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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Semiconductor devices – Micro-electromechanical devices – Part 18: Bend testing methods of thin film materials

Dispositifs à semiconducteurs – Dispositifs microélectromécaniques – Partie 18: Méthodes d'essai de flexion des matériaux en couche mince

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FOREWORD

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International Standard IEC 62047-18 has been prepared by subcommittee 47F: Micro-electromechanical systems, of IEC technical committee 47: Semiconductor devices.

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

FDIS	Report on voting
47F/155/FDIS	47F/162/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 on 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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- amended.

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SEMICONDUCTOR DEVICES –
MICRO-ELECTROMECHANICAL DEVICES –

Part 18: Bend testing methods of thin film materials

1 Scope

This part of IEC 62047 specifies the method for bend testing of thin film materials with a length and width under 1 mm and a thickness in the range between 0,1 μm and 10 μm. Thin films are used as main structural materials for Micro-electromechanical Systems (abbreviated as MEMS in this document) and micromachines.

The main structural materials for MEMS, micromachines, etc., have special features, such as a few micron meter size, material fabrication by deposition, photolithography, and/ or non-mechanical machining test piece. This International Standard specifies the bend testing and test piece shape for micro-sized smooth cantilever type test pieces, which enables a guarantee of accuracy corresponding to the special features.

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 62047-6:2009, *Semiconductor devices – Micro-electromechanical devices – Part 6: Axial fatigue testing methods of thin film materials*

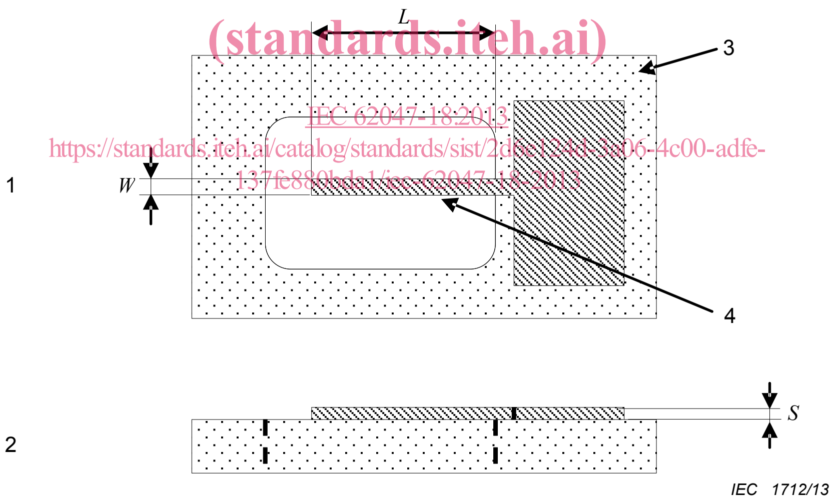
3 Symbols and designations

Symbols and corresponding designations are given in Table 1.

Table 1 – Symbols and designation of test piece

Symbol	Unit	Designation
W	µm	Width of test piece
L	µm	Length of test piece
S	µm	Thickness of test piece
L_{PA} L_{PB}, L_{PC}	µm	Distance between loading point, A, B or C, and root of the test piece respectively
P	µN	Force
δ	µm	Displacement
I_Z	$(\mu m)^4$	Moment of inertia of area
E	MPa	Elastic modulus of cantilever material

Figure 1 below shows a typical shape of cantilever beam test piece.



Key

1	Top view	3	Substrate
2	Side view	4	Test piece

Figure 1 – Schematically shown test piece with substrate

4 Test piece

4.1 Design of test piece

The test pieces are of a shape of cantilever beam as shown in Figure 1 and the shape of their cross-section shall be simple , in order to facilitate calculation of the moment of inertia of area. The shape of the cross-section of the test piece should be simple, for example rectangular or trapezoid. The relation between test piece length (L) of the parallel part of the test piece, the width (W) and thickness (S) should be $10 > L/W > 5$ and $100 > L/S > 10$.

The fixed end of the test piece shall be placed within a substrate as shown in Figure 1. Contact point of the test piece with substrate is important to avoid plastic deformation and/or fracture at the contact point of test piece root and substrate because of stress concentration (see Annex A). When a different shape of test piece is used which elastic deformation behavior does not follow Equation (1), the different shape of test piece and the equation in place of Equation (1) shall be recorded.

In order to minimize the influence of size, the size of test piece should have the same order as that of the objective device component.

4.2 Preparation of test piece

The test piece should be fabricated using the same process as when the thin film is applied to actual devices, because the mechanical properties depend on the fabrication processes. The test piece also shall be fabricated following the procedures specified in IEC 62047-6:2009, Clause 4.2 Preparation of test piece. The substrate removal process should be carefully chosen to prevent damaging the supporting part of the substrate (see Annex A) and the supporting part of the test piece.

The thin film, which has internal stress distribution along the thickness, cannot be tested due to curling after release from the substrate.

4.3 Test piece width and thickness

The width and thickness of each test piece shall be measured, as the film thickness is not usually uniform over a wafer. Both the width and thickness through the parallel part of the test piece shall be specified within the accuracy range of ± 1 % and ± 5 %. Each test piece should be measured directly (see IEC 62047-6:2009, 4.3 Test piece thickness).

4.4 Storage prior to testing

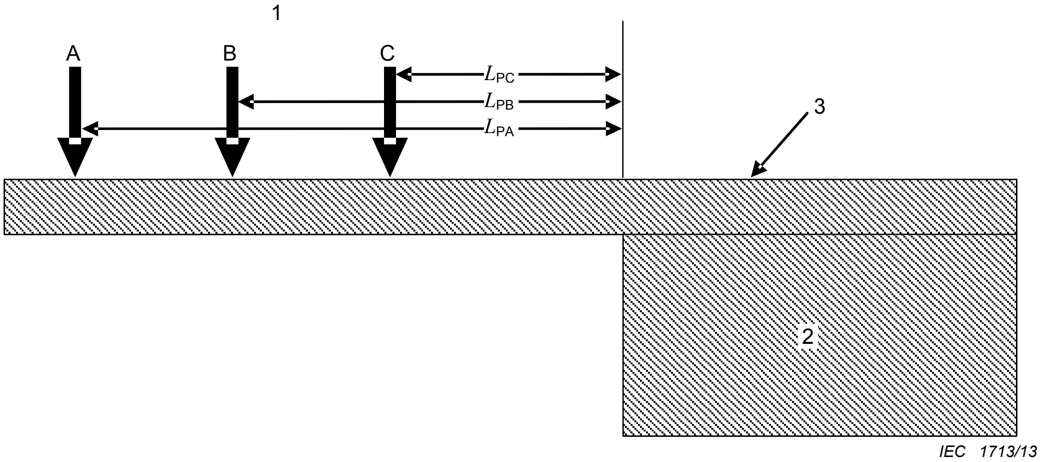
In the case of thin films, storage environment can affect the mechanical properties (see IEC 62047-6:2009, 4.4 Storage prior to testing).

5 Testing method

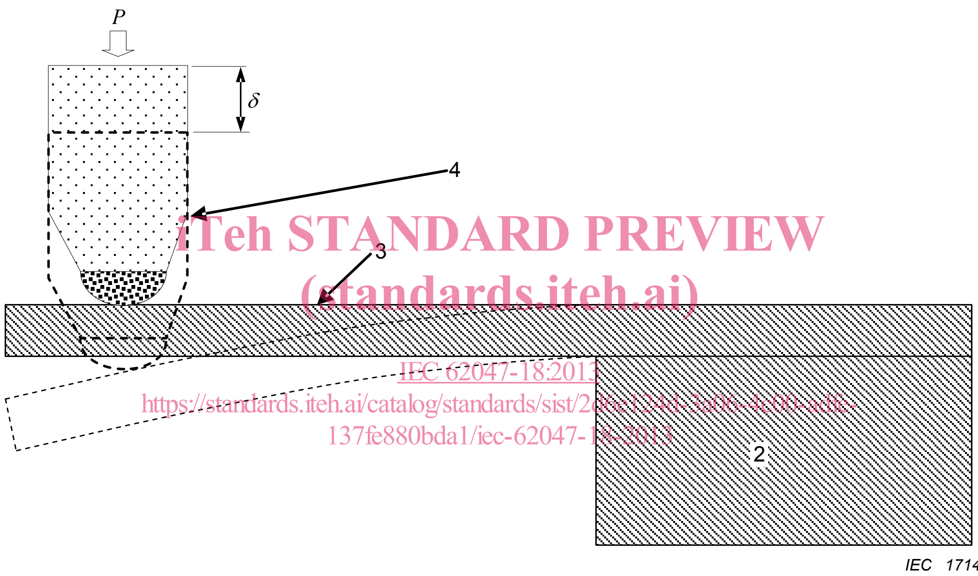
5.1 General

The employed testing machine includes features to facilitate displacement, loading and positioning, and should be equipped with a measurement system of force and displacement.

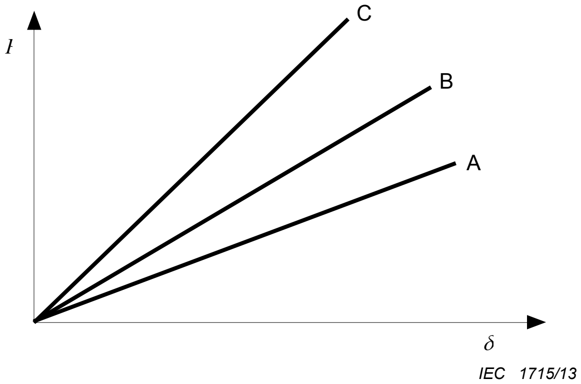
In case of measurement, loading is made on a point of the cantilever beam test piece as shown in Figure 2a) and 2b) using a sphere-shaped or a knife-edge shaped loading tool, and the positions of loading points (A, B or C) of test pieces as shown in Figure 2a) should be recorded with the relation between force (P) and displacement (δ) of the cantilever beam as shown in Figure 2c). The loading point location through the parallel part of the test piece shall be specified within the accuracy range of ± 1 % of the length of the test piece. The knife edge tip radius is 5 μm and the straightness shall be within the accuracy of ± 1 % of the length of the test piece. The angle between the knife-edge length direction and the test piece surface and the longitudinal direction of the test piece are within 2 ° and 4 ° respectively. These data shall be measured and recorded.



a) Cantilever beam test piece with loading point



b) Cantilever beam test piece with loading tool



c) Relation between force and displacement

Key

1	Loading point at A,B or C	3	Test piece
2	Substrate	4	Sphere shaped tip loading tool

Figure 2 – Measurement method

5.2 Method for mounting of test piece

A substrate including test pieces shall be mounted on the testing equipment so that the loading axis and the test piece surface are aligned at a right angle. Fixing of test pieces to substrates and to testing machines shall meet the following requirements:

a) The test pieces shall be securely fixed to the substrate, and shall not move during testing. The substrate should be firmly fixed on the tool of the test equipment, whose stiffness is higher than that of the substrate.
b) During testing, the substrate of test piece should be fixed, and the direction of loading axis of the testing machine should be within 5 ° from perpendicular to the substrate surface.

5.3 Method for loading

The contacting portion of the sphere part of the tool to be loaded on test pieces should be in the shape of a sphere as shown in Figure 2b) or a knife-edge. In case that the diameter of the sphere shape is extremely smaller than the thickness (S) and a width (W) of test pieces, the load should be carefully applied to avoid serious local deformation and fracture at the contact point of test piece with the sphere. Deformation of test pieces should be minimized within a range of pure elastic deformation. Movement of loading tool should go straight.

The displacement (δ) of cantilever beam shall be small for minimizing the contact point being off the initial loading point of test piece during bending.

A load cell with a resolution adequate to guarantee 5 % accuracy of the applied force shall be used. The drift of the load cell should be less than 1 % of the full-scale force during testing. (See IEC 62047-6:2009, 5.4 Method of loading.)

5.4 Speed of testing

The displacement speed or loading speed should be constant, and it shall be within the measurement equipment ability.

5.5 Displacement measurement

The resolution of the displacement sensor shall be more precise than 0,5 % of the maximum range of a displacement measurement. If possible, the direct measurement of test piece bending displacement (δ) is recommended because the load cell of low force range has a low stiffness.

5.6 Test environment

Testing temperature and humidity shall be controlled to avoid fluctuations during testing, and a particular attention is required for testing temperature.

5.7 Data analysis

The relation between force (P) and displacement (δ) of cantilever beam can be expressed as Equation (1) within an elastic region. When using a test piece of another shape, the shape shall be measured precisely with record. Data of force (P) and displacement (δ) shall be available to use with record.

$$\delta = \frac{P{L_P}^2}{3EI_Z} \tag{1}$$

The relation between force (P) and displacement (δ) of the cantilever beam depends on the cross-sectional shape of the test piece, which is the moment of inertia of area (I_z), and the distance between the loading point and the root of the test piece. It is recommended that the test piece shape, the measurement method and the measurement accuracy are recorded. Regarding the force and displacement relationship obtained as schematically shown in Figure 2c), the initiation part of the increasing force is sometimes not linear. This phenomenon is caused by twisted and/or curved shape of the test piece, partially delaminating of the test piece supporting part from the substrate or micro-fracture occurring at the contact point of the test piece with the loading tool. In this case, the results data should be used in the linear region only. When plastic deformation, fracture of supporting part of substrate and/or slip of loading tool on test piece occurs, the force and displacement relationship becomes not linear (see Annex B).

5.8 Material for test pieces

Cantilever beam type test pieces which enable to produce more than 5 pieces on the same substrate at the same time under the same conditions should be selected. The elastic modulus of the materials shall be known for reference of data analysis, and their elastic modulus shall be the same as or less than those of substrate materials in order to avoid stress concentration at the fixed portion (i.e. root of the cantilever beam test piece). Furthermore, higher yield stress is desirable for avoiding plastic deformation at the contact point of the root of the test piece with the substrate.

6 Test report

Test reports shall include at least the following information.

a) Mandatory
   1) reference to this international standard
   2) test piece material and elastic modulus for test pieces and substrate in the case of a single crystal: crystallographic orientation
   3) method and details of test piece fabrication
      – method of thin film deposition
      – fabrication process
      – heat treatment (annealing) conditions
   4) shape and dimensions of test pieces; especially
      – the moment of inertia of area (I_z)
   5) bending test conditions
      – type of testing machines with resolution and capacity of force sensor and displacement sensor
      – testing environment (temperature and relative humidity)
      – displacement rate or loading rate
   6) bending test results
      – tested test piece number
      – measurement and calculated value
      – comments in particular (defects, delamination or twist in test piece)
b) Optional
   1) Microstructure
   2) Internal stress
   3) Surface roughness of test piece
   4) Deformation characteristics