IEC 62047-22

Edition 1.0 2014-06

INTERNATIONAL STANDARD

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colour inside

**Semiconductor devices – Micro-electromechanical devices –
Part 22: Electromechanical tensile test method for conductive thin films on flexible substrates**

**Dispositifs à semiconducteurs – Dispositifs microélectromécaniques –
Partie 22: Méthode d'essai de traction électromécanique pour les couches minces conductrices sur des substrats souples**

IEC 62047-22:2014-06(en-fr)

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FOREWORD

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The text of this standard is based on the following documents:

FDIS	Report on voting
47F/186/FDIS	47F/190/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62047 series, published under the general title *Semiconductor devices – Micro-electromechanical devices*, can be found in the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 22: Electromechanical tensile test method for conductive thin films on flexible substrates

1 Scope

This part of IEC 62047 specifies a tensile test method to measure electromechanical properties of conductive thin micro-electromechanical systems (MEMS) materials bonded on non-conductive flexible substrates. Conductive thin-film structures on flexible substrates are extensively utilized in MEMS, consumer products, and flexible electronics. The electrical behaviours of films on flexible substrates differ from those of freestanding films and substrates due to their interfacial interactions. Different combinations of flexible substrates and thin films often lead to various influences on the test results depending on the test conditions and the interfacial adhesion. The desired thickness of a thin MEMS material is 50 times thinner than that of the flexible substrate, whereas all other dimensions are similar to each other.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62047-2:2006, *Semiconductor devices – Micro-electromechanical devices – Part 2: Tensile testing method of thin film materials*

IEC 62047-3:2006, *Semiconductor devices – Micro-electromechanical devices – Part 3: Thin film standard test piece for tensile testing*

IEC 62047-8:2011, *Semiconductor devices – Micro-electromechanical devices – Part 8: Strip bending test method for tensile property measurement of thin films*

ISO 527-3:1995, *Plastics – Determination of tensile properties – Part 3: Test conditions for films and sheets*

3 Terms, definitions, symbols and designations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
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)

Note 1 to entry: Gauge factor is expressed as $G_F = (R - R_O)/R_O e$, where R is the electrical resistance in the deformed configuration.

3.1.2
elongation at electrical failure
A_{telic}
engineering strain value at which the electrical resistance starts to exceed a predefined limit

3.2 Symbols and designations

The shape of the test piece and symbols are presented in Figure 1 and Table 1, respectively. The overall shape of the test piece is similar to a conventional thin-film or sheet test piece (in accordance with ISO 527-3) for tensile tests, but it has a multilayered structure.

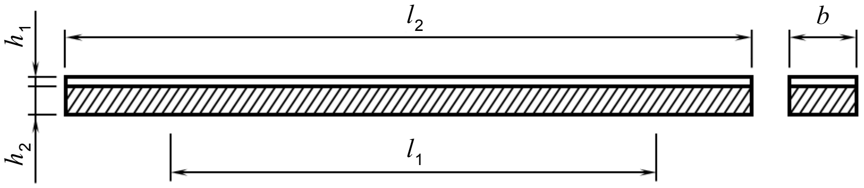


Figure 1 – Bilayered test piece

Table 1 – Symbols and designations of a test piece

Symbol	Unit	Designation
l_1	µm	Gauge length for strain and resistance change measurements
l_2	µm	Overall length
h_1	µm	Thickness of the first layer (or thin film)
h_2	µm	Thickness of the second layer (or substrate)
b	µm	Width

4 Test piece

4.1 General

The test piece shall be prepared using the same fabrication process as the actual device fabricated for flexible MEMS. Machining of the test piece shall be performed carefully to prevent formation of cracks or flaws and delamination in the test piece. Chemical etching or mechanical machining with a very sharp tool shall be applied to shape the test piece.

4.2 Shape of a test piece

The shape of a test piece is shown in Figure 1. Because the change in electrical resistance is related to strain or stress, electrical resistance shall be measured in a region of nearly uniform strain. To measure electrical resistance, attach lead wires to the conductive thin film of the test piece. Conductive thin films deposited on flexible substrates are usually very thin compared with the diameter of the lead wires, and the lead wires are easily detached from the test piece during the electromechanical test. Therefore, place the lead wires in tensile grips and secure the electrical contact by applying mechanical contact force. Tensile grips are described in detail in 5.2. For uniform strain distribution, the shape of the test piece is a rectangular strip, not a dog bone (see Figure 1 of ISO 527-3:1995 for other rectangular test pieces). To eliminate the effect of the fixed boundary near the grips (l_1), the gauge length shall be at least 20 times larger than the width (b).

4.3 Measurement of dimensions

To analyze the test results, the test piece dimensions shall be accurately measured because the dimensions are used to determine the mechanical properties of test materials. Gauge length (l_1), width (b), and thickness (h_1, h_2) should be measured with an error of less than ± 5 %. Thickness measurement shall be performed according to Annex C of IEC 62047-2:2006 and to Clause 6 of IEC 62047-3:2006. There can be some combinations of thin film and substrate where it is difficult to fulfil the tolerance of thickness measurement. In this case the average and the standard deviation of the thickness measurement should be reported.

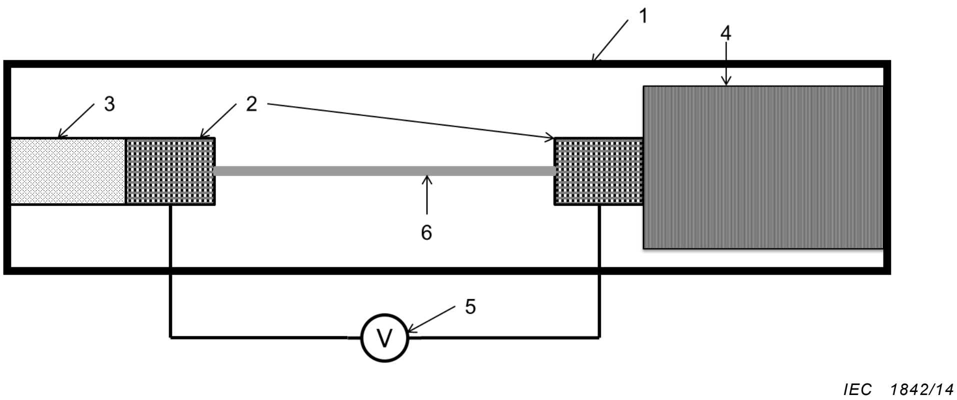
5 Testing method and test apparatus

5.1 Test principle

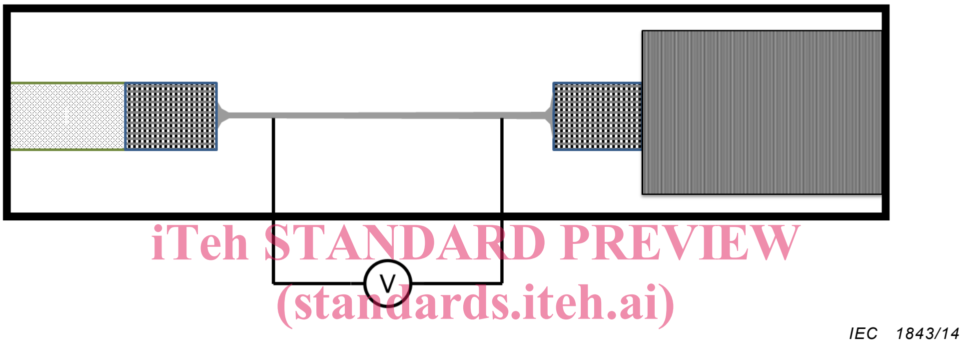
The test is performed by applying a tensile load to a test piece. The tensile strain induced by the tensile load shall be uniform in a pre-defined gauge section in the elastic region of the substrate or the thin MEMS material. To measure the change in electrical resistance along with the change in mechanical strain, carefully select the gauge section. The gauge section for measuring mechanical strain shall be coincident with or scalable to that for measuring electrical resistance. This constraint is an important point in this standard.

5.2 Test machine

The test machine is similar to a conventional tensile test machine except that it is capable of measuring electrical resistance during the test. The electrical measurement circuit can be a 2-wire or 4-wire method depending on the magnitude of the electrical resistance of the test piece. For a test piece with an electrical resistance greater than 1 kΩ, a 2-wire method can be utilized for ease of measurement. For a test piece with an electrical resistance less than 1 kΩ, the 4-wire method (Kelvin method) shall be utilized to eliminate contact and lead wire resistance. A schematic of the test machine is shown in Figure 2a). For a material sensitive to stress concentration and local plastic deformation, a test piece with rounded, gripped ends shall be used according to Figure 1 of IEC 62047-2:2006, and the test machine in Figure 2b) should be used.



a) Test machine setup using grips with an electrical contact



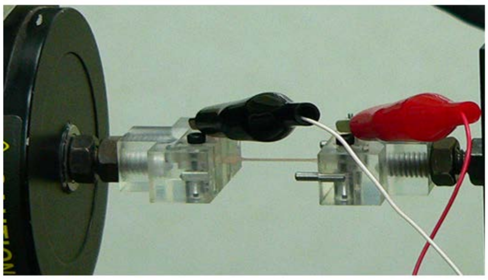
b) Test machine setup using electrical contacts on the test piece

Key

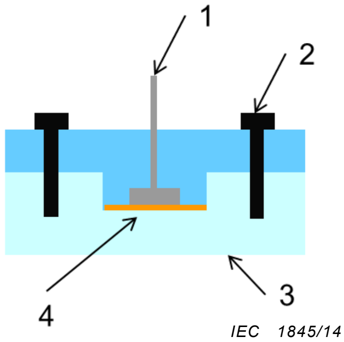
1	Machine frame	2	Grip
3	Loadcell	4	Actuator
5	Volt meter	6	Specimen

Figure 2 – Schematic of an electromechanical test machine

To measure electrical resistance, a tensile grip with electrical contacts is utilized, and the number of electrical contacts is dependent on the electrical measurement method (2-wire or 4-wire method). A schematic of the tensile grip is shown in Figure 3. In this standard, strain is estimated from the grip-to-grip distance. An optical or mechanical extensometer shall be used to measure the grip-to-grip distance.



a) Photograph of the installed tensile grip



b) Schematic of the tensile grip

Key

1	Probe pin	2	Bolt
3	Insulating jig	4	Specimen

Figure 3 – Electromechanical tensile grip

5.3 Test procedure

The test procedure is as follows:

a) Fix the test piece using the test apparatus tensile grip. The longitudinal direction of the test piece shall be aligned with the actuating direction of the test apparatus, and the deviation angle shall be less than 1 degree, as specified in 4.4 of IEC 62047-8:2011.

b) Verify the electrical measurement unit as well as the loadcell and strain measurement unit. The three signals provided by the measurement units shall be measured simultaneously with no time delay.

c) Apply a tensile load to the test piece at a constant strain rate (or grip-to-grip displacement rate). The strain rate shall range from 0,01 min^{-1} to 10 min^{-1} depending on the material system of the test piece and the actual usage condition of the customer.

d) Unload the test apparatus when electrical failure occurs in the test piece. After testing, carefully remove the test piece from the test apparatus to analyze its failure mechanism. If possible, preserve the fractured test piece after testing.

5.4 Test environment

Because electrical properties are temperature sensitive, fluctuations in temperature during the test shall be controlled to be less than ± 2 °C. Flexible substrates made of certain polymeric materials can be sensitive to humidity; thus, the change in relative humidity (RH) in the testing laboratory shall be controlled to be less than ± 5 % RH for such materials.

6 Test report

The test report shall contain the following information.

a) Reference to this international standard;

b) Test piece identification number;

c) Test piece preparation procedures;

d) Multilayered structure of the test piece;

e) Test piece dimensions and their measurement method;

f) Description of the testing apparatus;