate. Based on the printed pattern and its edge waviness, the ROI shall be captured, as described in 5.1, at an adequate resolution and magnification under a microscope. It shall be noted that the printed pattern shall be the bright region, if not, the graph shall be adjusted with the image processing software.

5.5 Data collection and analysis

For the measurement of the edge waviness of the patterns, the critical processes are representative data collection and comprehensive analysis. With appropriate preparation of the instrument and software, the following five steps are performed to achieve the correct measurement and qualification of the printed pattern edge waviness:

1) Find a region of interest (ROI)

First, a ROI on a representative sample shall be selected and captured as an image. The ROI shall contain a complete pattern in the scope of the tested edge waviness. The sampling length shall be measured and specified (see Figure 1).

2) Read the gray and edge values of each distance

Using a suitable software, the gray value of the test line and its distance to the inner edge can be read. The pixel number on the inner edge and the various test lines shall be exactly the same to guarantee an accurate analysis.

3) Calculate the RGV ratio

After serial data collection of the inner edge and various gray values of the test lines, the RGV ratio (see Formula (1)) of the inner edge and the RGV ratio of the distance to the inner edge shall be calculated.

$$\text{RGV ratio} = 1 - \frac{\text{RGV}_{\text{test line}}}{\text{RGV}_{\text{inner edge}}} \quad (1)$$

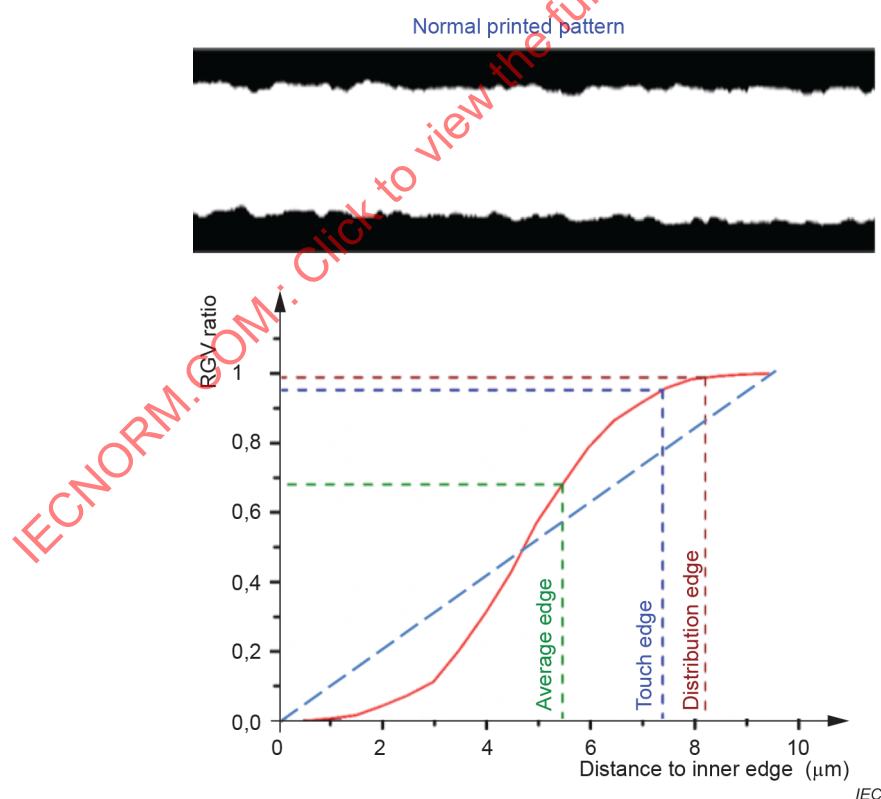
To obtain the accurate distribution graph, at least five equidistant test lines containing all the complete waviness scopes in the ROI shall be measured homogeneously. Then, the distribution curve of the RGV ratio-distance to the inner edge can be achieved with suitable mathematical smoothing. The experiments shall be repeated five times to confirm that the distribution curve is representative.

4) Read the edges

Read all the edges (average, touch and distribution) at the distribution graph. The RGV ratio with a single standard deviation ($1\sigma = 0,68$) corresponds to the average edge distance; the RGV ratio with a double standard deviation ($2\sigma = 0,95$) corresponds to the touch edge distance; and the RGV ratio with a triple standard deviation ($3\sigma = 0,99$) corresponds to the distribution edge distance, respectively.

5) Distribution curve variation analysis

The shape distribution curve varies with the different kinds of edge shapes. The graphs in Figure 2 to Figure 4 provide distribution curves derived from three kinds of edge samples: a normal edge, an edge with a spike (the salient bug pointed to the outer edge of the pattern, see the upper part of Figure 3) and an edge with a groove (the enclosed bug pointed to enter the edge of the pattern, see the upper part of Figure 4). For the regular sample without mutant, the distribution curve shows a balanced distribution along the diagonal. When there is a spike or a groove, the distribution curve shifts to one side of the diagonal. The distribution graph is an effective way not only to determine the average edge, touch edge, and distribution edge, but also to evaluate qualitatively the edge quality based on the shape of the curve.



NOTE The average edge, touch edge, and distribution edge are shown on the distribution graph. The sample is a normal printed pattern.

Figure 2 – Distribution graph of pattern edge waviness

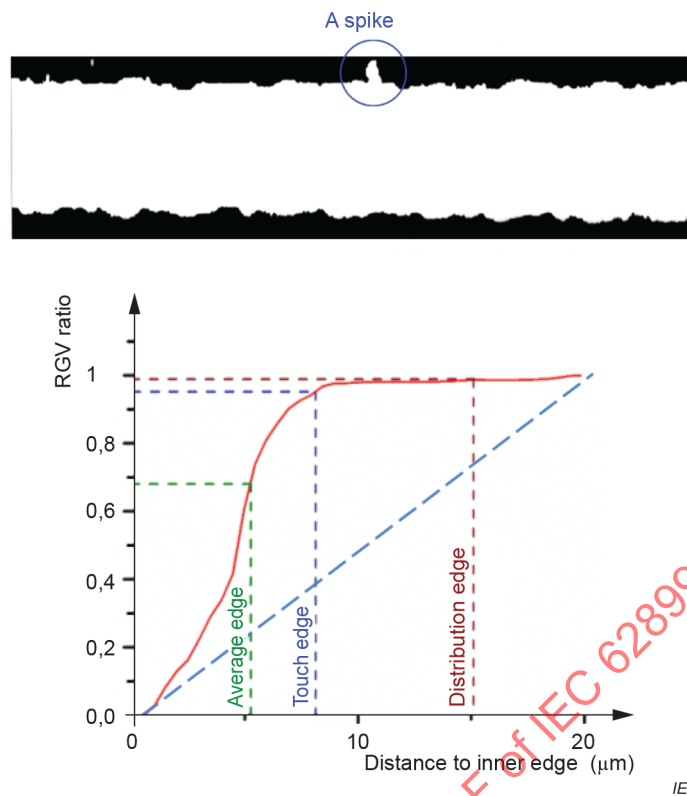


Figure 3 – Distribution graph of pattern edge waviness of the sample with a spike on the edge

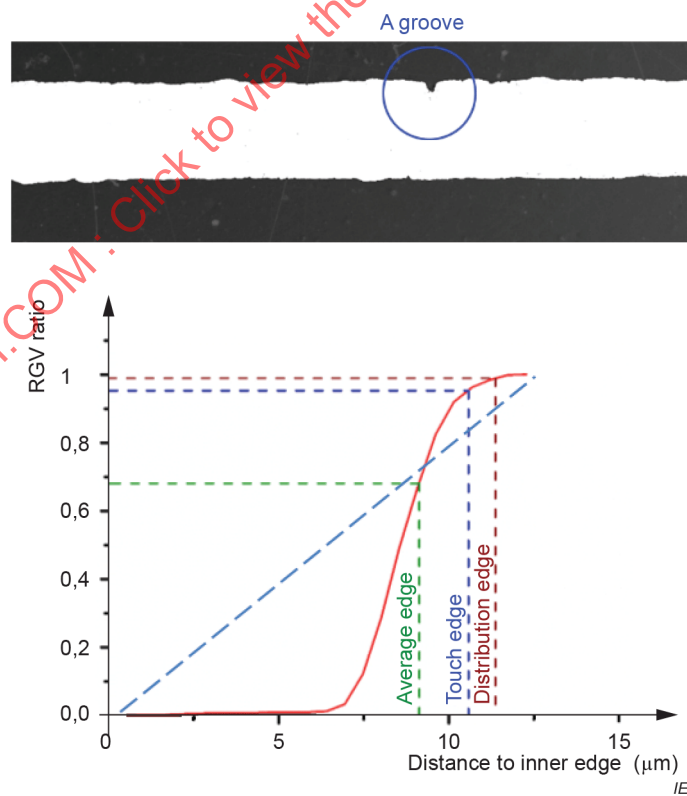


Figure 4 – Distribution graph of pattern edge waviness of the sample with a groove on the edge

5.6 Obtaining edge waviness and related attributes

With the information obtained in Figure 3 or Figure 4, the edge waviness and related attributes can be obtained:

- a) average edge (1σ edge): 9,10 μm → Figure 4;
- b) touch edge (2σ edge): 12,90 μm ;
- c) distribution edge (3σ edge): 15,38 μm → Figure 3.

6 Report of results

6.1 Test identification information

The report shall include the date of the measurements, the identity of the operator, the lot control identification, and the sampled position of the image.

6.2 Instrument specification

The report shall include a description of the instrument system used along with its specification, for example, the type of instrumentation and the resolution.

6.3 Results

The report shall include the items given in Table 1. The right column of Table 1 shows an example of what shall be included in the description.

Table 1 – Reporting items (example)

ORIGINATOR	Institute of Chemistry, Chinese Academy of Sciences
Test description	Results of May 13, 2015 print set
Date of report	May 20, 2015
Test operator	Optical microscope
INSTRUMENTATION	Optical microscope,
Type	8-Mpixel CCD
Resolution	2 μm
Pixel size	2 μm
MEASUREMENT SOFTWARE	
Measurement and analysis software	Image processing software
Version number	3.1
Edge detecting method	
TOLERANCE	
Edge waviness attributes measurements	Within the tolerance
SAMPLING SCHEME	Random sampling
PATTERN EDGE WAVINESS ATTRIBUTES	
Average edge	9,10 μm
Touch edge	12,90 μm
Distribution edge	15.38 μm