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Semiconductor devices – Micro-electromechanical devices –
Part 29: Electromechanical relaxation test method for freestanding conductive thin films under room temperature

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FOREWORD

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International Standard IEC 62047-29 has been prepared by subcommittee 47F: Micro-electromechanical systems, of IEC technical committee 47: Semiconductor devices.

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

FDIS	Report on voting
47F/295/FDIS	47F/298/RVD

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

This document 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 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 "http://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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

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SEMICONDUCTOR DEVICES –
MICRO-ELECTROMECHANICAL DEVICES –

Part 29: Electromechanical relaxation test method for freestanding conductive thin films under room temperature

1 Scope

This part of IEC 62047 specifies a relaxation test method for measuring electromechanical properties of freestanding conductive thin films for micro-electromechanical systems (MEMS) under controlled strain and room temperature. Freestanding thin films of conductive materials are extensively utilized in MEMS, opto-electronics, and flexible/wearable electronics products. Freestanding thin films in the products experience external and internal stresses which could be relaxed even under room temperature during a period of operation, and this relaxation leads to time-dependent variation of electrical performances of the products. This test method is valid for isotropic, homogeneous, and linearly viscoelastic materials.

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 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*

IEC 62047-21:2014, *Semiconductor devices – Micro-electromechanical devices – Part 21: Test method for Poisson's ratio of thin film MEMS materials*

IEC 62047-22:2014, *Semiconductor devices – Micro-electromechanical devices – Part 22: Electromechanical tensile test method for conductive thin films on flexible substrates*

3 Terms and symbols

3.1 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

3.1.1

gauge factor

G_F

ratio of the relative change in electrical resistance R to the change in mechanical strain ($\Delta\varepsilon$)

Note 1 to entry: Gauge factor is defined as $G_F = (\Delta R/R)/\Delta\varepsilon$, where ΔR is the change in resistance, R is the unstrained resistance, $\Delta\varepsilon$ is the change in the mechanical strain. R and ΔR are expressed in ohms and $\Delta\varepsilon$ in µm/m.

3.1.2

piezoresistive coefficient

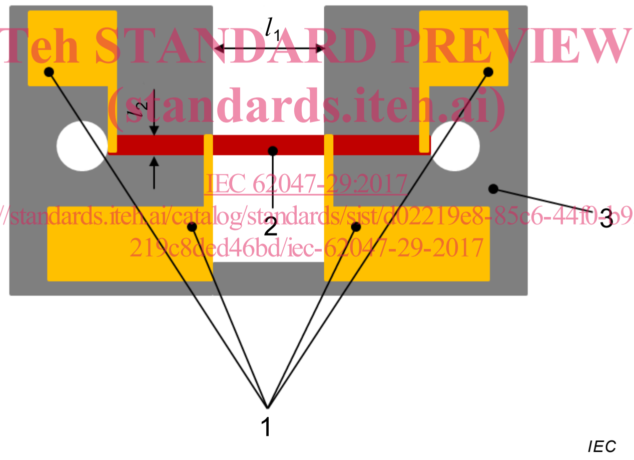
π

ratio of the relative change in electrical resistivity ρ, to the change in applied mechanical stress

Note 1 to entry: Piezoresistive coefficient is defined as $\pi = (\Delta\rho/\rho)/\Delta\sigma$, where $\Delta\rho$ is the change in resistivity, ρ the unstressed resistivity, $\Delta\sigma$ the applied mechanical stress. Stress is expressed in Pascal [Pa].

3.2 Symbols and designations

The shape of a 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 for strip bending test (see IEC 62047-8:2011), and it has a freestanding structure and four electric contacts for electrical measurements.



Key

1	electrical contacts for four wire measurement
2	test piece
3	substrate

Figure 1 – Freestanding 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	Width of a test piece
h	µm	Thickness of a test piece

4 Test piece

4.1 General

A test piece shall be prepared using the same fabrication process as the target film of an actual MEMS device. Shaping the test piece shall be performed to prevent formation of cracks, flaws, or delamination in 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 uniform strain. The electrical resistance shall be measured using four wire method, and this requires four electric contacts on the test piece. To eliminate the effect of the fixed boundary near the grips, the gauge length (l_1) shall be at least 20 times larger than the width (l_2). The width shall be more than 10 times the thickness (h).

4.3 Measurement of dimensions

Gauge length (l_1), width (l_2), and thickness (h) should be measured with an error of less than ± 5 %. The thickness should be measured according to Annex C of IEC 62047-2:2006 and in Clause 6 of IEC 62047-3:2006.

5 Test principle and test apparatus

5.1 Test principle

The test is performed by applying a prescribed tensile strain to a test piece and by measuring the change in electrical resistance under constant strain for a testing period. Both the electrical resistance and the mechanical stress relax as time, and the ratio of these two quantities characterizes the piezoresistive behaviour of a tested material. To this end, the tensile strain induced by the tensile load shall be uniform in a pre-defined gauge section and shall be in the elastic region of the test piece. The actuator of the test machine shall be controlled with a feedback loop to keep the strain constant since the strain in thin films usually creeps even under room temperature, and this leads to deviation of strain in the test piece. To measure the change in electrical resistance under constant strain, the gauge section for measuring mechanical strain shall be coincident with or scalable to that for measuring electrical resistance.

5.2 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.

5.3 Test machine

The test machine is similar to a conventional tensile test machine except that it is capable of feedback control of applied strain and measurement of electrical resistance during the test. The electrical resistance shall be measured with four wire method (Kelvin method) to exclude the effects of parasitic resistances from contact and lead wires. The electrical current for the four wire method measurement shall be as small as possible to prevent the test piece from heating, but to provide sufficient measurement resolution and accuracy. A schematic of the test machine is shown in Figure 2. A noncontact strain measurement method like digital image correlation shall be used to measure the strain not to disturb a test piece. The measured strain signal shall be connected to the test machine for the feedback control.