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INTERNATIONAL STANDARD

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Printed electronics –
Part 202-10: Materials – Resistance measurement method for thermoformable conducting layer

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IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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

Draft	Report on voting
119/436/FDIS	119/448/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.

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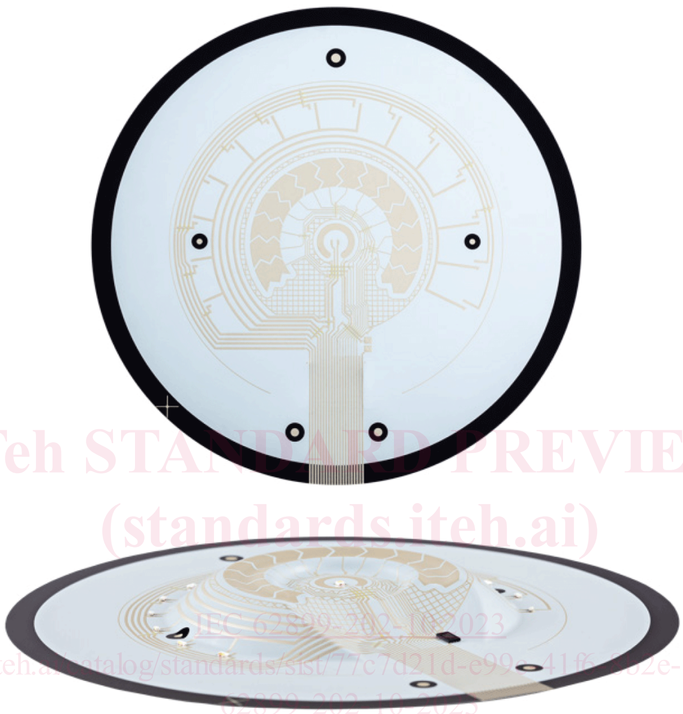
INTRODUCTION

In-mould-electronics (IME) manufacturing can include thermoforming during which two-dimensional electric films with conducting layers are thermoformed into three-dimensional shapes. During thermoforming, the substrate and printed layers will experience plastic strain leading to elongation (see Figure 1). The conductive layer's resistance increases as a function of plastic strain. Designers of electric circuitry should know how much the resistance changes. Using a standardized measurement method ensures comparability of the results.



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NOTE 1 The top image shows a 2D substrate and ink stack after printing and cure.

NOTE 2 The bottom image shows a substrate and ink stack after thermoforming into a 3D shape. The ink layers have been elongated.

Figure 1 – Substrate with ink stack in 2D (top) and 3D (bottom) shape

PRINTED ELECTRONICS –

Part 202-10: Materials – Resistance measurement method for thermoformable conducting layer

1 Scope

This part of IEC 62899 defines terminology and measurement methods for the resistance change of conductive ink layer(s) as a function of thermoplastic elongation. The method measures resistance changes in-situ or post-elongation.

This document is applicable to thermoformable substrates with conductive ink layers. The thermoformable substrates can have printed graphic ink as well and cover insulation layers.

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 – Part 202: Materials – Conductive ink*

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
in-mould-electronics
IME
3D circuit manufactured by integrating and embedding printed electronics and electronic components within shaped structures

Note 1 to entry: Manufacturing steps include, but are not limited to, printing, surface mounting, thermoforming and injection moulding.

3.2
thermoforming
process of shaping heated thermoplastic sheets or other articles, generally on a mould, followed by cooling

Note 1 to entry: In this document, the test structures are elongated in the measurement equipment; they are not thermoformed on a mould.

[SOURCE: ISO 472:2013, 2.1172, modified – Note 1 has been added.]

3.3
thermoformable substrate
substrate made of a material that deforms irreversibly when subjected to heating and force

3.4
conductive ink
fluid in which one or more conductive materials are dissolved or dispersed, and which is used to form an electrically conductive structure

[SOURCE: IEC 62899-202-7:2021, 3.1, modified – “printable fluid intended for printing in which one or more molecules, polymers, or particles” is changed to “fluid in which one or more conductive materials” and “which becomes an electrically conductive layer by post treatment such as heating” is changed to “and which is used to form an electrically conductive structure”.]

3.5
graphic ink
composite material containing colorants, functional components, vehicle and additives

Note 1 to entry: In most cases, it is applied as a fluid to a substrate by a printing process and setting or drying by either physical (evaporation) and/or chemical (polymerizations e.g., oxidation, radiation induced, or other) processes in order to form an image for decorative, informative or technical purposes.

Note 2 to entry: Functional components are materials in the graphic ink that add or enhance its characteristics.

Note 3 to entry: Graphic ink forms visual layers after post treatment such as heating.

[SOURCE: ISO 2834-2:2015, 3.5, modified – the term “printing ink” is changed to “graphic ink”, Note 2 and Note 3 are added.]

3.6
insulation layer
film-like structure formed by printing or coating of insulator ink on a substrate, which can become electrically insulating after post treatment

[SOURCE: IEC 62899-204:2019, 3.3, modified – “insulating layer” is changed to “insulation layer” and “electrically insulating body made of insulator ink, which is printed or coated on a substrate, followed as necessary by the application of a post treatment such as heating” is changed to “structure formed by printing or coating of insulator ink on a substrate, which can become electrically insulating after post treatment”]

3.7
ink stack
combination of ink layers printed on a substrate

Note 1 to entry: Ink layers can include graphic ink layers and conductive layers, or conductive layers only. A stack can also include an insulation layer.

3.8
elongation
increase of length of a test piece

[SOURCE: ISO 1924-3:2005, 3.3]

3.9
elongation at break
percent elongation of a test piece at rupture

[SOURCE: ISO 1382:2020, 3.171, modified – in the term, “ultimate elongation” has been removed.]

3.10
plastic strain
plastic strain component of a controlled strain

Note 1 to entry: The strained specimen does not return to its original size and shape after the deforming force has been removed.

[SOURCE: ISO 23718:2007:2007, 1.6.28, modified – in the term, the symbol has been removed and Note 1 is added.]

3.11
glass transition temperature
temperature where a polymer substrate changes from a rigid glassy material to a soft (not melted) material, and is usually measured in terms of the stiffness, or modulus

[SOURCE: ISO 11119-2:2020, 3.22, modified – in the term, the symbol has been removed.]

3.12
melting temperature
temperature at which transition between fully or partially crystalline solid becomes a liquid of variable viscosity, which is indicated by an endothermic peak in the DSC curve

[SOURCE: ISO 15309:2013, 3.4, modified – in the term, the symbol has been removed, Note 1 and Note 2 have been omitted.]

4 In-situ resistance measurement method

4.1 Measured value

The measured value is the conducting layer resistance change (%) as a function of time (s) or elongation (mm) at specified elongation speed (mm/s) and temperature (ºC).

Results include also conducting layer resistance change (%) between pre- and post-elongation at specified elongation (mm) and elongation speed (mm/s). Resistance measurements are made at room temperature (ºC).

4.2 Test specimen

4.2.1 Ink stack

Select the substrate material that can be elongated at elevated temperatures, i.e., it shall be thermoformable. The substrate shall include conductive ink layers that have been printed and cured in accordance with ink material specifications. The test specimen can also include graphic and insulation layers that have been printed and cured in accordance with ink material specifications. All of these layers shall be thermoformable as well.

The following four types of stacks are permitted:

a) substrate and conductive layer;
b) substrate, graphic layer and conductive layer;
c) substrate, conductive layer and insulation layer;
d) substrate, graphic layer, conductive layer and insulation layer.

The substrate, conductive ink layer, graphic ink layer and insulation layer form an ink stack (see Table 1).

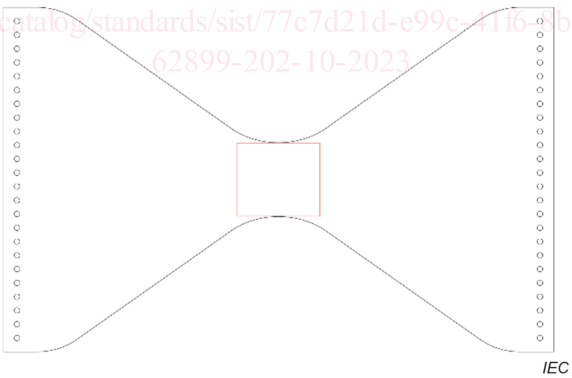
Table 1 – Test specimen ink stack

	Material	Specifications
Substrate	Thermoformable material	Nominal thickness shall be 0,175 mm or more. The tolerance of the nominal thickness shall be ±10 % for maximum and minimum values.
Graphic layer	Thermoformable graphic inks	This layer is optional. If used, select graphic ink materials, layer thicknesses and number of layers.
Conductive layer	Thermoformable conductive inks	Select conductive ink materials, layer thicknesses and number of layers.
Insulation layer	Thermoformable insulation layer	This layer is optional. If used, select insulation materials, layer thicknesses and number of layers.
NOTE 1 Films thinner than 0,175 mm can have internal stresses that cause flaws to the thermoformed shapes. NOTE 2 Test specimen with thicker substrate, for example, > 0,50 mm, will have longer heating times, and temperature distribution can be less homogeneous.		

4.2.2 Size and shape

The size of the elongated area shall be smaller than the size of the heater element in the measurement apparatus. However, the size of the test specimen can be larger so that it can be fastened into the test specimen holder of the measurement equipment.

The test specimen shape shall be suitable for uniaxial elongation (see Figure 2). The substrate shall be narrower in the elongation area than outside it. This is to concentrate conductive line elongation to the intended area. The substrate also has an hour-glass shape, and its middle is slightly curved. This is to improve uniform elongation of conductive ink lines. See more from Annex B.



NOTE The red rectangle comprises the elongation area.

Figure 2 – Example of test specimen shape

4.2.3 Conductive layer layout

All conductive lines shall have the same width in the elongated area. This is to minimize the elongation differences between the conductive lines. Suitable line widths are, for example, 0,3 mm, 0,45 mm, 0,6 mm, 1,0 mm, and 1,5 mm. The line width of 0,3 mm can be suitable only for appropriately stretching conductive inks or for small elongation (e.g., < 20 %). The conductive line width in the test specimen shall be recorded in the test report.

The conductive layer layout shall also include reference dots on both sides of conductive lines in the elongation area. They are used to measure the actual elongation of the conductive lines. The distance between the dots shall be below 10 mm, it can be for example 5 mm. If the test specimen ink stack includes an insulation layer, it shall not hide the reference dots. For example, the insulating layer is transparent or it has openings for the reference dots.