# IEC 62899-202-8

Edition 1.0 2024-03

# INTERNATIONAL STANDARD

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**Printed electronics –**
**Part 202-8: Materials – Conductive ink – Measurement of difference in resistance of printing direction of conductive film fabricated with wire-shaped materials**

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

| Draft | Report on voting |
|---|---|
| 119/476/FDIS | 119/483/RVD |

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 International Standard 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/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.

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# INTRODUCTION

The printing process for fabricating flexible devices is a very promising technology due to its high conductivity and efficiency. Specifically, a printed metal-based conductive layer on a flexible substrate can be employed as electrode or be interconnected for flexible devices. It can be commercialized as a type of composite material where the conductive layer is formed on the substrate as a conductor.

For metal-based transparent conductive (TC) films, silver or copper nanowires or metal mesh on a flexible substrate are a key component for many recently developed electronic products, ranging from smartphones to keypads of appliances such as refrigerators and washing machines. While indium tin oxide (ITO) is the conventional material for TC films, metal-based TC films fabricated using printed electronics technologies are being increasingly used as an alternative. TC film-fabricated nanowires have superior intrinsic properties owing to their wire shape. Their electrical performance can differ based on the printing direction and ink properties. The alignment of a wire depends on the printing equipment, ink composition, printing process, etc. [1] to [3][1].

In this document, a method to evaluate the difference in electrical properties based on the printing direction is proposed. In particular, the proposed method monitors changes in the resistance of a printed metal-based TC film on a flexible substrate.



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

# PRINTED ELECTRONICS –

# Part 202-8: Materials – Conductive ink – Measurement of difference in resistance of printing direction of conductive film fabricated with wire-shaped materials

## 1 Scope

This part of IEC 62899 provides a method for measuring the resistance difference of the printing direction of a printed conductive layer with wire-shaped or wire-type conducting materials. The method described in this document offers a measurement method and conditions for solution processed conductive films, fabricated by coating and printing process.

## 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.

IEC 62899-201, *Printed electronics – Part 201: Materials – Substrates*

IEC 62899-202, *Printed electronics – Part 202: Materials – Conductive ink*

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 terminology databases for use in standardization at the following addresses:

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

**3.1**
**conductive material**
ingredient of a printing or coating material, which itself is electrically conductive or becomes electrically conductive by post treatment such as heating

Note 1 to entry: The ingredient can be one or more small molecules, precursors, polymers, or particles.

Note 2 to entry: The ingredient might require post treatment to provide electrical conductivity.

[SOURCE: IEC 62899-101:2019, 3.19, modified – the notes have been added.]

**3.2**
**conductive ink**
fluid in which one or more conductive materials are dissolved or dispersed, and which is used to form a conducting structure

[SOURCE: IEC 62899-101:2019, 3.17, modified – “chemical precursors, polymers, or particles” have been replaced with “fluid in which one or more conductive materials”, “and which is used to form a conducting structure” has been added to the definition, and Note 1 has been removed.]

**3.3**
**conductive film**
substrate (sheet or roll) with a conductive layer

[SOURCE: IEC 62899-101:2019, 3.16]

**3.4**
**flexible substrate**
substrate showing reversible (i.e. elastic) mechanical behaviour within a certain range of applied mechanical stress

[SOURCE: IEC 62899-101:2019, 3.60, modified – the example has been removed.]

**3.5**
**wire-shaped material**
**wire-type material**
material with a high aspect ratio of length to diameter or width

**3.6**
**machine direction**
**MD**
direction in which the substrate or stock moves during printing

[SOURCE: IEC 62899-101:2019, 3.80]

**3.7**
**cross direction**
**CD**
direction at right angles to the machine direction of a substrate

[SOURCE: IEC 62899-101:2019, 3.25]

## 4 Test sample, apparatus and measuring device

### 4.1 Measurement environmental conditions

The temperature and humidity conditions for evaluation tests shall be at a temperature of 23 °C ± 1 °C, relative humidity of (50 ± 5) %, and an atmospheric pressure in accordance with ISO 291 unless otherwise specified.

### 4.2 Test apparatus

The difference in resistance based on the printing direction can be evaluated by connecting the metal grip and electrical connection to the silver paste and protective layer.

To measure resistance, the test sample can be placed on a rigid plate that connects to the measuring equipment as in Figure 1. The test sample is connected to the measuring equipment with two or four conductive wires.

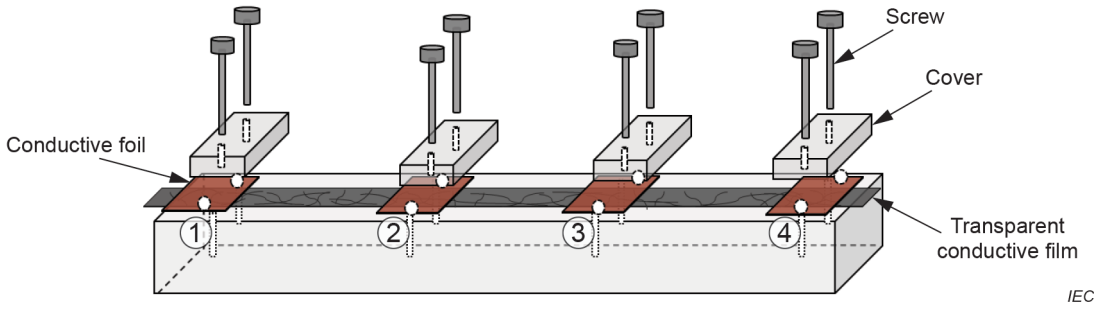


**Figure 1 – Schematic diagram of printed conductive film with screws for a four-wire measurement**

### 4.3 Measuring device

The electrical resistance of a printed conductive film shall be measured using the four-wire measurement method. The conditions for electrical measurement are listed in Table 1.

**Table 1 – Resistance range of the test piece and the applied current**

| **Resistance range of the test piece** | < 20 mΩ | < 200 mΩ | < 20 Ω | < 2 kΩ | < 20 kΩ | < 200 kΩ | < 20 MΩ |
|---|---|---|---|---|---|---|---|
| **Applied current** | 1 A | 100 mA | 10 mA | 1 mA | 100 µA | 10 µA | 1 µA |
| NOTE Table 1 is taken from IEC 62899-202:2023, Table 2. | | | | | | | |

### 4.4 Sample preparation for measuring resistance difference with printing direction

To reduce the line interference of equipment when measuring resistance, a rectangular shaped sample with a ratio over 30 shall be used.

The recommended sample size is 300 mm of length × 10 mm of width.

The tolerance of width and length is ±0,2 mm. The tolerance is based on IEC 62899-201 and IEC 62899-202.

Another size sample whose ratio of the longer side over the shorter side is at least 30 may be used for measuring the resistance anisotropy of the printed conductive layer.

To prepare the printed conductive film samples with different angles as shown in Figure 2 the angles should be measured from the machine direction (MD) as shown in Figure 2. The cross direction (CD) in Figure 2 means the transverse direction of the MD. The CD is at an angle of 90° from the MD. The samples can be prepared with angles of 0° to 180° from the machine direction (MD). The angles for the samples shall be agreed in advance between the trade partners.

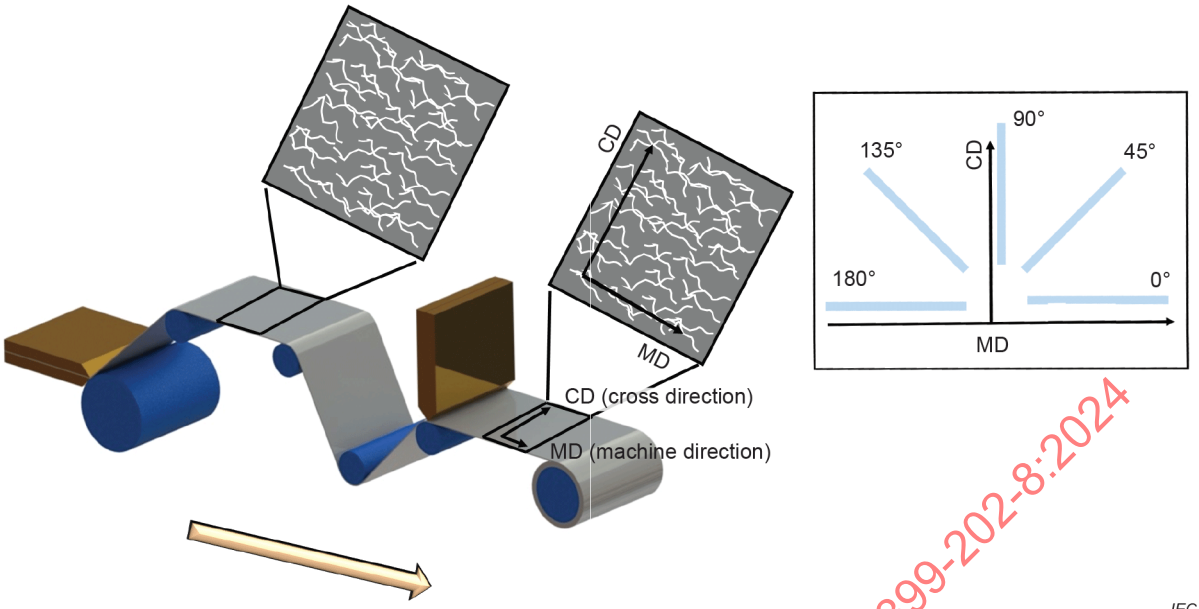


**Figure 2 – Samples with printing direction of conductive film fabricated with wire-shaped materials**

## 5 Test procedure

The test procedure is as follows:

a) Cut out a mother conductive film of minimum size that can be sampled from the film roll.
b) Record the sampling area in the report.
c) Cut out the individual sample pieces with angles from a mother conductive film.
d) Prepare the printed conductive lines.
e) Place the printed conductive film sample on a rigid plate as in Figure 1.
f) The wire connected to the printed conductive film samples is connected to the test equipment.
g) Measure the resistance.
h) Measure at least three strips per sample/angle with an accuracy of two decimals.

The detailed procedure of sample preparation should be referred to as indicated in Annex A.

## 6 Report

### 6.1 Reporting the resistance

The electrical resistance shall be reported as a table or a graph with angles as indicated in Annex A.

To evaluate the resistance difference, the resistance may be reported at various angles.

Report the resistance of at least three strips per sample/angle with an accuracy of two decimals.

### 6.2 Report of the results

The report shall include the following items:

a) specimen identification;
b) temperature;
c) humidity;
d) pressure;
e) angle;
f) resistance;
g) standard deviation of resistance.

# Annex A
(informative)

# Measurement of difference of printing direction of printed conductive film

## A.1 Sample preparation

The sample is prepared as illustrated in Figure A.1.

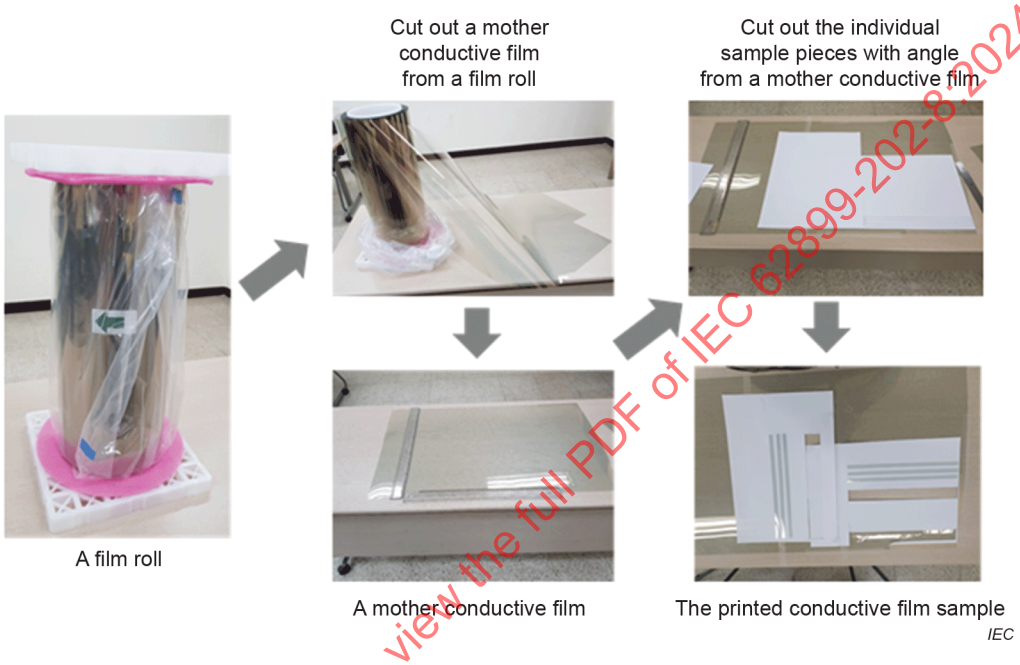


**Figure A.1 – Sample preparation**

## A.2 Settings for the test sample

The settings, tests conditions and test results for the test sample are as follows (see Figure A.2 and Table A.1):

1) mother film size: 800 mm × 600 mm
2) sample size: 300 mm × 10 mm

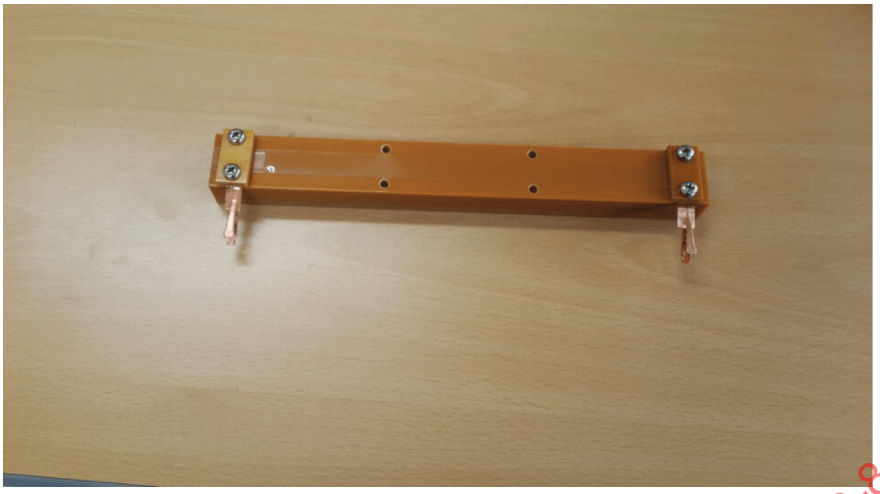

Figure A.2 – Holder with setting a test sample

3) Test results:

**Table A.1 – Test results**

| Angle | Samples | Resistance (KΩ) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | Average resistance of sample | Standard deviation (×10-3) | Average resistance |
| 0° | 1 | 1,02 | 1,01 | 1,01 | 1,01 | 5,77 | 1,01 |
| | 2 | 0,97 | 0,96 | 0,97 | 0,97 | 5,77 | |
| | 3 | 1,05 | 1,06 | 1,03 | 1,05 | 15,28 | |
| 45° | 1 | 0,92 | 0,91 | 0,91 | 0,91 | 5,77 | 0,95 |
| | 2 | 0,91 | 0,92 | 0,95 | 0,93 | 20,82 | |
| | 3 | 1,02 | 1,04 | 0,99 | 1,02 | 25,17 | |
| 90° | 1 | 0,91 | 0,90 | 0,90 | 0,90 | 5,77 | 0,89 |
| | 2 | 0,88 | 0,88 | 0,88 | 0,88 | 0,00 | |
| | 3 | 0,90 | 0,90 | 0,89 | 0,90 | 5,77 | |