IEC 62047-13

Edition 1.0 2012-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Semiconductor devices – Micro-electromechanical devices – Part 13: Bend - and shear - type test methods of measuring adhesive strength for MEMS structures

Dispositifs à semiconducteurs – Dispositifs microélectromécaniques – Partie 13: Méthodes d'essais de types courbure et cisaillement de mesure de la résistance d'adhérence pour les structures MEMS

IEC 62047-13:2012

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

Useful links:

IEC publications search - www.iec.ch/searchpub

The advanced search enables you to find IEC publications by a variety of criteria (reference number, text, technical committee,…).
It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available on-line and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary (IEV) on-line.

Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Liens utiles:

Recherche de publications CEI - www.iec.ch/searchpub

La recherche avancée vous permet de trouver des publications CEI en utilisant différents critères (numéro de référence, texte, comité d'études,…).
Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

Just Published CEI - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications de la CEI. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (VEI) en ligne.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

IEC 62047-13

Edition 1.0 2012-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Semiconductor devices – Micro-electromechanical devices – Part 13: Bend - and shear - type test methods of measuring adhesive strength for MEMS structures

Dispositifs à semiconducteurs – Dispositifs microélectromécaniques – Partie 13: Méthodes d'essais de types courbure et cisaillement de mesure de la résistance d'adhérence pour les structures MEMS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

PRICE CODE
CODE PRIX

P

ICS 31.080.99

ISBN 978-2-88912-937-9

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 13: Bend - and shear - type test methods of measuring adhesive strength for MEMS structures

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62047-13 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/109/FDIS	47F/119/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 of 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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 13: Bend - and shear - type test methods of measuring adhesive strength for MEMS structures

1 Scope

This part of IEC 62047 specifies the adhesive testing method between micro-sized elements and a substrate using the columnar shape of the specimens. This international standard can be applied to adhesive strength measurement of microstructures, prepared on a substrate, with width and thickness of 1 μm to 1 mm, respectively.

Micro-sized elements of MEMS devices are made up of laminated fine pattern films on a substrate, which are fabricated by deposition, plating, and/or coating with photolithography. MEMS devices include a large number of interfaces between dissimilar materials, at which delamination occasionally occurs during fabrication or in operation. Combination of the materials at the junction determines the adhesive strength; moreover, defects and residual stress in the vicinity of the interface, which are changing by processing condition, strongly affect the adhesive strength. This standard specifies the adhesive testing method for micro-sized-elements in order to optimally select materials and processing conditions for MEMS devices.

This standard does not particularly restrict test piece material, test piece size and performance of the measuring device, since the materials and size of MEMS device components range widely and testing machine for micro-sized materials has not been generalized.

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.

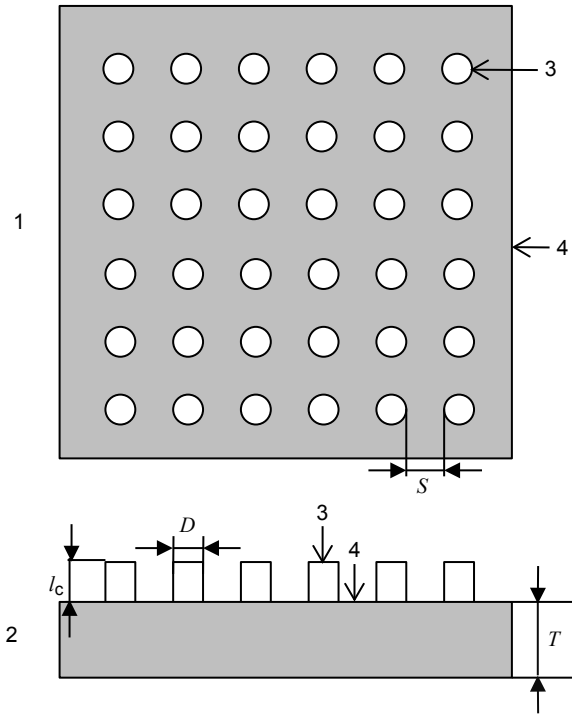
IEC 62047-2:2006, *Semiconductor devices – Micro-electromechanical devices – Part 2: Tensile testing method of thin film materials*

3 Terms and definitions

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

3.1
adhesive bend strength
nominal strength at failure on adhesive joint area by bending mode

3.2
adhesive shear strength
nominal strength at failure on adhesive joint area by shear mode



Key

	Configurations or specimen		Dimensions of specimen
1	Top view	D	diameter of columnar test piece
2	Side view	l_c	length of columnar test piece
3	Column type test piece	l_c/D	aspect ratio of columnar test piece
4	Substrate	T	thickness of substrate
		S	spacing between columnar test pieces

Figure 1 – Columnar test pieces

4 Test method

4.1 General

This standard specifies the adhesive testing methods between a columnar test piece (see Figure 1) and substrate. Displacement or force is applied to a columnar test piece at a constant speed and the force at delamination is measured to analyze the adhesive strength between the columnar test piece and substrate. A knife edge shape with tapered tip is utilized as the loading tool to apply the force to a columnar test piece. The angle of the knife edge is changed by loading types of measuring adhesive strength as follows.

In case of measuring adhesive bend strength by applying bending force at the end of a columnar test piece (bend type test), the knife edge of loading tool is used by slanting its apex in the upper direction against the test piece as shown in Figure 2 a). In such a case, it is easier to align the loading tool and a test piece since point load is applied at the end of the columnar test piece. Attention should be drawn to the fact that the bend type test is not pure bending, which includes compression component to the columnar root. The compression component increases by increasing the contact angle of the knife edge. In order to minimize the effect of compression component, the contact angle of the knife edge (θ_b) should be within a range of from 10° to 20°.

In case of measuring adhesive shear strength by applying shear force on the lateral face of a columnar test piece (shear type test), line load is applied to the test piece using a loading tool which is parallel to the lateral face of the cylinder as shown in Figure 2 b). In such a case, the test apparatus should have a precise alignment system, which can align the knife edge parallel to the lateral face of the cylinder. Or alternatively, the knife edge of loading tool is used by slanting its apex in lower direction against the test piece as shown in Figure 2 b) to minimize the effects of bend stress (see Clause A.2).The angle error (θ_s) should be within a range of from 0° to 15°. It should be noted that the test results from the bend type test are affected by the aspect ratio (l_c/D), when the aspect ratio is less than 1,2. See Clause A.2. In addition, the columnar test piece with the aspect ratio of less than 0,5 should not be applied in the bend type test; because the effects of the aspect ratio on the shear and the compression stress on the adhesive joint area significantly increase when the aspect ratio decreases. See Clause A.2 and Clause A.3.

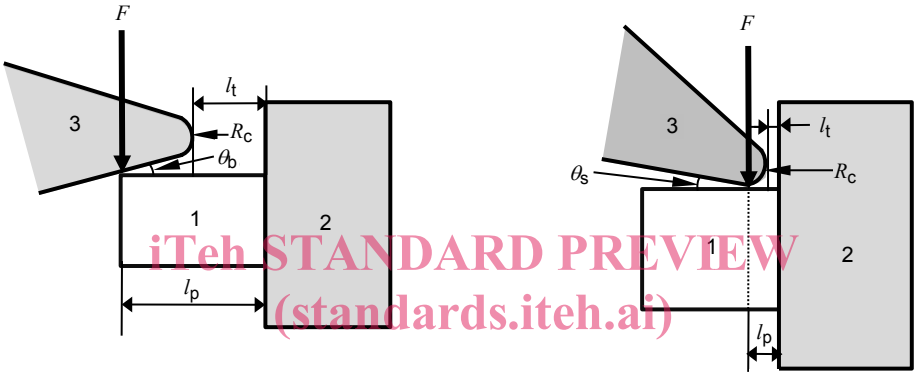


Figure 2a – Bend type test **Figure 2b – Shear type test**

NOTE This figure illustrates two types of the test method for measuring adhesive strength between a columnar test piece and substrate.

Key

	Configurations or specimen		Supply and dimensions of specimen
1	Columnar test piece	F	loading force supplied by a kind of actuator
2	Substrate	l_p	distance between the loading position and substrate
3	Knife edge of loading tool	l_t	distance between the tip of the loading tool and substrate
		θ_b	angle between the lateral face of a columnar test piece and contact face of knife edge for bend type test
		θ_s	angle between the lateral face of a columnar test piece and contact face of knife edge for shear type test

Figure 2 – Adhesive strength test method

4.2 Data analysis

In adhesive strength test by bend loading, adhesive bend strength is calculated by the following Equation (1).

$$\sigma_a = \frac{M_a}{Z} = \frac{32F_{\max} l_p}{\pi D^3} = \frac{32F_{\max} l_c}{\pi D^3} \quad (1)$$

where

σ_a is the adhesive bend strength;

Z is the section modulus of a columnar test piece;

M_a is the bend moment at delamination;

F_{max} is the maximum load at delamination;

l_p is the loading point from the root of a columnar test piece.

In adhesive strength test by shear loading, adhesive shear strength is calculated by the following Equation (2).

$$\tau_a = \frac{F_{max}}{A} = \frac{4F_{max}}{\pi D^2} \quad (2)$$

where

τ_a is the adhesive bend strength;

A is the adhesive joint area between a columnar test piece and substrate;

F_{max} is the maximum load at delamination.

In the bend type test, it is required to be attentive to the possibility of exfoliation due to shear force if the aspect ratio (l_c/D) of the columnar test piece is less than 1,2. See 4.1 and Clause A.2.

5 Test equipment

5.1 General

The test equipment shall be capable of applying microscopic displacement or micro-level force to the test piece. The test equipment consists of an actuator for applying displacement, a sensor for force measurement, a controller applying displacement or force at a constant speed, an alignment system between the test piece and the loading tool, and a recorder for detecting the load at delamination.

5.2 Actuator

Displacement or force should be linearly applied along the loading axis of the test piece at a constant speed. Thus, the actuator shall be capable of linearly applying displacement or force at a constant speed.

5.3 Force measurement sensor

Load cell with enough resolution, which guarantees 5 % accuracy of the measured adhesive strength shall be used for the force measurement. The force sensor shall be set to measure the force to the loading direction. The knife edge of the loading tool shall be located within the effective measuring area of the force sensor. See Figure 3.

5.4 Alignment system

The alignment system shall be capable of aligning the test piece and loading tool in the proper position to apply displacement or force in the correct direction (see 7.3).

5.5 Recorder

The test equipment shall include a recorder for detecting the force at delamination.

6 Test pieces

6.1 Design of test pieces

The test piece should satisfy the following two items:

a) It is recommended that the dimensions of a test piece, such as the columnar diameter and length,, are in the same order as the size of parts of a device to be evaluated;

b) Every gap between the test pieces (S) should provide more than twice compared with both the diameter of columnar test piece (D) and the length of test piece (l_c) to prevent each piece from having an influence on the test of adjacent test piece (see Figure 1). In addition, the gap (S) should be sufficiently larger than the width of the knife edge tip of the loading tool (l_k) to avoid loading two columnar test pieces at the same time. See Figures 1 and 3.

6.2 Preparation of test pieces

A number of columnar test pieces with the same manufacturing process and conditions are obtained, since a plurality of columnar test pieces are prepared on the same substrate.

The test pieces should satisfy the following two items:

a) Test pieces should be prepared on a substrate through an almost identical manufacturing process and under the same manufacturing conditions as those applied when fabricating the thin film of the device to be evaluated;

b) More than ten columnar test pieces should be prepared on the same substrate at the same time. Then, adhesive testing should be performed using more than ten columnar test pieces under the same testing conditions (see Clause A.1).

7 Test conditions

7.1 Method for gripping

Substrate of test pieces shall be fixed according to the following two items:

a) Substrate of test pieces shall be fixed at test device ensuring not to move during adhesive strength test. Clauses A.2 and A.3 of IEC 62047-2:2006 shall apply;

b) Substrate of test pieces shall be fixed such as the loading direction of the test device is parallel with the substrate surface. See 7.3.

7.2 Speed of testing

Displacement speed or loading speed should be constant. As the speed of testing will depend upon the testing environment, the type of testing machine employed and the stiffness of the test piece, the speed shall be the one which is more suitable for the particular combination of environment, material, test piece, and testing machine. Generally, the speed of testing should be chosen properly depending on the application of the materials.

7.3 Alignment of test piece

The alignment of the test piece shall satisfy the following item:

a) The surface of the test piece substrate shall be parallel to the axis of loading direction within 3° accuracy. See Figure 3 a) ;

In addition, the alignment of loading equipment and substrate should satisfy the following three items:

b) Contact surface of the loading knife edge shall be normal to the plane including loading axis and normal of a test piece substrate. See Figure 3 b);

c) In the case of the bend type test, the distance between the loading tool and the substrate, l_t should be larger than 10 % of the columnar length (l_c) to avoid contact between each other. See Figure 2 a);

d) In the case of the shear type test, the tip of loading tool should be kept at a distance (l_t) from the substrate to avoid contact between each other. l_t should be within a range of 10 % of the columnar diameter (D), provided that D is 10 μm and larger. l_t should be within 1 μm, provided that D is less than10 μm. See Figure 2 b).

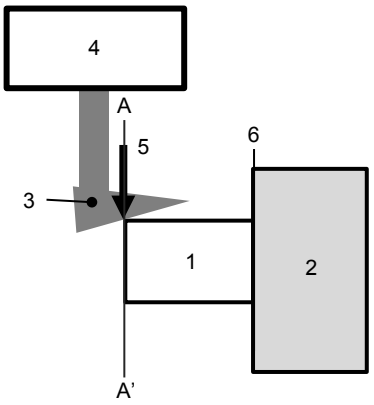


Figure 3a – Side view of columnar test piece and loading tool

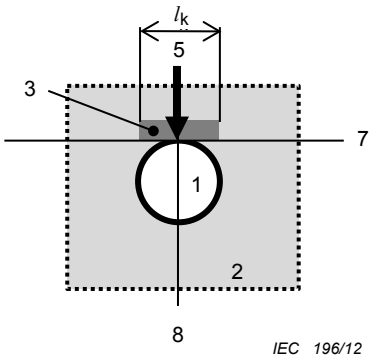


Figure 3b – Cross-section of A-A'

Key

	Configurations or specimen		Direction or plane for alignment
1	Columnar test piece	5	Loading axis (loading direction)
2	Test piece substrate	6	Surface of test piece substrate
3	Loading tool	7	Contact surface of the loading knife edge
4	Load cell	8	Plane including loading axis and normal of a test piece substrate
l_k	width of the knife edge tip		

Figure 3 – Alignment between columnar test piece and loading tool

7.4 Test environment

As the environment greatly affects the adhesive properties of micro-materials, the test temperature and humidity should be controlled within ± 1 °C and ± 5 %, respectively.

8 Test report

Test reports shall include at least the following:

a) reference to this standard, i.e. IEC 62047-13;

b) materials of the columnar test piece and substrate;

c) dimensions of the columnar test piece and substrate as well as spacing between adjacent columnar test piece;

d) preparation method of test piece and the details;

e) test conditions such as test device and test loading condition;

f) test environment such as temperature and humidity;

g) measurement results and calculated adhesive strength.