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Semiconductor devices - Micro-electromechanical devices - Part 52: Biaxial tensile testing method for stretchable MEMS

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IEC 62047-52 has been prepared by subcommittee 47F: Micro-electromechanical systems, of IEC technical committee 47: Semiconductor devices. It is an International Standard.

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

Draft	Report on voting
47F/505/CDV	47F/519A/RVC

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 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 webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,

– withdrawn, or

– revised.

1 Scope

This part of IEC 62047 specifies a testing method for measuring device performance and failure strain under biaxial tensile deformation in stretchable MEMS materials. The typical examples of the stretchable MEMS materials are flexible single crystalline silicon structures, MEMS circuit boards, interconnected MEMS on a stretchable substrate. The test piece has a cruciform geometry and the test piece thickness ranges from 1 µm to 100 µm with the same thickness as the actual devices. Since the failure strain can vary depending on loading conditions like uniaxial tension and equi-biaxial tension, a biaxial load is applied to a cruciform test piece with varying strain ratio between two perpendicular loading directions.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and symbols

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
loading direction 1
loading direction with larger strain between two perpendicular loading directions

3.1.2
loading direction 2
loading direction with smaller strain between two perpendicular loading directions

3.1.3
normal strain along the loading direction 1
e_1
measured displacement between two gauge markers divided by the initial distance between the two gauge markers along the loading direction 1

Note 1 to entry: This quantity has no unit.

3.1.4
normal strain along the loading direction 2
e_2
measured displacement between two gauge markers divided by the initial distance between the two gauge markers along the loading direction 2

Note 1 to entry: This quantity has no unit.

3.1.5
strain rate
normal strain along the loading direction 1 divided by testing time

Note 1 to entry: The unit of this quantity is s^{-1}.

3.1.6
biaxial strain ratio
normal strain along the direction 1 divided by normal strain along the direction 2

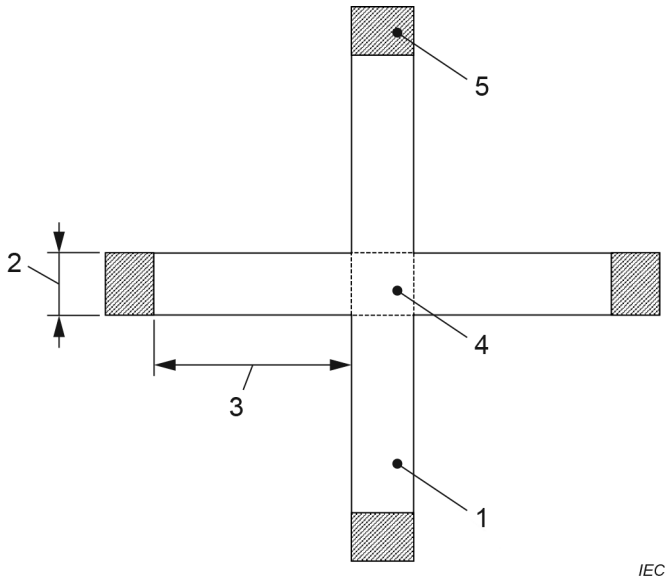
Note 1 to entry: This quantity has no unit.

3.1.7
failure strain
critical normal strain along the loading direction 1 at the moment of device failure

Note 1 to entry: This quantity has no unit.

4 Designations

The shape of the test piece is presented in Figure 1. The overall shape of the test piece is a cruciform with a long arm and grip area.



Key

1 arm of a cruciform test piece
2 width of arm
3 length of arm
4 gauge area of a test piece
5 grip area of a test piece

Figure 1 – Cruciform test piece for biaxial tensile testing

5 Test piece

5.1 General

The test piece for biaxial tensile testing method shall be prepared using the same preparation process for the actual MEMS devices. The cruciform geometry of a test piece shown in Figure 1 is formed by laser cutting, reactive ion etching, wet chemical etching or other machining techniques. The thickness of a test piece shall be identical to the actual MEMS devices and the gauge area of a test piece should be similar with the lateral dimensions of the actual MEMS devices.

5.2 Shape of a test piece

The thickness of a cruciform test piece shall be at least 10 times smaller than the width of the test piece arm. The length of the arm shall be at least 3 times larger than the gauge length of a test piece. When the geometric requirements are not satisfied, finite element analysis shall be provided to validate the geometric factors of a test piece. Fillets at the corner of the test piece should be provided to reduce stress concentration. In such cases, the radii of the fillets could be determined through finite element analysis.

5.3 Measurement of dimensions

To analyze the test results, the dimensions of the test piece shall be accurately measured because the dimensions are used to determine the strain of stretchable MEMS materials. The thickness and width should be measured using an electron or optical microscope and image analysis with an error of less than ±5 %. Information on dimensional measurement can be found in Annex C of IEC 62047-2:2006 and in Clause 6 of IEC 62047-3:2006.

6 Testing method and test apparatus

6.1 Test principle

The test is performed by applying strain to the test piece at the four grips. The specimen is stretched along with the two directions, which are perpendicular to each other. The biaxial stretching causes the strain field of the MEMS devices, which are measured by an optical microscope and CCD camera. During the stretching, the gauge area of the test piece is monitored using the microscope with a field of view larger than the gauge area. To measure the specimen during the test, the gauge area of the specimen should not shift away from the field of view. The loads applied to the test piece are measured by two individual load cells which are connected to the grips of each axis. The axial loads along the loading direction 1 increase by the biaxial stretching, and rapidly decrease when failures or damages induced by deformations of the test piece occur. The failure strain can be obtained from the loading displacement at the abrupt load drop. When the different normal strains are applied between the loading directions 1 and 2, the biaxial strain ratio, defined as the ratio of the normal strain along the loading direction 1 (e_1) to the normal strain along the loading direction 2 (e_2), should be taken into account, as well. Examples of biaxial tensile testing results for stretchable devices are given in Annex A and Annex B. If the test is performed with the electrical measures, it is possible to detect the failures from the electric signals. An example of the failure detection is described in Annex B.

6.2 Test apparatus

The test machine is shown in Figure 2. Four stages are positioned to apply biaxial tensile force to the cruciform test piece. To measure the applied load to the test piece along individual loading axes, two loadcells are installed to stage x1 and stage y1, respectively. Four jigs to fix the test piece are connected to the stages or the loadcells. Lead wires connect electrical measurement systems to the devices in the test piece for in-operando testing. The wires are thin enough to not interfere with the load measurement. The optical microscope and CCD camera are positioned above the center of the test piece and measure the deformation of the gauge area during the test. The entire testing system is mounted on an anti-vibration table.

6.3 Test procedure

The test procedure is as follows:

a) install a test piece on the four jigs. The alignment of the test piece is adjusted to remove residual stress;

b) connect lead wires to the cruciform test piece including MEMS devices, if in-operando biaxial tensile test is required. Before applying tensions, it is necessary to confirm the operation by applying current to the device;