



BSI Standards Publication

Semiconductor devices — Micro-electromechanical devices

Part 12: Bending fatigue testing method
of thin film materials using resonant vibration
of MEMS structures

National foreword

This British Standard is the UK implementation of EN 62047-12:2011. It is identical to IEC 62047-12:2011.

The UK participation in its preparation was entrusted to Technical Committee EPL/47, Semiconductors.

A list of organizations represented on this committee can be obtained on request to its secretary.

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**Semiconductor devices -
Micro-electromechanical devices -
Part 12: Bending fatigue testing method of thin film materials using
resonant vibration of MEMS structures
(IEC 62047-12:2011)**

Dispositifs à semiconducteurs -
Dispositifs microélectromécaniques -
Partie 12: Méthode d'essai de fatigue en
flexion des matériaux en couche mince
utilisant les vibrations à la résonance des
structures à systèmes
microélectromécaniques (MEMS)
(CEI 62047-12:2011)

Halbleiterbauelemente -
Bauelemente der Mikrosystemtechnik -
Teil 12: Verfahren zur Prüfung der Biege-
Ermüdungsfestigkeit von
Dünnschichtwerkstoffen unter
Verwendung der Resonanzschwingungen
bei MEMS-Strukturen
(IEC 62047-12:2011)

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Foreword

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In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 62047-2:2006 NOTE Harmonized as EN 62047-2:2006 (not modified).

Annex ZA
(normative)
Normative references to international publications
with their corresponding European publications

The following referenced documents are indispensable for the application 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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 62047-3	2006	Semiconductor devices - Micro-electromechanical devices - Part 3: Thin film standard test piece for tensile-testing	EN 62047-3	2006
ISO 12107	-	Metallic materials - Fatigue testing - Statistical - planning and analysis of data		-

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SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 12: Bending fatigue testing method of thin film materials using resonant vibration of MEMS structures

1 Scope

This part of IEC 62047 specifies a method for bending fatigue testing using resonant vibration of microscale mechanical structures of MEMS (micro-electromechanical systems) and micromachines. This standard applies to vibrating structures ranging in size from 10 μm to 1 000 μm in the plane direction and from 1 μm to 100 μm in thickness, and test materials measuring under 1 mm in length, under 1 mm in width, and between 0,1 μm and 10 μm in thickness.

The main structural materials for MEMS, micromachine, etc. have special features, such as typical dimensions of a few microns, material fabrication by deposition, and test piece fabrication by means of non-mechanical machining, including photolithography. The MEMS structures often have higher fundamental resonant frequency and higher strength than macro structures. To evaluate and assure the lifetime of MEMS structures, a fatigue testing method with ultra high cycles (up to 10^{12}) loadings needs to be established. The object of the test method is to evaluate the mechanical fatigue properties of microscale materials in a short time by applying high load and high cyclic frequency bending stress using resonant vibration.

2 Normative references

The following referenced documents are indispensable for the application 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 62047-3:2006, *Semiconductor devices – Micro-electromechanical devices – Part 3: Thin film standard test piece for tensile testing*

ISO 12107, *Metallic materials – Fatigue testing – Statistical planning and analysis of data*

3 Terms and definitions

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

3.1

amplitude

one-half the algebraic difference between the maximum value and minimum value in a loading cycle

3.2

load ratio

algebraic ratio of the maximum value and minimum value of the load of a cycle

3.3

S-N curve

plot of stress or strain (S) against the number of cycles (N) to failure

3.4

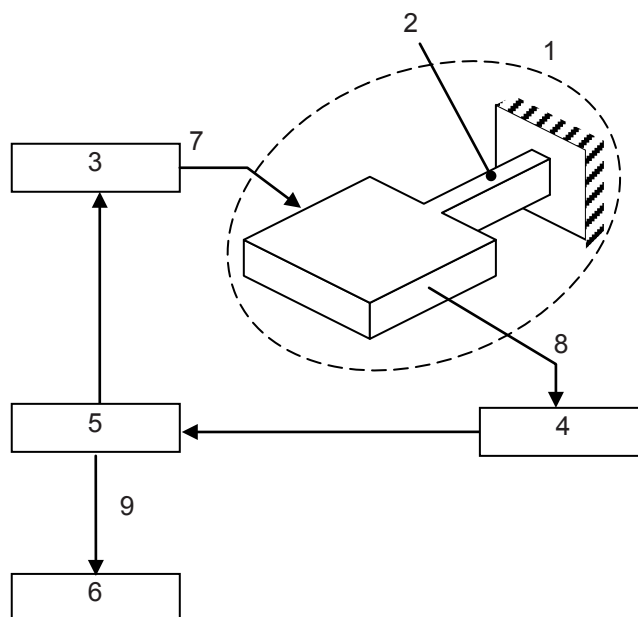
reference strength:

static strength or instantaneous failure strength

3.5

instantaneous failure strength

failure strength of quasi-static test or resonant vibration test at rapid amplitude growth



IEC 2064/11

Key

- | | |
|---------------------------|--------------------------|
| 1 Specimen | 2 Test part |
| 3 Actuator | 4 Sensor |
| 5 Controller | 6 Recorder |
| 7 Force | 8 Displacement or strain |
| 9 Amplitude and frequency | |

Figure 1 – Block diagram of the test method

4 Test equipment

4.1 General

The test equipment shall be capable of generating resonant vibration with constant amplitude and stable frequency to the test structure. A block diagram of the test equipment is shown in Figure 1. The test equipment consists of an actuator for oscillation, a sensor for amplitude detection, a controller for maintaining the resonant vibration at a constant amplitude, and a recorder for monitoring.

The amplitude control method is classified as follows.

a) Constant strain control

Applied strain in the test part is maintained at constant. It can be applied for elastic or inductile materials.

b) Constant stress control

Applied stress in the test part is maintained at constant. Load monitoring and closed loop control is crucial for the method.

4.2 Actuator

The actuator shall be capable of applying oscillation force of the necessary amplitude and frequencies along the required direction. Various kind of actuators can be used, e.g., electrostatic, piezoelectric, thermal, and electromagnetic actuators. The actuator may be installed in the test structure, as discussed in 5.1.

4.3 Sensor

The sensor shall be capable of measuring the movement of the specimen to determine the stress amplitude (for constant stress amplitude testing) or the strain amplitude (for constant strain amplitude testing) to the test part of the specimen.

The sensor and its associated electronics shall be accurate to within 1 % of the range of the stress or strain amplitude.

The sensor should measure the movement continuously, in order to maintain a constant vibration and detect failure effectively. If the specimen is an elastic material and will not show the change in the vibrating properties, however, it is permissible to measure the movement at regular time intervals.

The movement is detected by measuring displacement of the test structure or the stress or strain in the test structure. Clause A.2 shows a method for detecting rotational displacement of the mass from changes in capacitance. Clause B.2 shows a method using a strain gauge integrated in the specimen. Clause C.2 shows a method for detecting displacement of the mass using a non-contact displacement gauge.

4.4 Controller

The controller shall be capable of generating the oscillation signal to the actuator from the movement signal from the sensor, in order to maintain the required resonant vibration. During testing, the amplitude and frequency of the specimen shall be maintained at a constant level. One of the following methods should be applied for the specimen, depending on the vibration characteristics.

a) Closed loop method

The frequency and amplitude of the oscillation signal applied to the specimen shall be controlled to follow changes in the resonant frequency. In most cases, the signal applied to the actuator is generated from the movement signal of the specimen. A self-excited oscillation circuit or phase-locked loop circuit can be used as a means for maintaining the resonant frequency. An automatic gain control circuit (AGC) can also be used to maintain a constant amplitude by changing the amplitude of the oscillation signal based on the detected amplitude.

b) Open loop method

Elastic or inductile materials that show a linear response but no plastic deformation may be tested using an open loop method. This test may be performed by stopping at regular intervals and measuring the resonant characteristics, or by actuating the test structure from the start to the end of testing at a predetermined resonance frequency and oscillation signal amplitude.

The stability of the frequency and amplitude shall be maintained throughout the test to within ± 3 % of the desired value.

4.5 Recorder

The test equipment shall include a recorder for collecting the “record data” indicated in 8.6.

4.6 Parallel testing

The test may be conducted in parallel with a number of equipment units. In this case, steps should be taken to eliminate mutual electrical or mechanical interference among the equipment units.

5 Specimen

5.1 General

The specimen shall be capable of applying a constant and high-load amplitude to the test part via resonant vibration. Examples of specific structures are shown in the Clauses A.1, B.1, and C.1.

It is permissible to integrate a mechanism in the specimen for actuating or for sensing the movement of the specimen. An example of a structure integrating mechanisms for actuation and detecting amplitude is shown in Annex A.1. An example of a structure integrating a mechanism for detecting amplitude only is shown in Annex B.1.

5.2 Resonant properties

The specimen shall have resonance characteristics that enable the application of the required deformation (mode of vibration) in the specific frequency (resonance frequency) of the specimen. The resonant frequency should preferably be more than 1 000 Hz, in order to obtain a large number of the cycles in a short time. The quality factor of the specimen should be more than 100, in order to obtain a large amplitude. Steps should be taken to ensure, within this resonance frequency, that the specimen will not vibrate in a vibration mode different from that used in the test. For example, there should be no other resonant modes close to the mode used for testing.

5.3 Test part

The specimen shall have a test part in which stress sufficient to induce failure occurs. When the test is performed to evaluate the reliability of the actual device, the deformation in the test part at resonant vibration (in-plane and out-of-plane bending) shall be the same as that of the actual device. If only low stress can be applied to a structure similar to the actual device, a notch or another means may be introduced to concentrate the stress in the targeted section of the test part.

5.4 Specimen fabrication

Refer to Clause 5 of IEC 62047-3 when manufacturing the test part of the specimen. The specimen should be fabricated by the same method as the target MEMS device for reliability evaluation is fabricated. Furthermore, the same shapes, dimensions, and multilayer film structures should be used.

6 Test conditions

6.1 Test amplitude

The test amplitude should be specified from the appropriate reference strength of the specimen. The reference strength should be determined through the methods in 7.1. One of the following procedures should be chosen for determining the test amplitude during testing, based on the reference strength.