IEC 63203-401-1

Edition 1.0 2023-10

INTERNATIONAL STANDARD

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colour inside

Wearable electronic devices and technologies –
Part 401-1: Devices and systems: functional elements – Evaluation method of the stretchable resistive strain sensor

Technologies et dispositifs électroniques prêt-à-porter –
Partie 401-1: Dispositifs et systèmes: éléments de fonctionnement – Méthode d'évaluation de la jauge de contrainte extensible de type résistif

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CONTENTS

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WEARABLE ELECTRONIC DEVICES AND TECHNOLOGIES –

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FOREWORD

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IEC 63203-401-1 has been prepared by IEC technical committee 124: Wearable electronic devices and technologies. It is an International Standard.

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

Draft	Report on voting
124/223/FDIS	124/239/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 63203 series, published under the general title *Wearable electronic devices and technologies*, 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- withdrawn, or
- revised.

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WEARABLE ELECTRONIC DEVICES AND TECHNOLOGIES –

Part 401-1: Devices and systems: functional elements – Evaluation method of the stretchable resistive strain sensor

1 Scope

This part of IEC 63203-401 specifies a measurement method of tensile strain for stretchable, resistive strain sensors. This document describes characterization procedures for evaluation of the gauge factor, linearity, response characteristics, and hysteresis of unimodal tension sensors but is not appropriate for assessment of the physical properties of the sensor material such as the elastic modulus, elastic limit, and Poisson's ratio.

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 62899-202-4:2021, *Printed electronics – Part 202-4: Materials – Conductive ink – Measurement methods for properties of stretchable printed layers (conductive and insulating)*

ISO 291:2008, *Plastics – Standard atmospheres for conditioning and testing*

ISO/TS 12901-2:2014, *Nanotechnologies – Occupational risk management applied to engineered nanomaterials – Part 2: Use of the control banding approach*

3 Terms and definitions

3.1 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

3.1.1
stretchable substrate
stretchable material
substrate or material able to recover original size and shape immediately after the removal of the extending force causing deformation

Note 1 to entry: In this document, the notion of "stretchability" is based on the elasticity of the substrate.

[SOURCE: IEC 63203-101-1:2021, 3.10 [1]]

3.1.2
gauge factor
G_F
ratio of the change in electrical resistance divided by the original resistance (R_O, resistance in the undeformed configuration) to engineering strain (e) along the axis of the stretching

Note 1 to entry: Gauge factor is expressed as $G_F = \frac{(R - R_O)/R_O}{e}$, where R_O is the initial resistance in the undeformed configuration, R is the electrical resistance in the deformed configuration, and e is the tensile strain.

[SOURCE: IEC 62047-22:2014, 3.1.1 [2] modified – "along the axis of the stretching" has been added to the definition, and, in the note to entry, "where R is the electrical resistance in the deformed configuration" has been replaced with "where R_O is the initial resistance in the undeformed configuration, R is the electrical resistance in the deformed configuration, and e is the tensile strain".]

3.1.3
gauge length
length of the strain-sensitive section of a stretchable strain sensor in the direction of the measurement axis

3.2 Symbols and abbreviated terms

Symbol	Unit	Description
a	mm	Width of the resistive thin film
h	µm	Thickness of the resistive thin film
l_0	mm	Gauge length of the sensor
l_1	mm	Length of the stretchable resistive thin film

4 Test environments

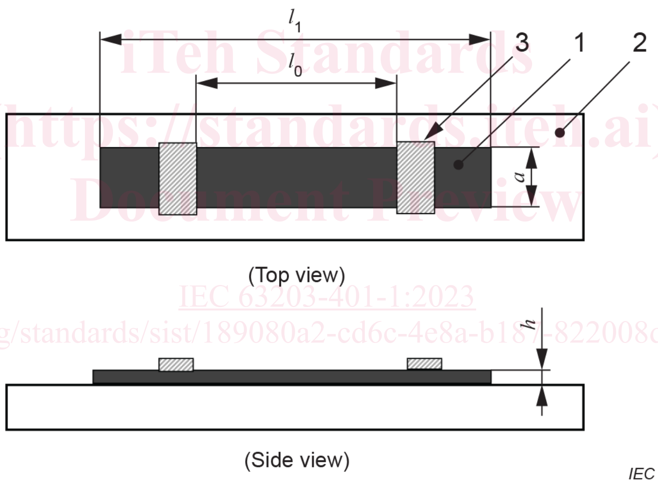
The tests shall be performed under constant temperature and humidity conditions. As environmental conditions, including temperature and humidity, can affect the electrical and mechanical properties of resistive materials and substrates, the testing temperature and humidity shall be monitored during testing. Fluctuations in temperature during a test shall be kept to less than ±2 °C. Thus, when testing such materials, the change in relative humidity (RH) in the testing laboratory shall be kept to less than ±10 % RH. The recommended temperature and relative humidity are 23 °C ± 2 °C and relative humidity of 50 ± 10 %, respectively, conforming to standard atmosphere class 2 specified in ISO 291. Whenever testing is conducted, the environmental conditions shall be recorded.

5 Test specimen

5.1 Shape of the test specimen of the stretchable strain sensor

The shape of the stretchable strain sensor to be tested shall be rectangular or square. The test specimen has a stretchable substrate, and the resistive thin film is deposited on this stretchable substrate or on a single layer of resistive composite materials. Figure 1 presents the basic shape of the test specimen including pads or metal layer for electrical connection. For the pad, the thin metal film or coating is deposited or fabricated on the resistive sensor layer. The film materials with low stiffness are fabricated as thin as possible (for example, less than a few micrometers in thickness) so that the stretching of the resistive sensor material is not restricted due to the pad material. Some resistive composite sensor materials can be sensitive to the deposition process. Thus, there will be a possibility that the resistive sensor materials can be damaged during the deposition process. In this case, metal clips can be used for electrical connection instead of metal pads. The length of the stretchable resistive thin film l_1 can be the same as the length of the stretchable substrate. The width of stretchable substrate is more than or equal to the width of the resistive thin film.

For uniform strain distribution, a rectangular strip shape is recommended. Since the change in electrical resistance is related to the strain, the electrical resistance is measured in a region of nearly uniform strain within the gauge length. The gauge length is chosen as the region where the strain of the stretchable sensor layer is uniform over the cross-sectional area.



Key

1 Stretchable strain sensor material
2 Stretchable substrate
3 Pad for electrical connection

Figure 1 – Shape of a test specimen of the stretchable strain sensor

5.2 Measurement of dimensions

The length of the stretchable strain sensor, in particular the gauge length of the sensor shall be measured accurately, because the dimension of the length can be used to determine the mechanical and electrical properties of the strain sensor. Each test specimen should be measured directly. The test specimens' dimensions shall be specified within the maximum error of ±5 %.

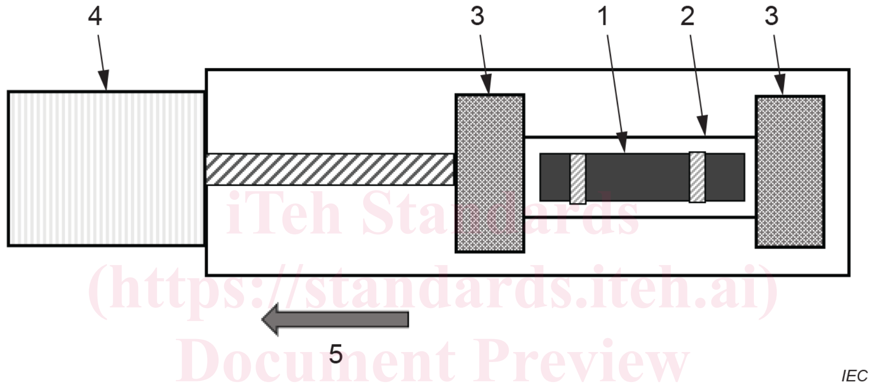
6 Test method and test apparatus

6.1 General

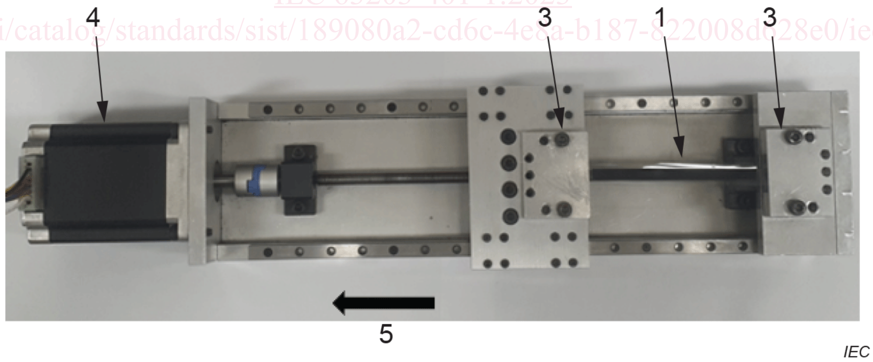
The test is performed by applying a tensile load to a test specimen. The tensile strain induced by the tensile load shall be uniform in a pre-defined gauge section in the elastic region of the substrate or the thin resistive material. To measure the change in electrical resistance along with the change in mechanical strain, the section of gauge shall be selected carefully. The gauge section used to measure the mechanical strain shall be coincident with or scalable to the section used to measure the electrical resistance.

6.2 Test apparatus and measurement

The stretching test machine includes the grips to hold a test sample, the actuating motor which regulates moving distance and moving speed while testing. Stretching shall be applied along the tensile axis of the test sample to avoid the bending or twisting of the test piece. An example of a stretching test machine is shown in Figure 2.



(a) Schematic drawing of stretching test machine (top view)



(b) Photograph of example of a stretching test machine (top view)

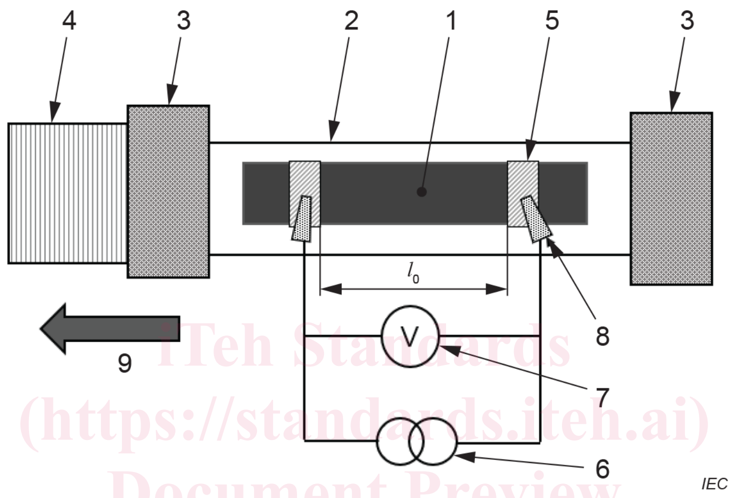
Key

1 Stretchable strain sensor	2 Stretchable substrate
3 Grip	4 Actuating motor
5 Actuating direction	

Figure 2 – Example of stretching test machine

A vertical stretching test machine can be used if the deformation of the stretchable sensor due to its own weight can be ignored. The electrical measurement circuit can use two-wire or four-wire methods depending on the magnitude of the electrical resistance of the sensor. For a sensor that has an electrical resistance greater than 1 kΩ, a two-wire method can be used for ease of measurement. For a sensor that has an electrical resistance 1 kΩ or less, the four-wire method shall be used to eliminate contact- and lead-wire resistance.

Figure 3 shows the schematic drawing of the two-wire method and test machine setup. The test machine consists of grips, load cell (or strain measurement sensor), motor or actuator. Prepare a stretchable specimen with a gauge length longer than the distance between the grips. The resistance measurement setup consists of a constant-current source, a voltmeter, metal clips or electrodes. The clips that are made of rust-resistant metal or that have a surface treatment (such as gold plating) to prevent rust shall be used.



Key

1 Stretchable sensor material	2 Stretchable substrate
3 Grip	4 Motor or actuator
5 Pad	6 Constant current source
7 Voltmeter	8 Metal electrode (or metal clip)
9 Actuating direction	

Figure 3 – Schematic drawing of a stretching test machine and two-wire measurement method

Figure 4 shows the schematic drawing of the four-wire method and test machine setup. The resistance measurement setup consists of a constant-current source, a voltmeter, metal electrodes or metal clips (voltage electrode), and metal electrodes (current electrode). Therefore, the constant-current source pad and voltmeter pad for electrical connection are required at each side of the sample. The fabrication of pads is explained in 5.1. Figure 4 a) illustrates the initial test setup, and Figure 4 b) illustrates the test setup during stretching. The examples of sensor resistance or changes in resistance during stretching test are illustrated in Annex A.

The quality-certified rulers or mechanical extensometer are used to measure the stretched gauge length (l_s). Several optical methods using laser, interference light, camera, and image systems such as digital image correlation (DIC) systems can be utilized to measure the stretched gauge length. Several methods are available to measure resistance changes of the sensor with sufficient resolution and accuracy.