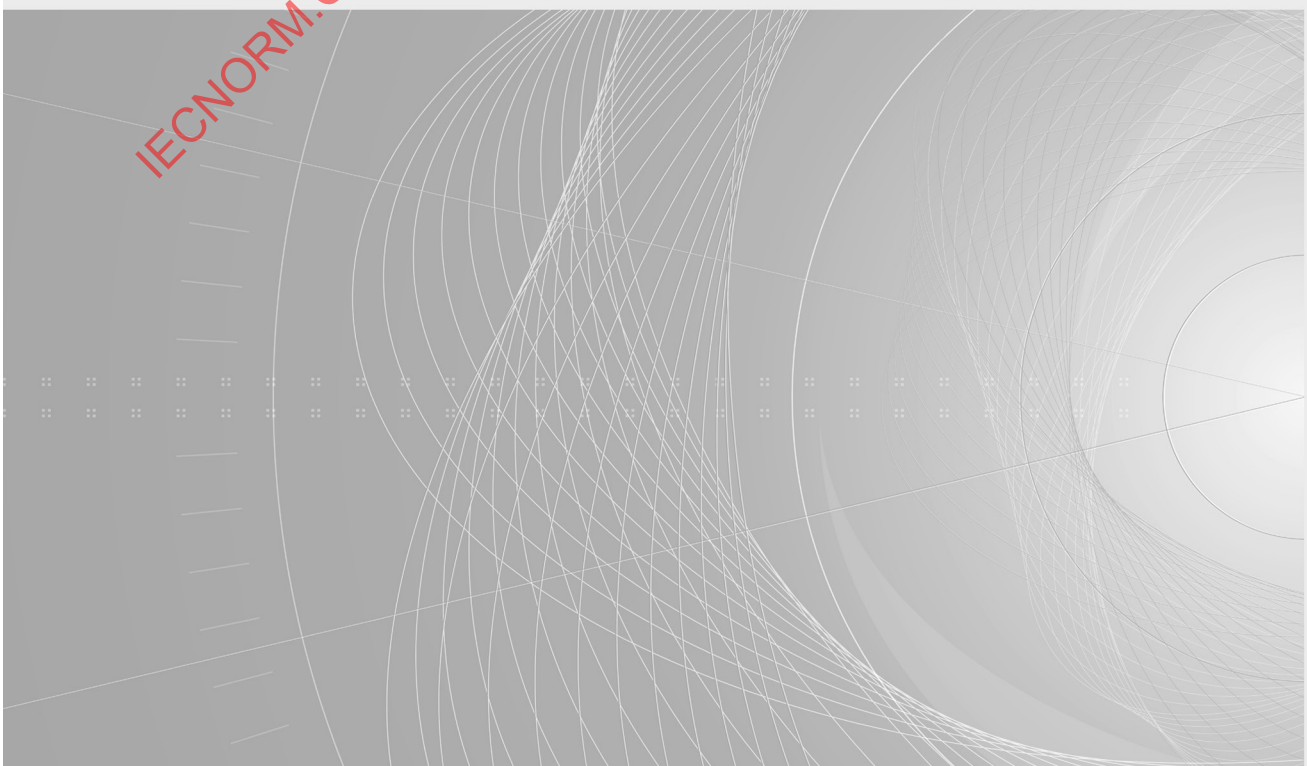
IEC 62899-202-9

Edition 1.0 2023-08

INTERNATIONAL STANDARD

colour inside

Printed electronics –
Part 202-9: Materials – Conductive ink – Printed patterns for mechanical test



IEC 62899-202-9:2023-08(en)

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

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

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC 62899-202-9

Edition 1.0 2023-08

INTERNATIONAL STANDARD

colour inside

Printed electronics –
Part 202-9: Materials – Conductive ink – Printed patterns for mechanical test

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.180; 87.080

ISBN 978-2-8322-7328-9

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

PRINTED ELECTRONICS –

Part 202-9: Materials – Conductive ink – Printed patterns for mechanical test

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.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 62899-202-9 has been prepared by IEC technical committee 119: Printed Electronics. It is an International Standard.

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

Draft	Report on voting
119/435/FDIS	119/449/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.

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

Printing processes are highly promising technologies for the fabrication of flexible electronics such as flexible displays, sensors, batteries, printed circuit boards, etc. During their lifetime, flexible printed electronics can experience various mechanical deformations in random directions such as bending, torsion, creasing, and rolling. Repeated mechanical deformations lead to significant stress and can cause the failure of flexible electronics products. Therefore, a standard test method to evaluate the mechanical reliability of flexible printed electronics is recommended. Mechanical test methods for final products such as flexible displays, sensors, and batteries are recommended in the industry. Moreover, a mechanical test for printed circuits and printed devices is recommended because the printing materials will be used and commercialized as basic components to develop the final printed electronics.

To test the mechanical reliability of printed circuits and printed devices, a proper mechanical test method and a standard pattern are recommended. Several mechanical test methods for flexible printed electronics such as the bending test, rolling test, and torsion test are already proposed in IEC. These previous methods suggested mechanical test methods but they focused on measuring the device reliability of the final product such as the flexible display, sensor, and battery rather than the reliability of each component. Therefore, to test the mechanical reliability of printed circuits and printed devices, standard printed patterns are required to perform mechanical tests.

In this document, basic conductive traces and features of printed patterns are proposed for mechanical tests. The standard pattern in this document can be a useful guideline to test the mechanical reliability of new materials for flexible printed electronics. The information obtained by using the standard patterns in this document will be beneficial to the ink suppliers to figure out the best use of their ink and to the users to improve the reliability of their products.

PRINTED ELECTRONICS –

Part 202-9: Materials – Conductive ink – Printed patterns for mechanical test

1 Scope

This part of IEC 62899 describes basic patterns to evaluate the electrical reliability of a conductive layer under mechanical deformation. Using the standard pattern described in this document, the comparison of the electrical reliability of a conductive layer under mechanical deformation is possible when the sample dimension is identical.

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*

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

IEC 62899-202-5, *Printed electronics – Part 202-5: Materials - Conductive ink – Mechanical bending test of a printed conductive layer on an insulating substrate*

IEC 62899-502-1, *Printed electronics – Part 502-1: Quality assessment – Organic light emitting diode (OLED) elements – Mechanical stress testing of OLED elements formed on flexible substrates*

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

3.1
conductive ink
fluid intended for printing in which one or more molecules, polymers, or particles are dissolved or dispersed, and which becomes an electrically conductive layer by post treatment such as heating, UV and IR curing

[SOURCE: IEC-62899-202:2016, 3.2, modified – “intended for printing” and “UV and IR curing” have been added.]

3.2
bending test
deformation test by application of external stress perpendicular to the plane of a printed element

[SOURCE: IEC-62899-101:2019, 3.12]

3.3
torsion test
action of twisting a system, device or substrate, by subjecting one end of the specimen to a torsional load, while the other end is held in place, or rotated in the opposite direction

[SOURCE: IEC-62899-101:2019, 3.140, modified – the note has been removed.]

3.4
rolling test
test for measuring the endurance of a flexible printed electronics system while or after rolling and unrolling it onto and from a cylindrical roller with a specified radius

[SOURCE: IEC-62899-101:2019, 3.114, modified – the note has been removed.]

4 Standard environmental conditions

Standard atmospheric conditions for measurement shall apply as specified in IEC 62899-202:

a) temperature: (23 ± 2) °C;
b) relative humidity: (50 ± 10) %; in case of paper substrate: (50 ± 2) %.

5 Mechanical test methods

The mechanical test methods for printed patterns shall be in accordance with the following:

a) bending test: IEC 62899-201, IEC 62899-202-5, IEC 62899-502-1;
b) torsion test: IEC 62899-502-1;
c) rolling test: IEC 62899-502-1.

6 Printed patterns for mechanical test

6.1 General

To test the mechanical reliability of a conductive layer, a proper mechanical test method and a standard pattern are necessary. Depending on the mechanical deformations such as bending, torsion, and rolling, the mechanical reliability of the printed pattern can be different. Therefore, standard patterns for each mechanical test method are proposed in this document. According to the printing technique used, such as inkjet printing, screen printing, or gravure printing, the width of the pattern can be selected. The tolerance of the sample length and width is ±1 mm. The tolerance of the printed pattern length and width shall be ±10 %. In this document, the representative dimensions widely used in the printing process are suggested as the printing pattern for the mechanical test. During mechanical testing, damage formation in the grip part shall be avoided. For in situ measurement of electrical resistance, the pad area can be used as a grip part, but the line area shall not be included in the grip part. For an ex situ test which measures electrical resistance before and after the mechanical test or at regular intervals, the user can modify the pad size and add extra space at the edge of the sample for stable grip during mechanical test.

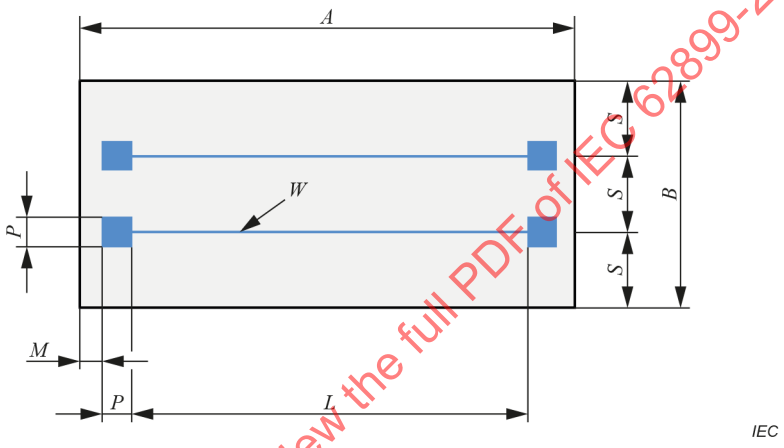
6.2 Patterns for bending test

6.2.1 General

Bending test methods for printed electronics are specified in IEC 62899-201, IEC 62899-202-5, and IEC 62899-502-1. For the bending test, the size of the sample and of the printed pattern, and the pattern direction are important factors in mechanical reliability. In this document, a basic line pattern and directional pattern are proposed. For electrical measurement, each end of the pattern may include a conductive pad with a square shape for probe contact. Several patterns may be printed together on one substrate for multiple measurements. A pad size (P) of 1 mm to 5 mm is allowed by the user. The margin area, M (0 mm to 5 mm), at the edge of the sample can be included in the sample to avoid additional stress during sample gripping.

6.2.2 Printed patterns for bending test

The dimensions of the printed pattern and sample for the bending test are shown in Figure 1.



A (sample length): 70 mm

B (sample width): 10 mm to 30 mm

L (pattern length): $L = A - 2 \times (P + M)$

M (margin area): 0 mm to 5 mm

S (space): $B/3$

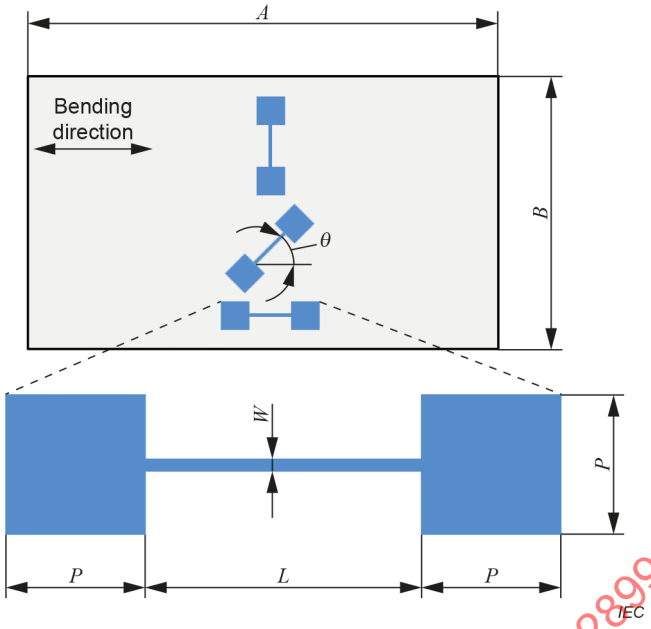
P (pad size): 1 mm to 5 mm

W (pattern width): 0,01 mm to 3 mm (selected according to the printing technique)

Figure 1 – Printed patterns for bending test

6.2.3 Directional patterns for bending test

According to the direction between the printed patterns and bending directions, the mechanical reliability can be changed significantly. The patterns for testing the directional property of the conductive layer are shown in Figure 2. The patterns shall be located at the bending part of the test machine. By changing the angle between the bending direction and pattern direction, the electrical resistance change as a function of the angle can be measured. The pattern angles of 0° and 90° shall be tested, but other angles such as 30°, 45°, and 60° are optional.



A (sample length): 70 mm

B (sample width): 30 mm to 50 mm

L (pattern length): 10 mm to 30 mm

P (pad size): 1 mm to 5 mm

W (pattern width): 0,01 mm to 3 mm (selected according to the printing technique)

θ (angle between pattern direction and bending direction): 0° to 90°

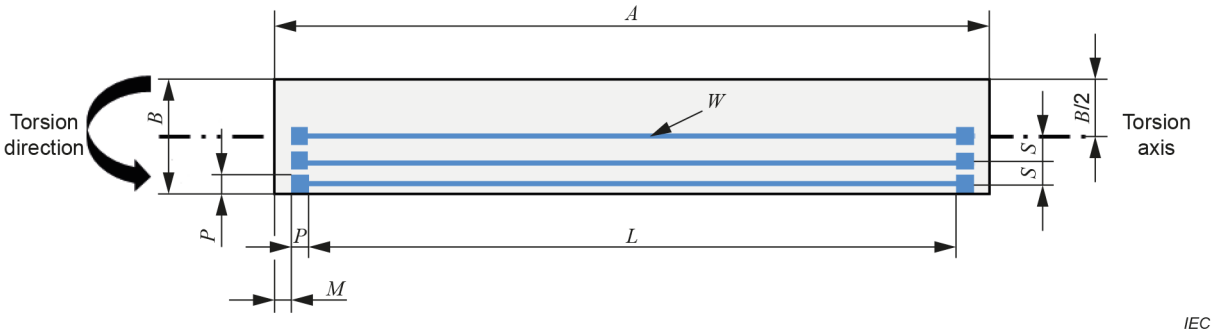
Figure 2 – Directional patterns for bending test

6.3 Patterns for torsion test

Torsion test methods for printed electronics are specified in IEC 62899-502-1. Patterns shall be printed by conductive ink on the flexible substrate. For electrical measurement, each end of the pattern may include a conductive pad with a square shape for probe contact. The user may select the proper dimension for the width of the pattern. The user may select the pad size (P) from 1 mm to 5 mm.

The dimensions of the printed pattern and sample for torsion are shown in Figure 3. For the torsion test, the position of the pattern is very important because the mechanical stress is changed depending on the distance from the torsion axis. For the torsion test, at least three patterns are required, as follows:

1) a pattern shall be on the torsion axis;
2) another pattern shall be located sufficiently far from the axis;
3) additional patterns are prepared between the axis and the edge of the sample.



A (sample length): 70 mm

B (sample width): 10 mm to 30 mm

L (pattern length): $L = A - 2 \times (P+M)$

M (margin area): 0 mm to 5 mm

S (space): $(B - P)/4$

P (pad size): 1 mm to 5 mm

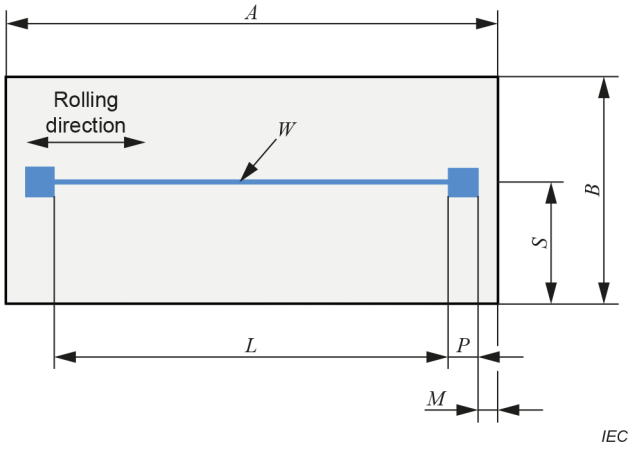
W (pattern width): 0,01 mm to 3 mm (selected according to the printing technique)

Figure 3 – Printed patterns for torsion test

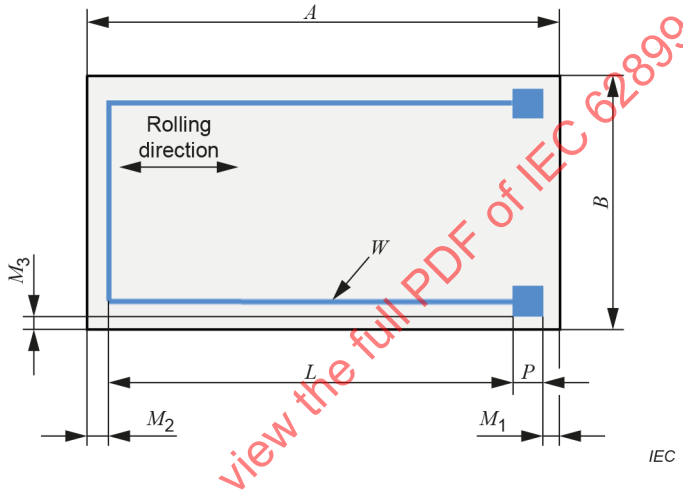
6.4 Patterns for rolling test

Rolling test methods for printed electronics are specified in IEC 62899-502-1. Patterns shall be printed by conductive ink on the flexible substrate. For electrical measurement, each end of the pattern can include a conductive pad with a square shape for probe contact. According to the printing technique used, such as inkjet printing, screen printing, or gravure printing, the width of the pattern can be properly selected.

The dimensions of the printed pattern and sample for the rolling test are shown in Figure 4(a) and Figure 4(b). The straight line pattern as shown in Figure 4(a) may be used for the rolling test, and the electrical resistance can be measured before and after the rolling test. For in situ monitoring of the electrical resistance change of the printed pattern during the rolling test, the pad for the electrical contact shall be located on the same side as shown in Figure 4(b) because one side of the sample should be gripped for rolling and will be curled. The pattern length (L) can be selected by considering the sample length and pad size. The user can choose the proper pad size (P) from 1 mm to 5 mm.



(a)



(b)

The dimensions of the sample straight pattern are as follows:

A (sample length): 50 mm to 200 mm

B (sample width): 30 mm to 70 mm

L (pattern length): $L = A - 2 \times (P + M)$

M_1, M_2, M_3 (margin area): 0 mm to 5 mm

S (space): B /2 mm

P (pad size): 1 mm to 5 mm

W (pattern width): 0,01 mm to 3 mm (selected according to the printing technique)

The dimensions of the returning pattern are as follows:

A (sample length): 50 mm to 200 mm

B (sample width): 30 mm to 70 mm

L (pattern length): $L = A - (P + M_1 + M_2)$

M_1, M_2, M_3 (margin area): 0 mm to 5 mm

P (pad size): 1 mm to 5 mm

W (pattern width): 0,01 mm to 3 mm (selected according to the printing technique)

Figure 4 – Printed patterns for rolling test for (a) simple straight pattern and (b) returning pattern

6.5 Electrical measurement of printed pattern

The electrical resistance change of a printed pattern shall be measured before and after the mechanical test. The two-wire method for electrical resistance measurement using two pads is applicable for evaluating the resistance change. For a more accurate evaluation of electrical resistance, the resistance value of the printed pattern can be measured by the four-probe method (IEC 62899-202). Pairs of probes for constant-current source and for voltmeter shall be connected to each pad area of the printed pattern for the four-wire measurement method. The electrical resistance of the printed pattern can be measured in situ during mechanical deformations.

6.6 Reporting of the results

6.6.1 Reporting of the results of the bending test

The report shall include the following items:

a) specimen identification (including pattern dimension and sample size): A, B, L, W, S, P, θ;
b) test conditions (temperature, relative humidity);
c) printing technique;
d) bending test method identification: bending radius, bending strain [1][1], number of bendings;
e) bending direction: inner or outer bending;
f) nominal pattern thickness;
g) number of samples;
h) initial resistance value before bending test, resistance value after or during bending test, normalized resistance value according to the initial resistance after or during bending test.

6.6.2 Reporting of the results of the torsion test

The report shall include the following items:

a) specimen identification (including pattern dimension and sample size): A, B, L, W, S, P;
b) test conditions (temperature, relative humidity);
c) printing technique;
d) torsion test method identification: torsion angle, rotation angular velocity, number of cycles;
e) nominal pattern thickness;
f) number of samples;
g) initial resistance value before torsion test, resistance value after or during torsion test, normalized resistance value according to the initial resistance after or during torsion test.

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