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TECHNICAL REPORT

colour inside

Printed electronics – Part 402-4: Printability – Measurement of qualities – Classification and measurement methods for morphology

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FOREWORD

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IEC TR 62899-402-4 has been prepared by IEC technical committee 119: Printed Electronics. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
119/300/DTR	119/357/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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 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- withdrawn,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.

INTRODUCTION

The IEC 62899-402 series specifies basic measurement methods for printed patterns prepared using printed electronics technology. An overview of the documents in the IEC 62899-402 series is given in IEC 62899-401.

Since the surface morphologies of printed patterns strongly affect the electrical properties of patterns as well as the printing process such as overlay printing onto the patterns, IEC TC 119 plans to prepare other documents to measure the vertical variance of printed patterns, such as the future IEC 62899-402-5 which deals with "'surface roughness", the future IEC 62899-402-6 which deals with "thickness" and the future IEC 62899-402-7 which deals with "surface profile"'. These future documents were designed based on assumptions from classical technologies such as photolithography. However, the cross section of patterns by photolithography has usually a trapezoidal or rectangular shape, and the surface of the patterns is always flat and smooth. In contrast, the actual surface of the printed pattern has various morphologies, because the characteristic surface morphologies are formed by the various printing technologies used in printed electronics, and factors that cannot be controlled perfectly are included in the process of forming the surface. Reflecting those features, the range of variance to be measured in the area of printed electronics becomes very broad, and various measurement methods are used in those measurements. In order to prepare the subsequent documents, the current measurement methods should be reviewed in a technical report. This review will clarify the relation between the morphologies and the appropriate measurement methods.

According to the complicated surface morphologies, it is not easy to specify the measuring point on the surface. This problem will also be reviewed in this document by organizing the definitions of morphologies.

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Part 402-4: Printability – Measurement of qualities – Classification and measurement methods for morphology

1 Scope

This part of IEC 62899-402, which is a Technical Report, is a preparatory work for the documents dealing with the measurement method of the vertical direction (surface forms) of printed patterns made by printed electronics technology.

The printed pattern of interest in this document is limited to straight lines on substrates with a flat surface. This document focuses on the classification and measurement methods for surface forms from the nanometer scale to the micrometer scale, and suggests the strategy for the subsequent documents.

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 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
pattern profile
characteristics of the cross sectional form in the width direction

Note 1 to entry: Three shapes, ie trapezoid, arch and side horn are proposed as typical shapes (see Figure 1).

Figure 1 – Typical pattern profile

Note 2 to entry: The side horn shape is called coffee stain in the academic area. However side horn is used in this document.

3.2
micro surface roughness of the printed pattern
amplitude and short-wavelength (less than 10 µm) component of the surface

3.3
thickness of the printed pattern
improved thickness
maximum distance between the top surface and bottom side in the width direction of the printed pattern

3.4
pattern roughness in the line direction
variation in thickness in the line direction

4 Classification of surface forms for future standardization work

Surface forms can be classified as shown in Figure 2. "Pattern micro roughness" expresses the finest unevenness (less than 5 µm) on the surface of the printed lines. "Pattern profile" includes a larger unevenness (from 5 µm to 200 µm). The area of "Pattern roughness" (or waviness) overlaps "Pattern profile", but this shows the waviness with a long range frequency and can be separated from the fine unevenness. "Pattern thickness" can be based on a different concept than the above three parameters, but it is also added to Figure 2 since it has a deep relation with these parameters.

Standards on the measurements for the vertical direction can be prepared according to this classification.

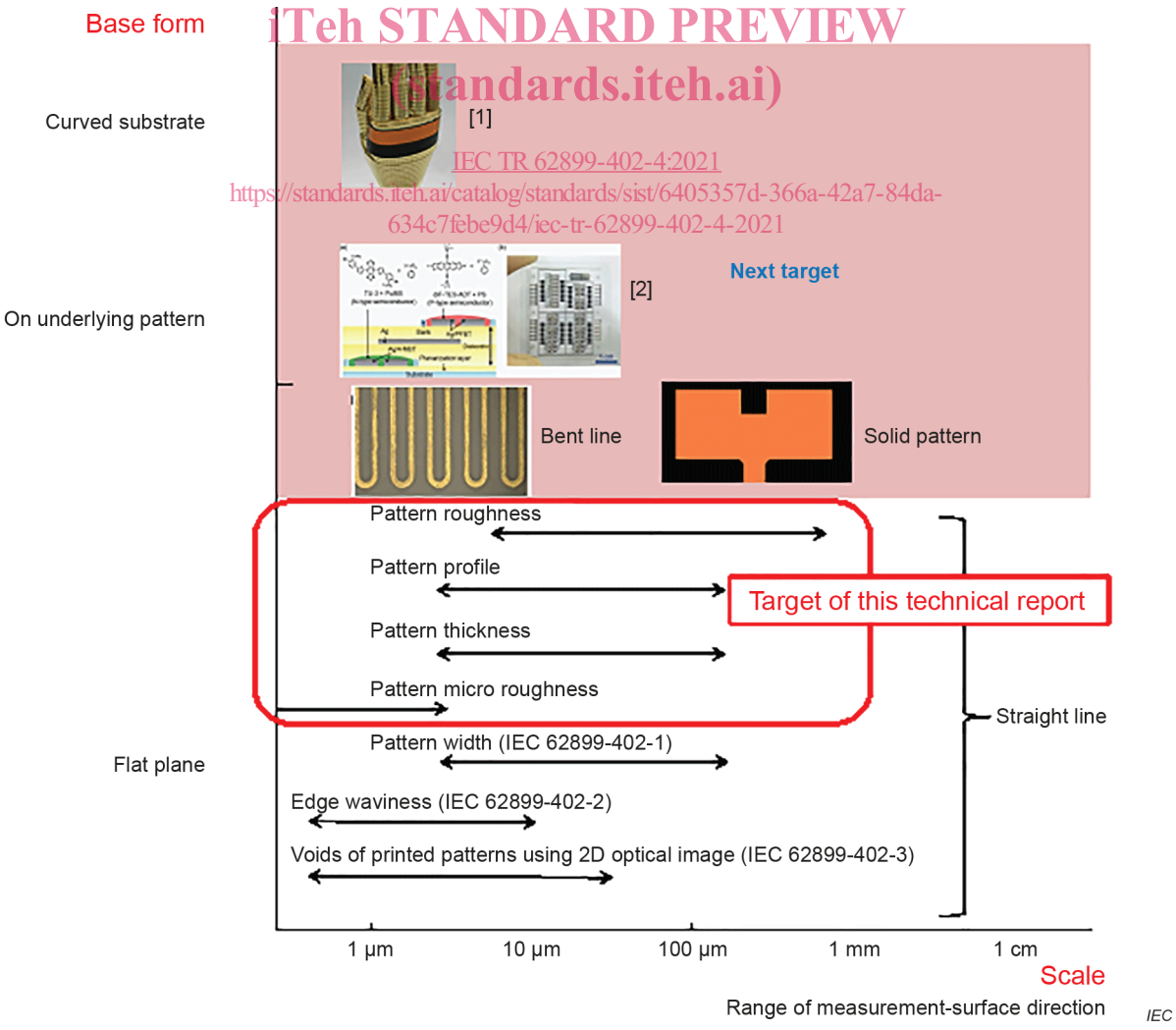


Figure 2 – Classification of parameters and future standardization work in TC 119

5 ISO documents concerning surface roughness

ISO/TC 213 (Dimensional and geometrical product specifications and verification) is a TC that handles product dimensions and tolerances. Since the surface roughness is one of the factors that affects them, ISO/TC 213 has prepared many standards related to the surface roughness such as data processing, definitions of terms (see Figure 3). However, it is not possible to find a document for the measurement method that can be directly used in the printed electronics industry. The summary of the ISO standards is listed in Table 1.

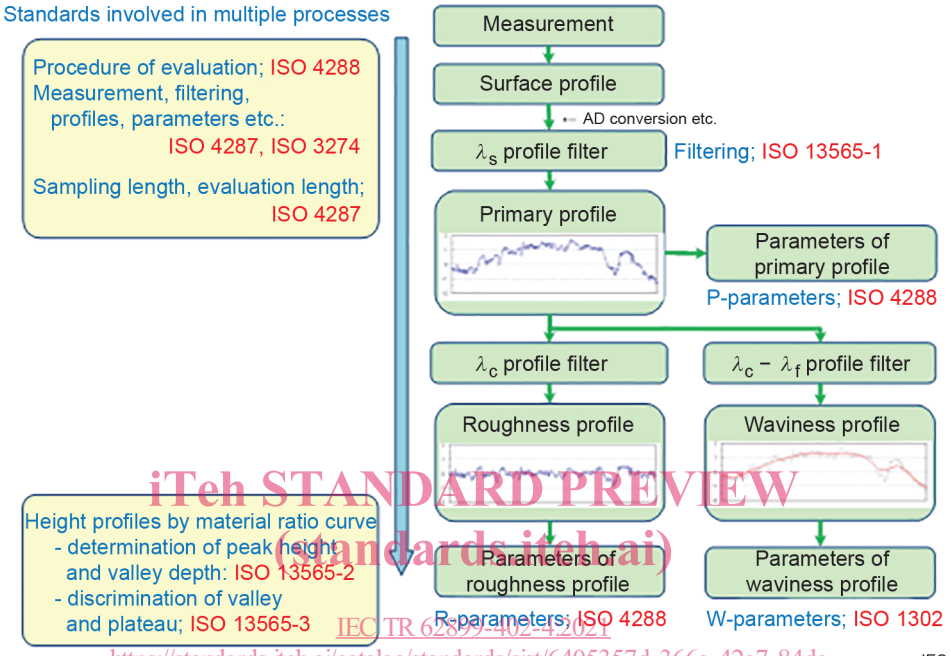


Figure 3 – Flow of data processing and related standards

Table 1 – The ISO standards related to the surface roughness

Document No	Title	Brief summary
ISO 1302 [8]	Geometrical Product Specifications (GPS) – Indication of surface texture in technical product documentation	This document specifies the rules for the indication of surface texture in technical product documentation. The parameters of waviness profile are described.
ISO 3274 [9]	Geometrical Product Specifications (GPS) – Surface texture: Profile method – Nominal characteristics of contact (stylus) instruments	Describes profiles and the general structure of contact (stylus) instruments for measuring surface roughness and waviness.
ISO 4287 [10]	Geometrical Product Specifications (GPS) – Surface texture: Profile method – Terms, definitions and surface texture parameters	Surface profile parameters such as peak, valley, curves and related parameters are defined.
ISO 4288 [11]	Geometrical Product Specifications (GPS) – Surface texture: Profile method – Rules and procedures for the assessment of surface texture	The rules of basic procedure on evaluation are described, and this also gives rules for measuring roughness profile parameters by using stylus instruments according to ISO 3274.
ISO 13565-1 [12]	Geometrical Product Specifications (GPS) – Surface texture: Profile method; Surfaces having stratified functional properties – Part 1: Filtering and general measurement conditions	Describes a filtering method. This filtering method suppresses the valley influence on the reference line such that a more satisfactory line is generated. The method will be effective when the surfaces have a relatively small amount of waviness.

Document No	Title	Brief summary
ISO 13565-2 [13]	Geometrical Product Specifications (GPS) – Surface texture: Profile method; Surfaces having stratified functional properties – Part 2: Height characterization using the linear material ratio curve	This document contains the determination of peak height and valley depth and the evaluation process.
ISO 13565-3 [14]	Geometrical Product Specifications (GPS) – Surface texture: Profile method; Surfaces having stratified functional properties – Part 3: Height characterization using the material probability curve	This part of ISO 13565 provides a numerical characterization of surfaces consisting of two vertical random components, namely, a relatively coarse "valley" texture and a finer "plateau" texture.

6 Examples of measurement

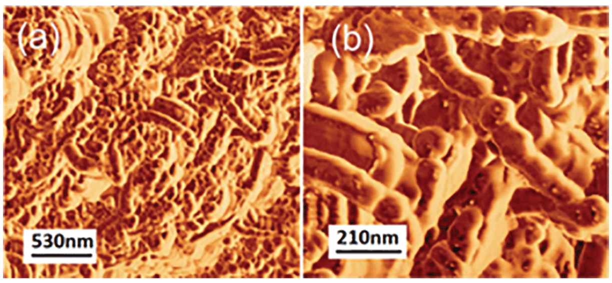
6.1 Micro surface roughness of the printed pattern

6.1.1 AFM approach

AFM (atomic force microscope) is one of the tools that are able to quantitatively measure the surface roughness. This measurement can be applied to the even surface of the printed pattern, and preferably applied to measure the small unevenness caused by particles since it has a resolution of 5 nm to 10 nm laterally and sub-nanometer vertically. The measurement area of AFM is generally 1 μm^2 to 10 μm^2.

Examples of the AFM measurement can easily be found, but there are not so many cases applied to the surface of printed layers.

AFM analysis on the printed pattern is reported by Menon et al.[3][1]. The pattern was prepared by the screen printing and carbon nanotube (CNT) ink (multiwalled carbon nanotubes (MWCNTs) are used as CNT). Intertwine between MWCNTs is quite important since it greatly affects the conductivity and other properties. The resolution of AFM measurement is appropriate for the detection of the diameter and length of CNT and is suitable for evaluating intertwine. (see Figure 4). The RMS of surface roughness is obtained in this document. However, the detail of the relationship between the surface roughness and conductivity is not mentioned.



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SOURCE: See [3].

Figure 4 – AFM image of MWCNT printed pattern

The R-parameters on the printed carbon electrode are reported by Wongkaew et al. [4]

Immobilization of a bio-recognition element on the surface of a functional working electrode (screen-printed carbon electrode) is fundamental for effective biosensor development. The surface morphology of the working electrode is remarkably changed by enzyme immobilization.

[1] Numbers in square brackets refer to the Bibliography.