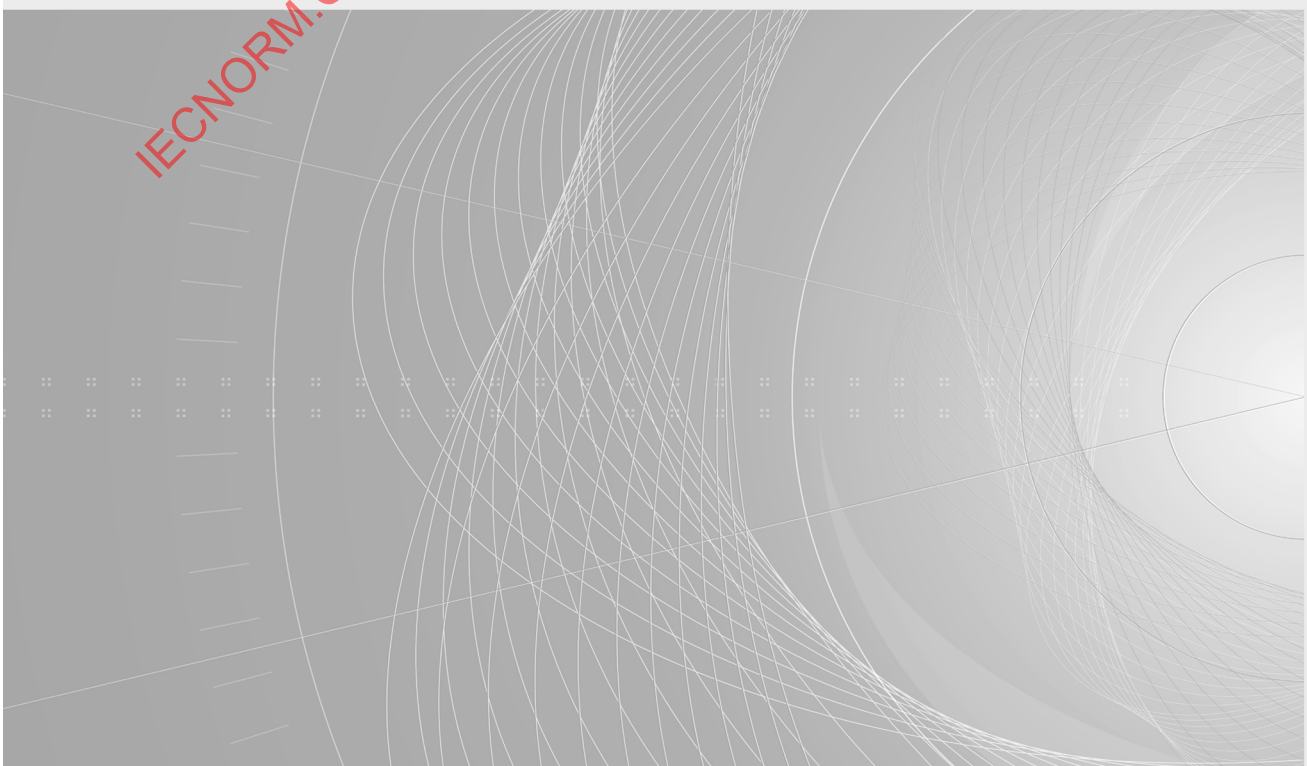
IEC 62899-202-4

Edition 1.0 2021-10

INTERNATIONAL STANDARD

colour inside

Printed electronics –
Part 202-4: Materials – Conductive ink – Measurement methods for properties of stretchable printed layers (conductive and insulating)



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PRINTED ELECTRONICS –

Part 202-4: Materials – Conductive ink – Measurement methods for properties of stretchable printed layers (conductive and insulating)

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 62899-202-4 has been prepared by IEC technical committee 119: Printed electronics.

This International Standard is to be used in conjunction with IEC 62899-202:2016.

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

Draft	Report on voting
119/370/FDIS	119/376/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/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.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The IEC 62899-20x series relates mainly to measurement methods for materials of printed electronics. The series also includes storage methods, packaging and marking, and transportation conditions.

The IEC 62899-20x series is divided into parts for each material. Each part is prepared as a generic specification containing fundamental information for the area of printed electronics.

The IEC 62899-20x series consists of the following parts:

Part 201: Materials – Substrates

Part 201-2: Materials – Substrates – Measurement methods for properties of stretchable substrates

Part 202: Materials – Conductive ink

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

Part 202-4: Materials – Conductive ink – Measurement methods for properties of stretchable printed layers (conductive and insulating)

Part 202-5: Materials – Conductive ink – Mechanical bending test of a printed conductive layer on an insulating substrate

Part 202-6: Materials – Conductive ink – Measurement method for resistance changes under high temperature and humidity – Printed metal-based conductive layer on a flexible substrate

Part 202-7: Materials – Printed film – Measurement of peel strength for printed layer on flexible substrate by the 90° peel method

Part 203: Materials – Semiconductor ink.

Part 204: Materials – Insulator ink – Measurement methods of properties of insulator inks and printed insulating layers

(Subsequent parts will be prepared for other materials.)

Furthermore, each part will also include sectional specifications, blank detail specifications, and detail specifications of each material.

This part of IEC 62899 deals with stretchable printed layers (conductive and insulating) used in printed electronics and contains the test conditions, the measurement methods and the storage conditions.

PRINTED ELECTRONICS –

Part 202-4: Materials – Conductive ink – Measurement methods for properties of stretchable printed layers (conductive and insulating)

1 Scope

This part of IEC 62899 defines the terminology and measurement methods for the properties of stretchable printed layers, such as conductive ink, for forming stretchable conductors by printing, stretchable conductive films obtained from conductive ink, and stretchable printed wiring consisted by conductive ink with insulator.

Stretchable printed layers (conductive and insulating) handled by this document apply to the stretchable electric wiring printed on stretchable substrates, for example fabric integrated wearable devices, skin patchable devices, and so on.

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 60243-1, *Electric strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 61557-2, *Electrical safety in low voltage distribution systems up to 1 000 V AC and 1 500 V DC – Equipment for testing, measuring or monitoring of protective measures – Part 2: Insulation resistance*

IEC 62631-3-1, *Dielectric and resistive properties of solid insulating materials – Part 3-1: Determination of resistive properties (DC methods) – Volume resistance and volume resistivity – General method*

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

ISO 105-C10, *Textiles – Tests for colour fastness – Part C10: Colour fastness to washing with soap or soap and soda*

ISO 105-E04, *Textiles – Tests for colour fastness – Part E04: Colour fastness to perspiration*

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
stretchable substrate
substrate material (e.g., plastic sheet) that can be mechanically deformed by applying tensile loading (stress) and that exhibits reversible mechanical behaviour (elastic deformation) up to at least 10 % tensile strain

Note 1 to entry: In this document, the stretchable substrate is used to evaluate stretchable conductive layers and insulating layers.

[SOURCE: IEC 62899-101:2019, 3.132, modified – the note has been added.]

3.2
stretchable insulator
electric insulator (typically in the form of a film) that exhibits a decrease in resistivity of less than 10 % during mechanical deformation up to at least 10 % tensile strain

[SOURCE: IEC 62899-101:2019, 3.131]

3.3
stretchable cover lay film
electrically insulating film made from a stretchable insulator and used as cover layer for stretchable conductors

[SOURCE: IEC 62899-101:2019, 3.130]

3.4
stretchable conductor
electric conductor that exhibits a decrease in conductivity of less than 10 % during mechanical deformation up to at least 10 % tensile strain

[SOURCE: IEC 62899-101:2019, 3.129]

3.5
stretchable wiring
wiring system consisting of stretchable conductors with a stretchable insulator

[SOURCE: IEC 62899-101:2019, 3.133]

4 Atmospheric conditions for measurement and conditioning

The standard atmosphere for evaluation (test and measurement) and storage of the specimen shall be a temperature of 23 °C ± 2 °C and relative humidity of (50 ± 10) %, conforming to standard atmosphere class 2 specified in ISO 291.

5 Measurement methods of properties of stretchable conductive inks

The measurement methods of properties of stretchable conductive inks are compliant with IEC 62899-202.

6 Measurement methods of properties of stretchable conductive layers

6.1 Stretch dependence of the conductive layer's resistance

6.1.1 General

- When the "stiffness of stretchable substrate" is close to "stiffness of functional layer", an A-type test (I-shape test piece) is used. In the case that "stiffness of stretchable substrate" is larger than “stiffness of functional layer”, a B type test (U-shape test piece) is used.
- Prepare a test piece that is a stretchable substrate with a printed pattern of functional layers.
- Clip the part without the functional layer pattern of the substrate.
- Stretch the test piece.
- If the elongation of the substrate and the elongation of the functional layer pattern part are almost equal, it is judged that the stiffness of the functional layer is lower than the substrate.

However, if the part without the functional layer selectively expands and the elongation of the functional layer is obviously smaller than the elongation of the substrate parts, the stiffness of the functional layer is judged to be high.

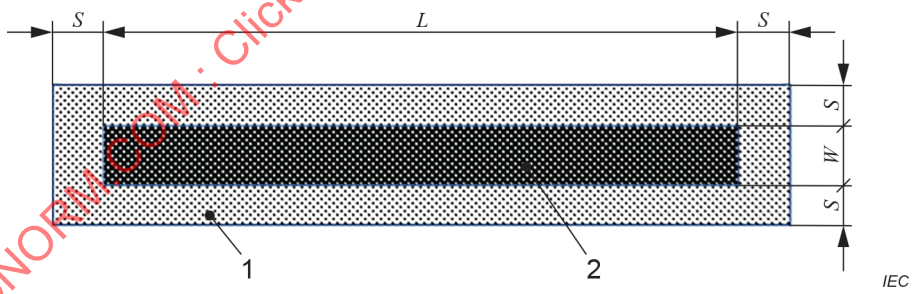
6.1.2 Test piece

6.1.2.1 Substrate

The substrate shall not break at the maximum stretch length of the conductive film during the measuring. The substrate for the test piece shall be a stretchable substrate which is estimated to have higher stretchability than at least the conductive layer to be measured. The kind of stretchable substrate materials may be selected as agreed between user and supplier.

6.1.2.2 A-type test piece

The dimensions of the A-type test piece are as shown in Figure 1.



Key

1 stretchable substrate

2 stretchable printed conductor

L 80 mm to 240 mm (selected as agreed between the user and supplier)

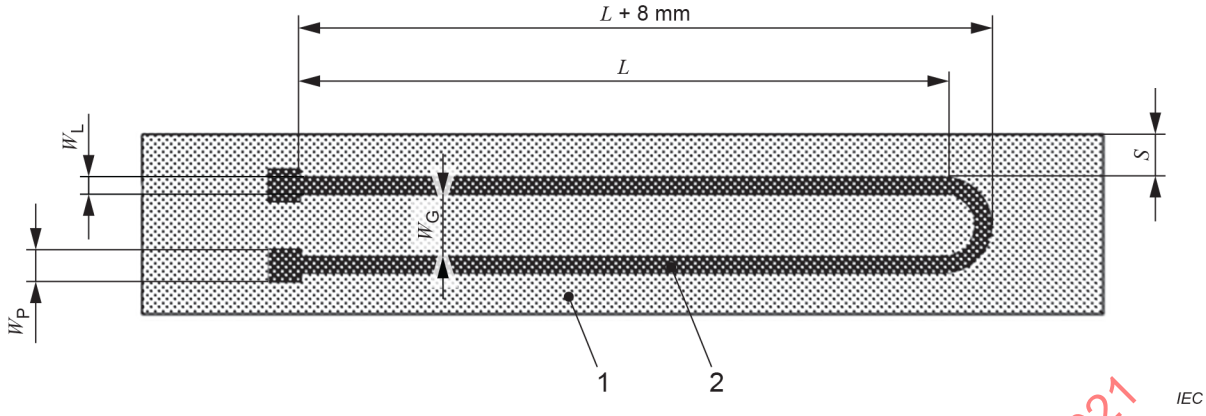
W 10,0 mm ± 0,2 mm

S 10 mm ± 2 mm

Figure 1 – Test piece type A (I-shape test piece)

6.1.2.3 B-type test piece

The dimensions of the B type test piece are as shown in Figure 2.



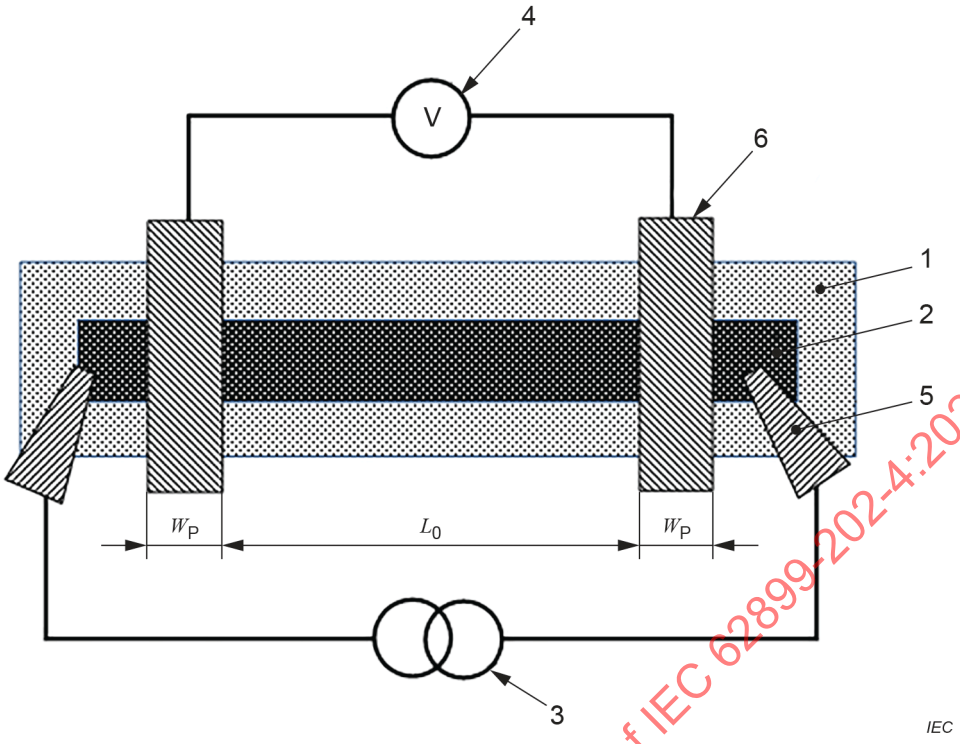
Key

1	stretchable substrate
2	stretchable printed conductor
L	80 mm to 240 mm (selected as agreed between the user and supplier)
W_L	3,0 mm ± 0,2 mm
W_P	5,0 mm ± 0,2 mm
S	10 mm ± 2 mm
W_G	10,0mm ± 0,2 mm

Figure 2 – Test piece type B (U-shape test piece)

6.1.3 Equipment and tools

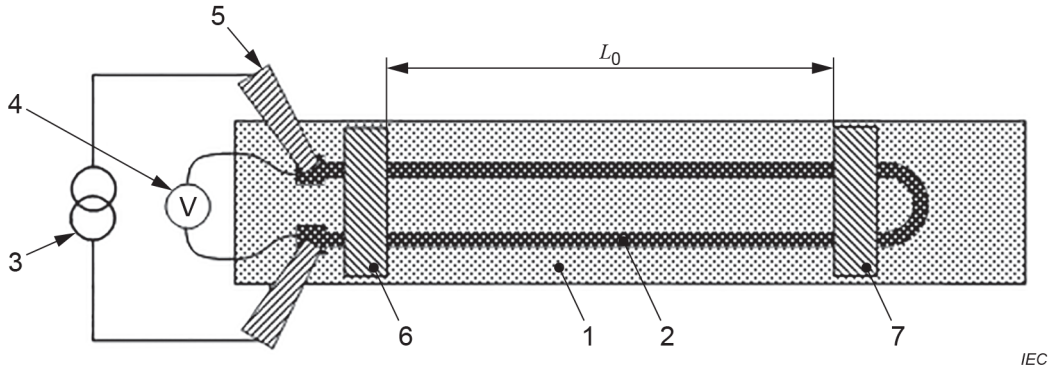
The resistance value is measured by the four-electrode method. The test equipment consists of a constant-current source, a pair of clips (current electrode), a voltmeter and a pair of plate clips that can be motion controlled to any interval, as shown in Figure 3. The width of the plate clip (W_p) is more than 10 mm. The plate clips are made of metallic material, and their surface to contact with the test piece shall be a shiny surface and gold-plated. If a B-type test piece is used, it will be set as shown in Figure 4.



Key

1 stretchable substrate
2 stretchable printed conductor
3 constant current source
4 volt meter
5 clip (current electrode)
6 plate clip (voltage electrode)
L_0 initial sample length
W_p width of the plate clip

Figure 3 – Setting and circuit for the test piece type A



Key

1 stretchable substrate
2 stretchable printed conductor
3 constant current source
4 volt meter
5 clip (current electrode)
6 static clip (insulator)
7 moving clip (insulator)
L_0 initial sample length

Figure 4 – Setting and circuit for the test piece type B

6.1.4 Step-by-step stretch test (static)

6.1.4.1 Procedure

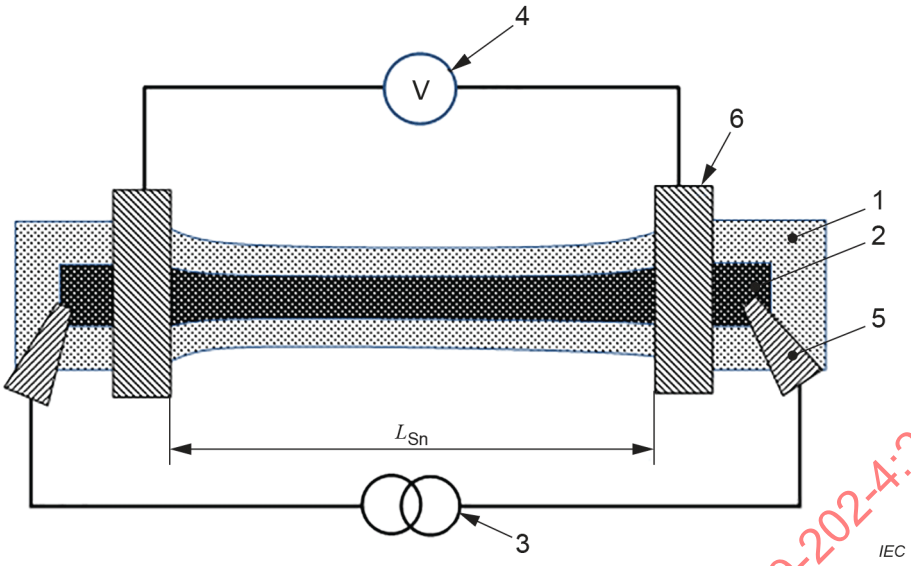
a) Set the test piece to the test equipment. The test piece is placed horizontally. However if the deformation of the test piece due to its own weight can be ignored, a vertical test machine may be used. For proper clamping any pre-stressing as well as wrinkling or slacking of the test piece should be avoided. The initial sample length L_0 should be at least 50 mm. A sample length L_0 of 100 mm is recommended, or slacking of the test piece should be avoided.

b) The initial resistance value is measured and recorded. The stretch rate of this step is 0 %.

c) The test piece is stretched to E % length, followed by 1 min waiting while passing constant current, keeping for one minute, after that, resistance value is recorded. The time required for single stretching step up should be within 10 s.

d) The test piece is stretched to 2 × E % length, followed by 1 min waiting while passing constant current, after that, resistance value is recorded.

e) The test piece is stretched to N × E% length followed by 1 min waiting while passing constant current, as shown in Figure 5, after that, resistance value is recorded. The minimum stretch unit E (%) is selected from 1 %, 2 %, 5 %, 10 %. At least 10 steps are required to reach the upper limit. This operation is repeated until the resistance value becomes more than 1 000 times the initial value. The number of steps N is determined by a reasonable agreement between the user and supplier.



Key

1 stretchable substrate

2 stretchable printed conductor

3 constant current source

4 volt meter

5 clip (current electrode)

6 plate clip (voltage electrode)

L_{sn} stretched length ($L_{sn} = L_0 + N \times E \times 0{,}01 \times L_0$)

Figure 5 – Example of test piece being stretched (test piece type A)

6.1.4.2 Reporting of the results

The report shall include the following items:

a) test piece identification;

b) test conditions (room temperature and room humidity);

c) test piece size: L, W, S, L_0;

d) selected stretch unit (E %), initial resistance value, resistance value in each stretch step, normalized resistance value at each stretch step by the initial resistance, the number of steps that the resistance value reached 1 000 times or over of the initial value;

e) tester, test place, and test time (for example company name, city, year).

6.1.5 Cyclic stretch test (dynamic)

6.1.5.1 Procedure

a) Set the test piece on the test equipment. The test piece is placed horizontally. However if the deformation of the test piece due to its own weight can be ignored, a vertical test machine may be used. For proper clamping, any prestressing as well as wrinkling or slacking of the test piece should be avoided. The initial sample length L_0 should be at least 50 mm. A sample length L_0 of 100 mm is recommended, or slacking of the test piece should be avoided.

b) The initial resistance value is measured and recorded.

c) The test piece is cyclically stretched by the selected stretch ratio while measuring resistance value, and recorded by the automatic recorder such as a data logger. The stretch ratio shall be at least 10 %, and 20 % should be applied if there is no agreement between user and supplier. Cyclic stretch frequency is 1 Hz. Cyclic stretch waveforms are selected by agreement between the user and supplier, from sine wave, trapezoidal wave, or triangular wave.

In the case of a trapezoidal wave, the stretching time and returning time should be within 10 s, the stretch speed in the case of the sine wave and the triangular wave is determined by the stretch ratio.

d) This cycle is continued until the resistance value becomes more than 1 000 times the initial value. The maximum number of stretching cycles is 10 000. If the number of chosen cycles is smaller, as agreed between the user and supplier, the test shall end once the chosen number of cycles has been performed.

NOTE In this test method, mechanically only the function of stretching the sample is necessary, there is no need to measure tensile stress. Therefore, the test equipment can be easily configured by using a crankshaft type mechanism for example such as IPC-TM-650. (In this case, the stretching waveform is limited to the sine wave type.) Also, the linear motor mechanism easily realizes a triangular or trapezoidal stretching cycle.

6.1.5.2 Reporting of the results

The report shall include the following items:

a) test piece identification;

b) test conditions (room temperature and room humidity);

c) test piece size: L, W, S, L_0;

d) cyclic stretch rate (%);

e) cyclic stretch frequency (Hz);

f) cyclic stretch wave form;

g) initial resistance value, every 100 cycles; the resistance value when the test piece is being stretched and the resistance value when the test piece is not being stretched; the normalized resistance value, and the number of cycles by which the resistance value exceeds 1 000 times the initial value;

h) tester, test place, and test time (for example company name, city, year).

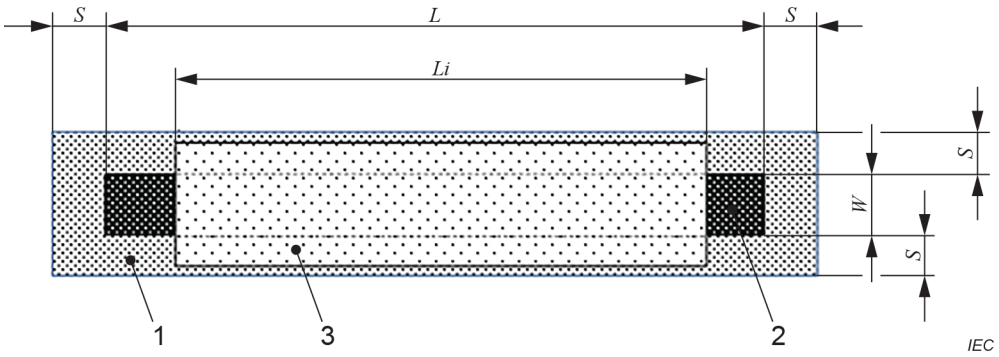
6.2 Washing durability

6.2.1 Test method and condition

Washing durability is in accordance with ISO 105-C10. Especially when there is no agreement on the washing method, the washing machine type is ISO 6330 A-typed washing machine, the washing method is 4H, and the drying method is Line.

6.2.2 Test piece type A with cover insulator

For the test piece, a stretch insulation layer is added to the A-type test piece of 6.1.2.2. The elastic insulating layer is formed by printing or laminating. The dimensions of the test piece are as shown in Figure 6.



Key

1 stretchable substrate

2 stretchable conductor

3 stretchable insulator

L 80 mm to 240 mm (selected as agreed between the user and supplier)

Li 60 mm to 220 mm (subtract 20 mm from L)

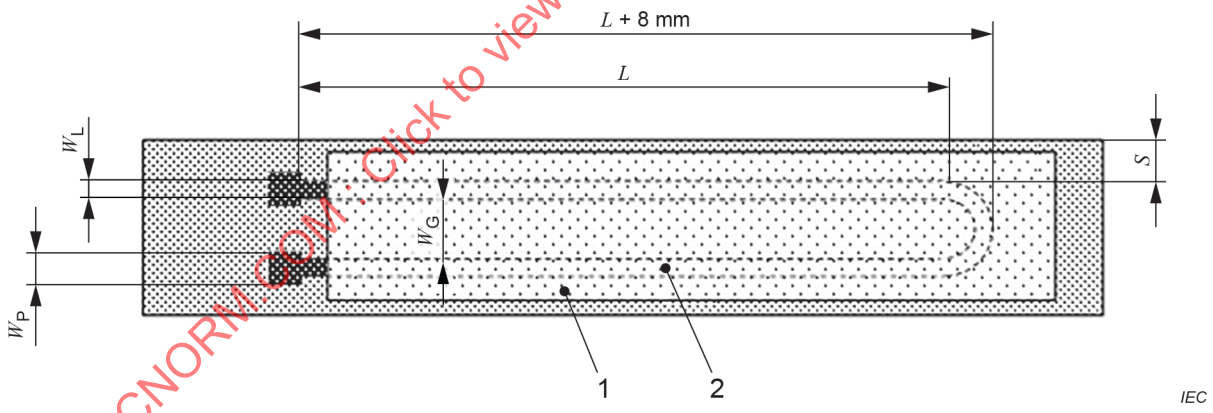
W 10,0 mm ± 0,2 mm

S 10,0 mm ± 2,0 mm

Figure 6 – Test piece type A with cover insulator

6.2.3 Test piece type B with cover insulator

For the test piece, a stretch insulation layer is added to the B-type test piece of 6.1.2.3. The elastic insulating layer is formed by printing or laminating. The dimensions of the test piece as shown in Figure 7.



Key

L 80 mm to 240 mm (selected as agreed between the user and supplier)

W_L 3,0 mm ± 0,2 mm

W_P 5,0 mm ± 0,2 mm

S 10,0 mm ± 2,0 mm

Figure 7 – Test piece type B with cover insulator

6.2.4 Reporting of the results

The report shall include the following items:

a) washing method and conditions;

b) initial resistance value, resistance value after washing;

c) test place, and test time (for example company name, city, year).

6.3 Sweat durability

6.3.1 Test method and condition

Sweat durability is in accordance with ISO 105-E 04. The conditions for sweat durability may be selected as agreed between the user and supplier.

6.3.2 Test piece

The same test piece as in 6.2.

6.3.3 Reporting of the results

The report shall include the following items:

a) condition for sweat durability test;

b) initial resistance value, resistance value in after sweat durability test;

c) test place, and test time (for example company name, city, year).

7 Measurement methods of insulation between conductive lines

7.1 Insulation resistance between conductive lines

7.1.1 Test piece

7.1.1.1 Substrate

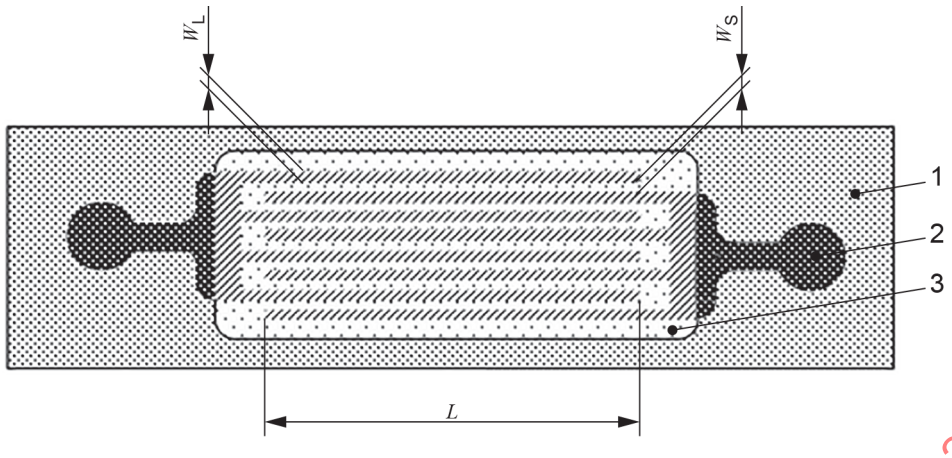
The substrate for the test piece shall be a stretchable substrate having an elastic area of 50 % or more. Elastic polymer films and sheets, or stretchable resin coated fabrics can be used as stretchable substrate. The type of stretchable substrate materials may be selected as agreed between the user and supplier.

7.1.1.2 Dimensions of test piece

The dimensions of the test piece are as shown in Figure 8. The test piece substrate shall have a margin of at least 5 mm. The cover coating layer is formed as necessary. The cover coating layer shall have a margin of at least 1 mm from the conductive line edge.

7.1.2 Procedure

Maintain the test piece horizontally and measure the insulation resistance between the terminals using a high resistance meter in accordance with IEC 61557-2. The applied voltage shall be 500 V if not specified otherwise. Read the resistance value after 1 min from the voltage applied.



Key

1 stretchable substrate

2 stretchable conductor

3 stretchable insulator

L 25 mm ± 1 mm

W_L 1,0 mm ± 0,1 mm

W_S 1,0 mm ± 0,1 mm

Figure 8 – Test piece for insulation resistance between conductive lines

7.1.3 Reporting of the results

The report shall include the following items:

a) test piece identification;

b) test conditions (room temperature and room humidity);

c) structure of test piece (presence / absence of cover coating layer);

d) applied voltage (V);

e) insulation resistance (Ω).

7.2 Electric strength between conductive lines

7.2.1 Test piece

7.2.1.1 Substrate

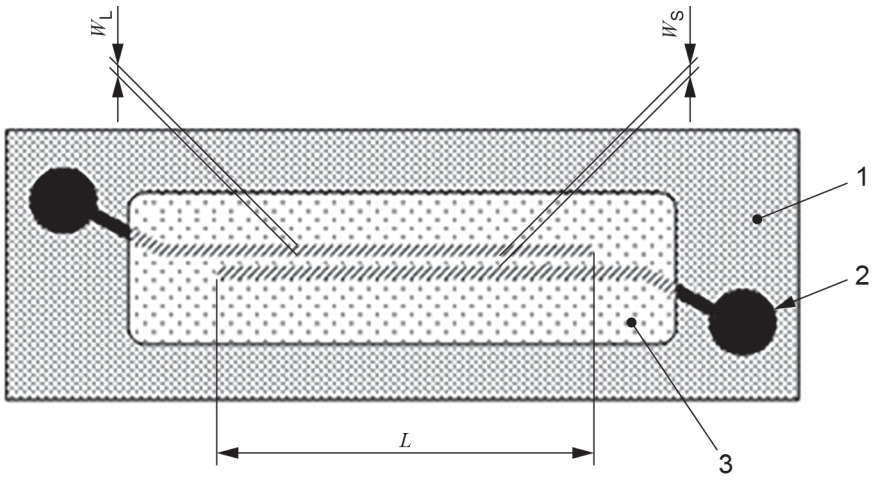
Same as in 7.1.1.1.

7.2.1.2 Dimensions of test piece

The dimensions of the test piece are as shown in Figure 9. The test piece substrate shall have a margin of at least 5 mm. The cover coating layer can be formed if necessary. The cover coating layer shall have a margin of at least 3 mm from the conductive line edge.

7.2.2 Procedure

Hold the test piece on a horizontal insulation table and measure the breakdown voltage between terminals with an electric breakdown tester in accordance with IEC 60243-1. Apply an AC voltage across the terminals, and gradually increase the voltage and read the voltage value at which the dielectric breakdown occurred. At least five test pieces shall be measured and the maximum, minimum and average values shall be recorded.



Key

1 stretchable substrate

2 stretchable conductor

3 stretchable insulator

L 25 mm ± 1 mm

W_L 1,0 mm ± 0,1 mm

W_S 1,0 mm ± 0,1 mm

Figure 9 – Test piece for electric strength between conductive lines

7.2.3 Reporting of the results

The report shall include the following items:

a) test piece identification;

b) test conditions (room temperature and room humidity);

c) structure of test piece (presence / absence of cover coating layer);

d) numbers of test piece;

e) breakdown voltage (maximum, minimum and average values).

7.3 Insulation resistance of cover insulation layer side

7.3.1 Test piece

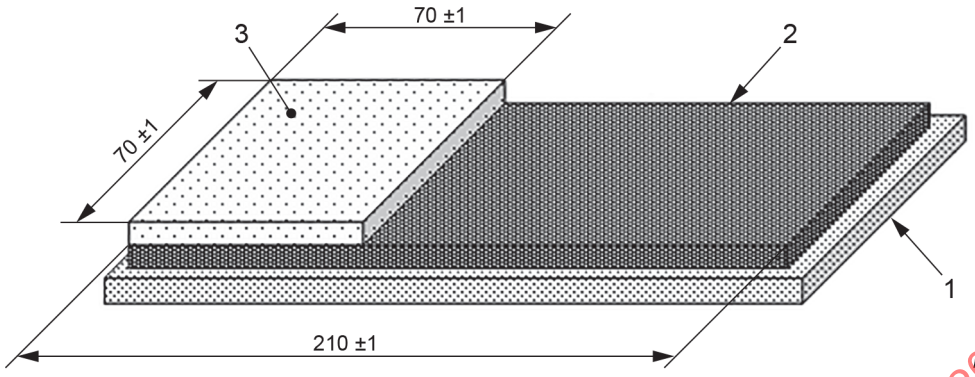
7.3.1.1 Substrate

Same as in 7.1.1.1.

7.3.1.2 Dimensions of the test piece

The dimensions of the test piece are as shown in Figure 10. The test piece consists of a substrate, a rectangular stretchable conductor of 70 mm × 210 mm, and a cover insulation layer of 70 mm × 70 mm. The test piece substrate shall have a margin of at least 5 mm. An error in the dimensions of ±1 mm is allowed for the stretchable conductor and cover insulation layer.

Dimensions in millimetres



Key

1 stretchable substrate

2 stretchable conductor

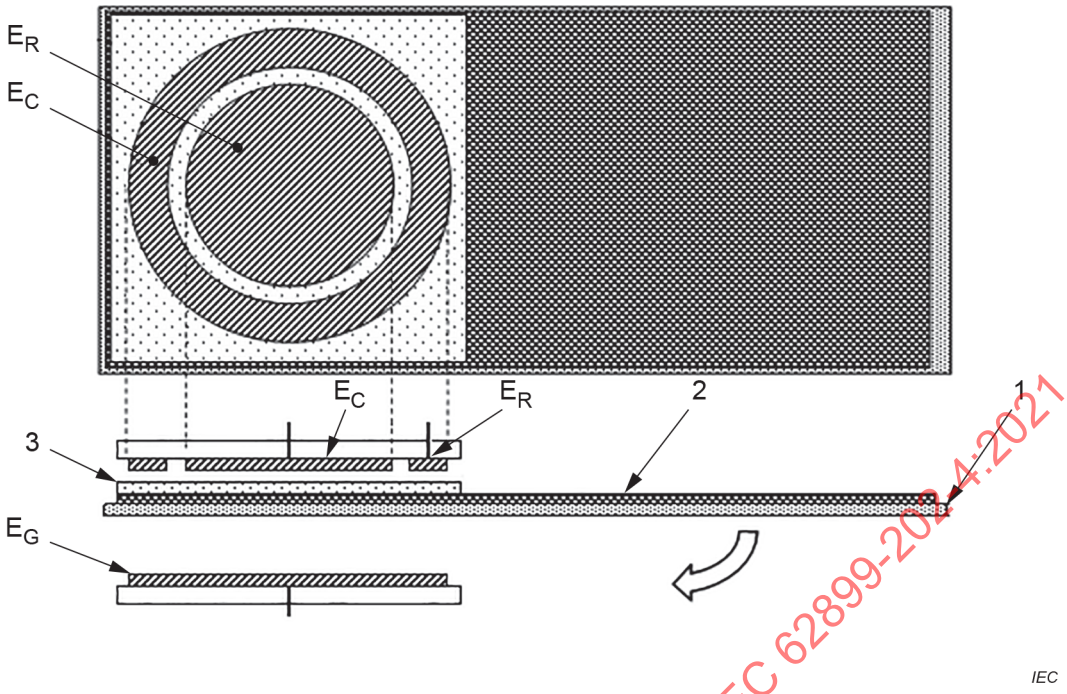
3 stretchable insulator

Figure 10 – Test piece for insulation resistance of insulating layer

7.3.2 Procedure

Insulation resistance of the cover insulating layer side is measured by the following procedure using an electrode with a guard ring for volume resistivity measurement conforming to IEC 62631-3-1. As shown in Figure 11, the test piece is inserted between the electrode with the guard ring and the ground electrode. It is folded in half and sandwiched between both electrodes.

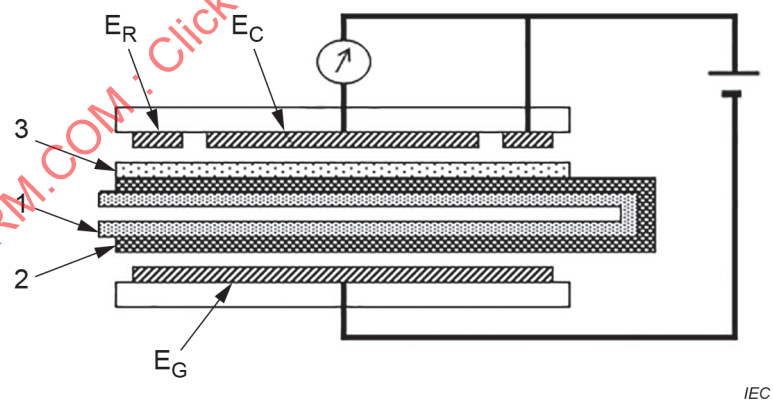
The measuring circuit is connected as shown in Figure 12. The applied voltage shall be 500 V if not specified otherwise. Read the resistance value after 1 min from the voltage applied, and the resistance value calculated from the current value after 1 min is recorded.



Key

1 stretchable substrate
2 stretchable conductor
3 stretchable insulator
E_C circular electrode
E_R guard ring electrode
E_G ground electrode

Figure 11 – Setting for the test piece



Key

1 stretchable substrate
2 stretchable conductor
3 stretchable insulator
E_C circular electrode
E_R guard ring electrode
E_G ground electrode

Figure 12 – Setting and circuit for cover insulation layer