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Semiconductor devices – Micro-electromechanical devices – Part 47: Silicon based MEMS fabrication technology – Measurement method of bending strength of microstructures

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SEMICONDUCTOR DEVICES –
MICRO-ELECTROMECHANICAL DEVICES –

Part 47: Silicon based MEMS fabrication technology – Measurement method of bending strength of microstructures

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IEC 62047-47 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/474/FDIS	47F/481/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 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- withdrawn, or
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SEMICONDUCTOR DEVICES –
MICRO-ELECTROMECHANICAL DEVICES –

Part 47: Silicon based MEMS fabrication technology – Measurement method of bending strength of microstructures

1 Scope

This part of IEC 62047 specifies the requirements and testing method to measure the bending strength of microstructures which are fabricated by micromachining technology used in silicon-based micro-electromechanical system (MEMS).

This document is applicable to the in-situ bending strength measurement of microstructures manufactured by microelectronic technology process and other micromachining technology.

With the devices scaling, the bending strength degradation, induced by defects and contaminations, becomes more severe. This document specifies an in-situ testing method of the bending strength based on MEMS technique. This document does not need intricate instruments (such as scanning probe microscopy and nanoindenter) and special test specimens.

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Since in-situ on-chip tester in this document and device are fabricated with the same process on the same wafer, this document can give some practical reference for the design part.

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2 Normative references

There are no normative references in this document.

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3 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
testing structure
nanostructure (for example, cantilevered or fixed beams) specially made to measure the properties of materials

[SOURCE: IEC 62047-45:2024, 3.1]

3.2
testing device
microstructure that transmits force or displacement to a testing structure and the force or displacement can be read out at the same time

[SOURCE: IEC 62047-45:2024, 3.2]

3.3
beam of constant strength
beam whose maximum normal stress on each cross-section is equal

3.4
in-situ on-chip tester
structure that integrates both the testing structure and the testing device on one chip, which is used to evaluate the process-related mechanical properties of MEMS devices

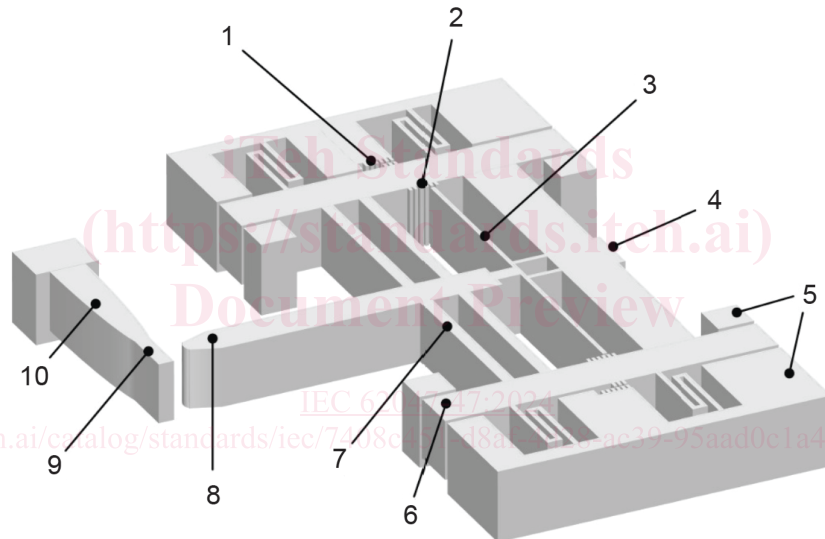
Note 1 to entry: In-situ on-chip tester and MEMS devices are manufactured simultaneously.

[SOURCE: IEC 62047-45:2024, 3.3]

4 Requirements

4.1 In-situ on-chip tester design requirements

The schemes of the in-situ on-chip tester are shown in Figure 1 and Figure 2.



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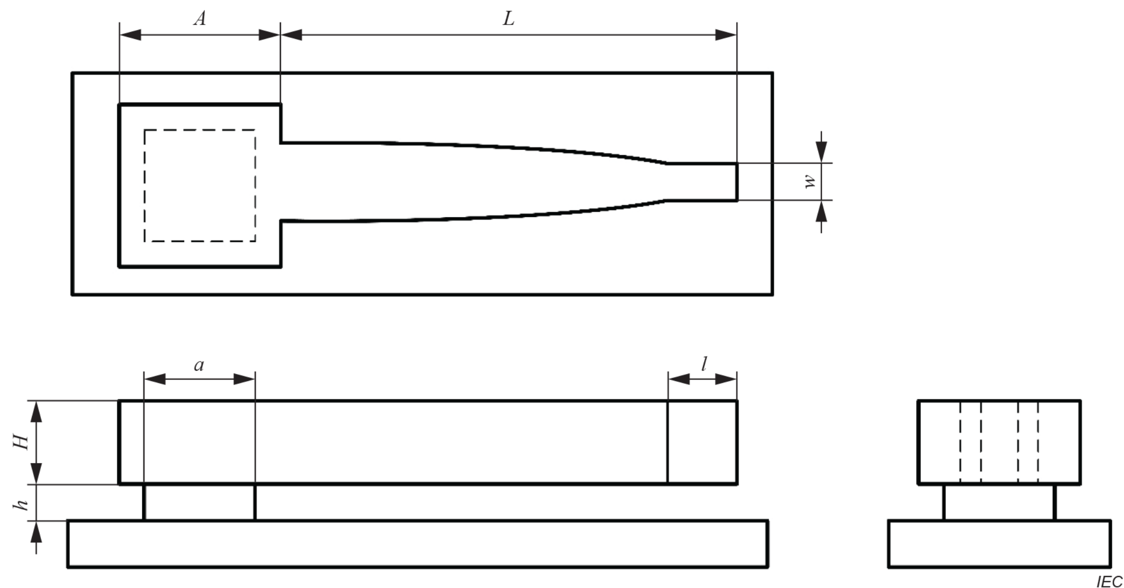
Key
1 displacement ruler
2 deflection ruler
3 magnifying lever
4 loading point
5 collision block
6 movable framework
7 elastic beam
8 on-chip needlepoint
9 loading segment
10 beam of constant strength

The testing device includes 1 to 10, and the testing structure includes 8 to 10.

Figure 1 – The in-situ on-chip bending strength tester



Key

H thickness of the beam of constant strength

h height of the anchor beam in the bonding area

A dimension of the bonding area of the beam of constant strength

a dimension of the bonding area

L length of the beam of constant strength arm, which should be designed with sequential values

l length of the loading segment

w width of the loading segment

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Figure 2 – Three-view drawing of the testing structure

The design of the in-situ on-chip tester should be as follows:

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a) The testing structure should adopt the structure of the beam of constant strength, which can eliminate the error caused by the stress concentration and extraction process defects;

b) The drive of the testing device should generate enough force to bend the testing structure, such as off-chip probe loading, on-chip thermal drive loading or on-chip electrostatic loading;

c) To prevent the elastic beam of the testing device breaking earlier than the beam of constant strength, the strength of the elastic beam should be designed high enough. Design dimensions are shown in Annex A;

d) To prevent the bonding surface of the testing structure breaking earlier than the beam of constant strength, the strength of the bonding surface should be designed high enough. Design dimensions are shown in Annex A;

e) The loading segment should meet the condition of l >20 μm to ensure that the influence of linewidth loss on the strength characteristics of the testing structure is less than 5 %;

f) The ruler design of the testing device should satisfy the resolution requirement. The ruler should be clearly monitored by optical microscopy;

g) The design of the testing structure should take full account of machining error and leave enough machining tolerance. The influence of the process during structure formation on the surface roughness of the structure should also be considered in the design of the testing structure.

4.2 In-situ on-chip tester fabrication requirements

Requirements for in-situ on-chip tester are as follows:

a) The fabrication process of the testing device and testing structure is the same as that of MEMS device;

b) The testing structure is applied to materials that can be used as the movable structure layer of MEMS devices, such as crystal silicon.

4.3 Testing environment requirements

Testing should be carried out in the actual manufacturing environment of the MEMS device chip.

5 Testing method

5.1 General

The detection of microstructure bending strength is to use the drive (this document takes off-chip probe loading as an example) to load the testing device, and then make the on-chip needlepoint of the testing device apply to the testing structure. The deformation and damage of the testing structure are monitored through the optical microscope, and the bending strength of the testing structure is determined by reading the number of the deflection ruler of the testing device.

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5.2 Microstructure bending strength testing method operation process

The microstructure bending strength testing method operation process is as follows:

a) As shown in Figure 3, when testing the bending strength of the microstructure, the chip of the in-situ on-chip tester is fixed on the probe station. A horizontal positive pressure is applied with the probe at the loading point until the fracture of the testing structure is observed through the microscope, and the maximum reading d of the deflection ruler is recorded in the process. The reading d is substituted into the Formula (1) to calculate the bending strength;

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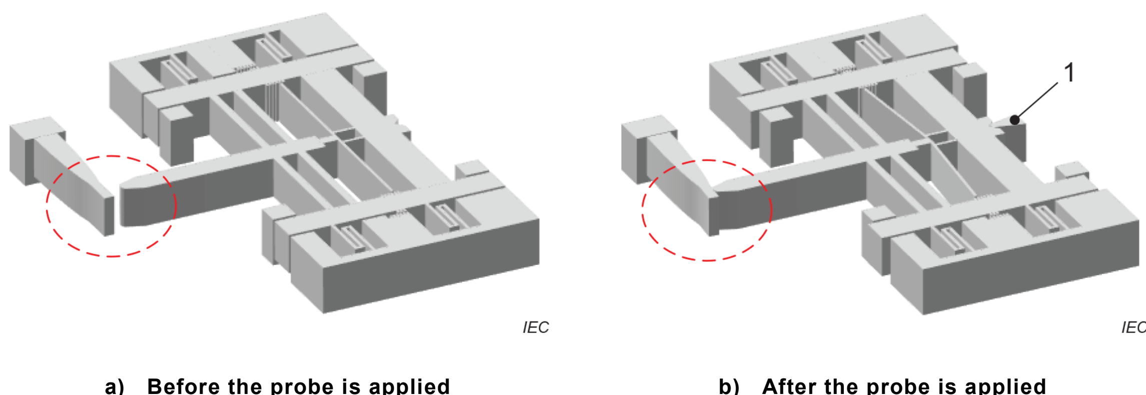

a) Before the probe is applied

b) After the probe is applied

Key

1 driven loading

Figure 3 – Microstructure bending strength testing method operation process

b) The probe and whole in-situ on-chip tester should be present in the field of view under optical microscopy. During the operation process, the probe loading should be less than 1 μm/s. After the testing structure breaks, the probe force should be stopped in time and the probe should be slowly withdrawn until it is separated from the testing device;

c) In order to obtain sufficient resolution and appropriate probe pressure, Table 1 gives the recommended dimension of the testing structure design.