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INTERNATIONAL STANDARD

Printed electronics –
Part 202-3: Materials – Conductive ink – Measurement of sheet resistance of conductive films – Contactless method

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International Standard IEC 62899-202-3 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
119/240/FDIS	119/246/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- withdrawn,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
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INTRODUCTION

Conductive films, transparent or non-transparent, are a key element for electronic products. A widespread method used for the measurement of the sheet resistance of conductive films is the 4-point probe measurement. Nevertheless, making an electrical contact with the probes is sometimes critical for the measurement. For some devices or films which are covered with an insulating layer or composed of micro-/nano-structures, establishing an electrical contact is difficult, which makes the 4-point probe method not suitable for the measurement of sheet resistance (see Table A.1 and Figures A.1 and A.2 in Annex A). The 4-point probe method is also sensitive to contact force and layer thickness. The eddy-current-based measurement method, which does not require electrical contact, is widely used for this purpose in the industry. This document specifies a standard method for measurement of sheet resistance using a contactless eddy-current method.

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1 Scope

This part of IEC 62899 defines terms and specifies a standard method for the measurement of the sheet resistance of printed conductive films using a contactless eddy-current method.

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

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
sheet resistance
R_s
electrical resistance of a thin film material measured across the opposite ends of a square area

Note 1 to entry: The unit of sheet resistance is expressed in ohms (Ω). However, for the purpose of this procedure, it represents the unit of ohms per square with the thickness of the film.

[SOURCE: IEC TS 61836:2016, 3.4.81, modified – the second sentence of the note has been added.]

3.2
eddy current
electric current induced within conductors by a time-varying magnetic field in the conductor

3.3
4-probe measurement
method to measure the resistance of a material whose measured value is independent on the probe resistance

Note 1 to entry: In this method, 4 probes contact the test sample in a linear arrangement. A voltage drop is measured between the two inner probes while a current source supplies current through the outer probes. The resistance of the sample can be calculated by Ohm's law. Furthermore, the resistivity of the sample can be obtained by consideration of the geometric factors of the sample.

[SOURCE: IEC TS 62607-2-1:2012, 2.1.6]

3.4
4-point measurement
type of 4-probe measurement defined in 3.3 in which a pointed electric tip is used as a probe

Note 1 to entry: A 4-point measurement is generally used to measure the sheet resistance of a thin film sample with relatively large width compared to the spacing between the probes.

[SOURCE: IEC TS 62607-2-1:2012, 2.1.8, modified – the reference to the term number in the definition has been changed.]

4 Background to the eddy-current method

When a conductive material is placed in an oscillating magnetic field generated by an RF generator unit as shown in Figure 1, it sets up eddy current in the material, which leads to Joule heating. Power absorbed in this process, assuming no flux leakage and negligible skin effect phenomena, is shown as follows [1, 2][1]:

$$P_\mathrm{s} = (U_\tau^2 / 8\pi n^2)\sigma t \quad (1)$$

where

U_τ = RMS primary RF voltage

n = number of primary turns on the ferrite core

σ = conductivity of the sample

t = thickness of the sample.

The significant point is that the power absorbed is directly proportional to σt, that is, conductivity times thickness.

The system includes a feedback system to hold U_τ constant by adjusting the in-phase RF drive current I_τ. Then the power flowing into the sample can be monitored by noting the change in the RF drive current itself [2]:

$$P_\mathrm{s} = U_\tau I_\tau = (U_\tau^2 / 8\pi n^2)\sigma t \quad (2)$$

or

$$I_\tau = (U_\tau / 8\pi n^2)\sigma t \quad (3)$$

In general, the coupling from the RF unit to the sample is not unity, due to the existence of flux leakage arising from the finite permeability of the ferrite core. This reduces the dependence of I_τ on σt, but the relation remains linear [2]:

$$I_\tau = K(U_\tau / n^2)\sigma t \quad (4)$$

where K is a constant involving the coupling parameters of the core. The conductivity of the sample is obtained from this linear relationship.

1 Numbers in square brackets refer to the Bibliography.

5 Specimen

5.1 Specimen

The specimen shall be a conductive layer with the sheet resistance of 0,01 ohms per square to 1 000 ohms per square. The thickness of the film shall be 5 nm or thicker (see Table C.1 in Annex C). The layer shall be a continuous one. There shall be no underlying conductive layer or pattern which can influence the magnetic field.

5.2 Substrate

The substrate shall be an insulated material such as polymers, paper, glass, etc. The effective sheet resistance of the substrate (bulk resistivity divided by the thickness in centimeters) shall be at least 1 000 times that of the film.

5.3 Defects

The specimen shall be visually inspected before the test. It shall not include any void, dirt, oil, scratch, and other defects.

NOTE The surface can be inspected with additional instruments such as thermography.

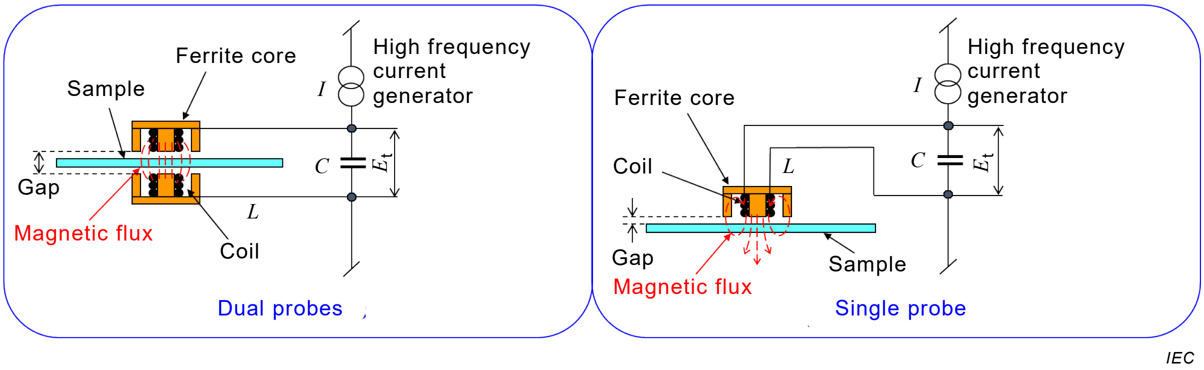
5.4 Size

The size of the specimen shall be at least twice greater than the size of the probe, considering the spread of the magnetic flux from the probe.

6 Apparatus

6.1 General

The apparatus for an eddy-current gauge consists of a high frequency current generator and probe(s) made of ferrite core and wound with coil. For reliable measurement of a wide range of resistance, it is recommended that the frequency of the RF generator cover a broad range (40 kHz to 10 MHz). There are two types of eddy-current gauges, dual and single probes, as shown in Figure 1. In a dual type apparatus, the magnetic flux flows from the top probe to the bottom one, while in the single probe type apparatus, it flows from the inner core to the outer ring. Both types may be used for measurement, since the data from both types of apparatus does not show significant difference (see Table 1).



Key

C Capacitor

I Current

L: Inductor

E_t High frequency voltage

Figure 1 – Schematic diagram of eddy-current probe apparatus (left: dual, right: single)

Table 1 – Comparison between dual and single probes

	Dual probes [ohms per square]	**Single probe** [ohms per square]
1	75,75	74,83
2	75,79	74,75
3	76,28	75,36
4	76,32	75,20
5	76,28	74,83
6	75,87	75,08
7	76,09	75,68
8	75,94	75,43
9	76,24	75,18
10	75,97	75,84
AVG	76,05	75,22

6.2 Sample stage

For a single probe type apparatus, the specimen shall be placed on the stage of an insulating material (see Figure 2). If the stage is positioned on a stand table made of metal, the thickness of the insulating stage or separation between the sample and the metal table shall be 50 mm or greater. If less than 50 mm, eddy current could be generated in the metallic table, and would influence the result of the measurement (see Figure 2).