IEC 62047-25

Edition 1.0 2016-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Semiconductor devices – Micro-electromechanical devices – Part 25: Silicon based MEMS fabrication technology – Measurement method of pull-press and shearing strength of micro bonding area

Dispositifs à semiconducteurs – Dispositifs microélectromécaniques – Partie 25: Technologie de fabrication de MEMS à base de silicium – Méthode de mesure de la résistance à la traction-compression et au cisaillement d'une micro zone de brasure

IEC 62047-25:2016-08(en-fr)

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.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
The advanced search enables 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 It also gives information on projects, replaced and withdrawn publications.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 online and also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC 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 l'IEC
La Commission Electrotechnique Internationale (IEC) 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 IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue
Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub
La recherche avancée permet de trouver des publications IEC 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.

IEC Just Published - webstore.iec.ch/justpublished
Restez informé sur les nouvelles publications IEC. 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 de termes électroniques et électriques. Il contient 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 15 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary
65 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

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

IEC 62047-25

Edition 1.0 2016-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Semiconductor devices – Micro-electromechanical devices – Part 25: Silicon based MEMS fabrication technology – Measurement method of pull-press and shearing strength of micro bonding area

Dispositifs à semiconducteurs – Dispositifs microélectromécaniques – Partie 25: Technologie de fabrication de MEMS à base de silicium – Méthode de mesure de la résistance à la traction-compression et au cisaillement d'une micro zone de brasure

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 31.080.99

ISBN 978-2-8322-3609-3

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 25: Silicon based MEMS fabrication technology – Measurement method of pull-press and shearing strength of micro bonding area

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 62047-25 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/249/FDIS	47F/252/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.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website 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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 25: Silicon based MEMS fabrication technology – Measurement method of pull-press and shearing strength of micro bonding area

1 Scope

This part of IEC 62047 specifies the in-situ testing method to measure the bonding strength of micro bonding area which is fabricated by micromachining technologies used in silicon-based micro-electromechanical system (MEMS).

This document is applicable to the in-situ pull-press and shearing strength measurement of the micro bonding area fabricated by microelectronic technology process and other micromachining technology.

Micro anchor, fixed on the substrate through the micro bonding area, provides mechanical support of the movable sensing/actuating functional components in MEMS devices. With the devices scaling, the bonding strength degradation, induced by defects, contaminations and thermal mismatch stress on bonding surface, becomes severer. This standard specifies an in-situ testing method of the pull-press and shearing strength based on a patterned technique. This document does not need intricate instruments (such as scanning probe microscopy and nanoindenter) and to prepare the test specimen specially.

Since the testing structure in this standard can be implanted in device fabrication as a standard detection pattern, this document can provide a bridge, by which the fabrication foundry can give some quantitative reference for the designer.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 62047-1, *Semiconductor devices – Micro-electromechanical devices – Part 1: Terms and definitions*

ISO 10012, *Measurement management systems – Requirements for measurement processes and measuring equipment*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62047-1 and ISO 10012 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

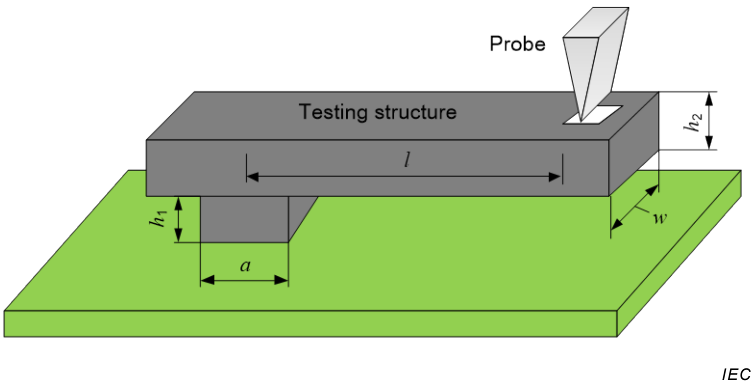
- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
anchor
silicon-glass bonding area which supports the MEMS function structure

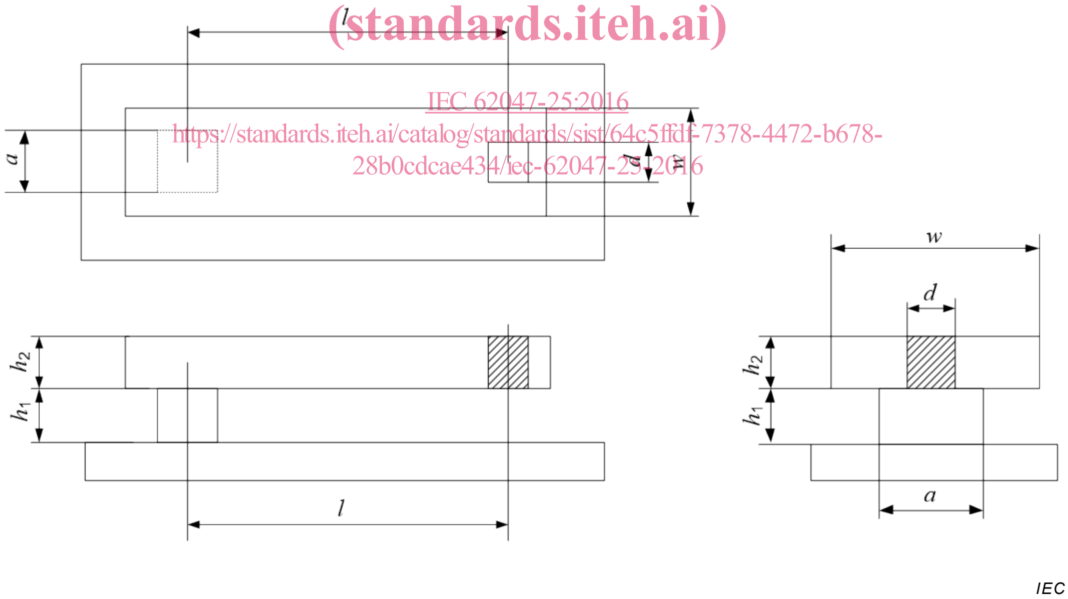
4 Requirements

4.1 Testing structure design requirements

The schemes of testing structures are shown in Figure 1 and Figure 2.



a) The scheme of the pull-press testing structure



b) The three-view drawing of the pull-press testing structure

Key

h_2 thickness of the testing structure arm

h_1 height of the anchor beam in the bonding area

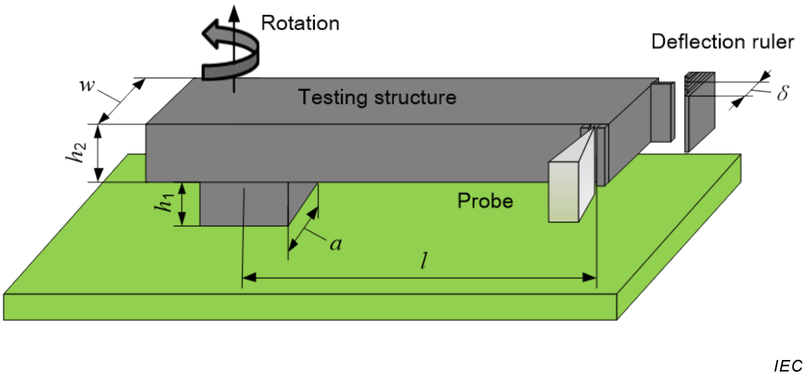
a side length of the bonding area

l length of the testing structure arm, this parameter should be designed with sequential values

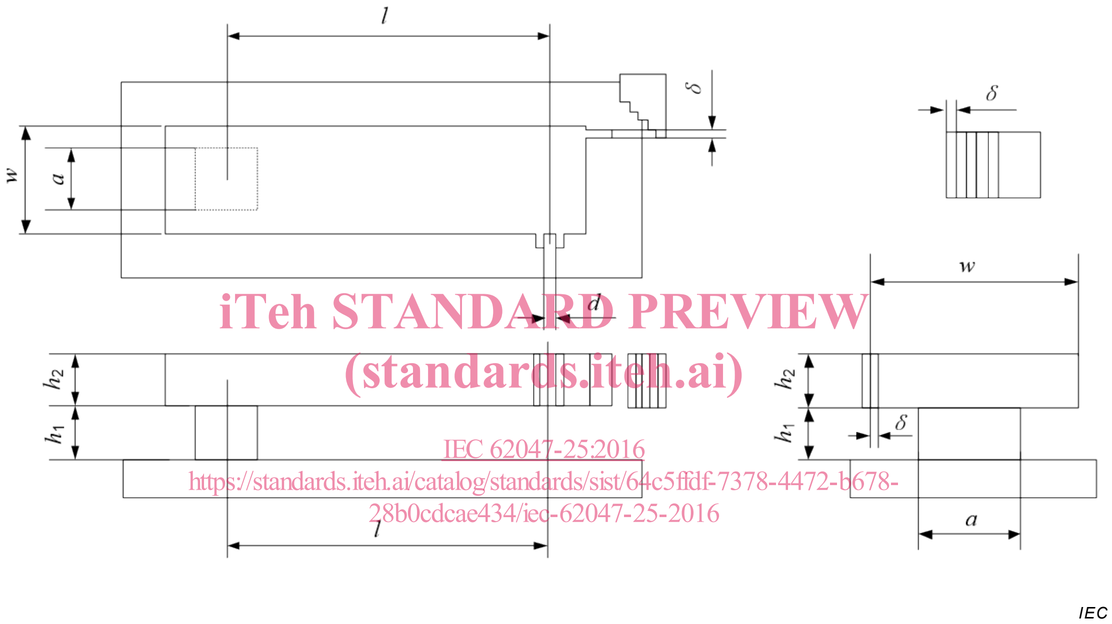
w width of the testing structure arm

d dimension of the loading point

Figure 1 – Pull-press testing structure



a) The scheme of the shearing testing structure



b) The three-view drawing of the shearing testing structure

Key

h_2 thickness of the testing structure arm

h_1 height of the anchor beam in the bonding area

a side length of the bonding area

l length of the testing structure arm

w width of the testing structure arm

d dimension of the loading point

δ resolution of the rotation ruler

Figure 2 – Shearing testing structure

The design of the testing structure should be as follows:

a) To prevent the testing structure arm from breaking earlier than the bonding area, the strength of the arm should be designed high enough. For instance, if the arm thickness is limited by design rule, a wider arm design is recommended.

b) The arm length of pull-press strength testing structure should be designed with sequential values. The common difference, the length interval, should satisfy the requirement of the testing resolution. The consumed area by the testing structure should be also taken into consideration.

c) The design of the ruler within the shearing strength testing structure should satisfy the resolution requirement. The ruler should be clearly monitored by the optical microscopy.

d) The testing structure should be designed to be robust enough to withstand the dimension deviation induced by fabrication process. The roughness of the structure surface caused by the wet or dry etching process, isotropic or anisotropic etching process should be also taken in consideration in design work.

4.2 Testing structure fabrication requirements

Requirements for bulk silicon testing structures with micro bonding area(s) are the following:

a) The fabrication of testing structures should meet the requirements of bulk silicon processes.

b) The testing structure material is bulk silicon, so the physical and chemical characteristics should refer to the silicon wafer used in the practical fabrication processes.

c) It is highly recommended to use RIE process to etch the anchor of the testing structure to ensure the anchor formation.

In case of strength testing of micro bonding area other than silicon based MEMS, similar structures may be prepared by using different materials, and other requirements shall be proposed.

4.3 Testing environment requirements

Testing environment requirements are the following:

a) A kind of violent air flow is prohibited during the testing operation. The testing bench should be stabilized.

b) Environmental contaminations caused by the dusts and fragments from the fracture of the testing structure should be taken into consideration in testing operation processes.

5 Testing method

5.1 General

During the testing operation process, the testing structure is placed on the probe station. The deformation or fracture of the structure is monitored by microscopy and the bonding strength can be calculated utilizing the testing structure parameters.

5.2 Pull-press testing method

5.2.1 Imposing the loading force

During the testing operation with pull-press testing method, the loading force is imposed vertically at the loading point on the structure arm.

5.2.2 Pull-press testing method operation process

The pull-press testing method operation process is as follows:

a) During the operation process, the chip with testing structure is fixed on the probe station. The loading force is imposed vertically at the loading point on the structure arm by the station needle (A) until the arm is deformed to contact with the bottom surface and the bonding area (B or C) is monitored by the microscopy, see Figure 3. The bonding strength is defined to be higher than $\sigma_{li,T}$ (or $\sigma_{li,C}$) while the fracture occurs in the structure with arm length of l_{i+1} ($l_i > l_{i+1}$) and does not occur in the structure with arm length of l_i, where $\sigma_{li,T}$ and $\sigma_{li,C}$ are tensile strength and compressive strength respectively, namely the maximum stress value at the bonding area when the corresponding testing structure arm deforms to contact with the bottom surface, acquired by finite element analysis. And subscript T and subscript C represent tensile and compressive stress respectively.

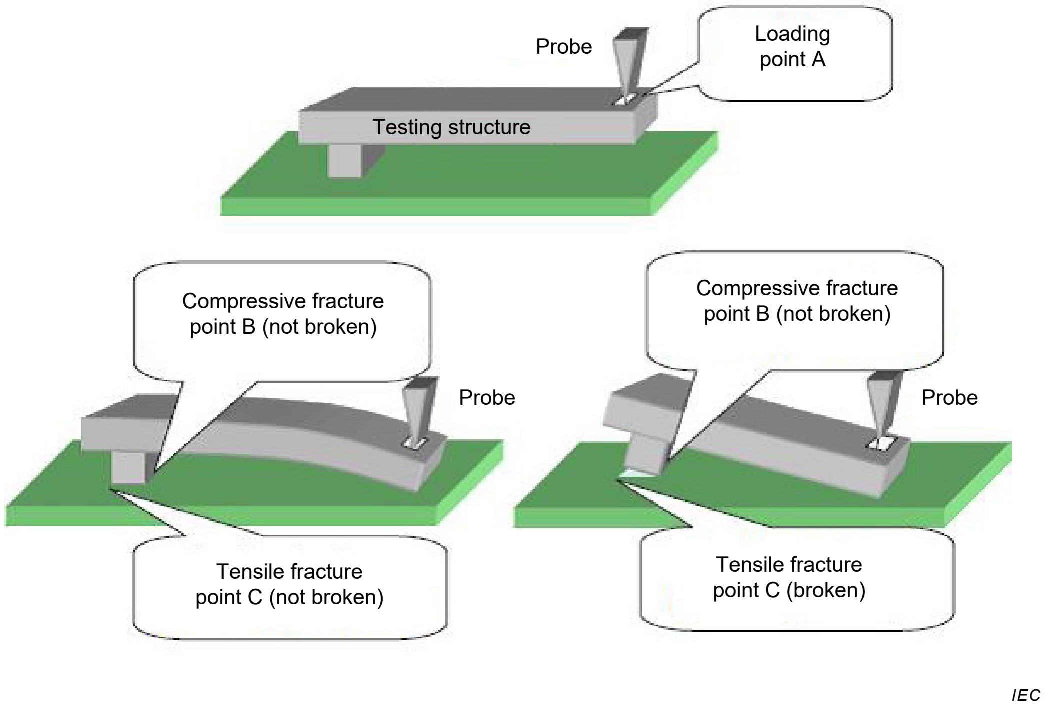


Figure 3 – Pull-press testing method operation process

b) The loading should be perpendicular to the bottom surface and the loading process should be slow and stable. The needle and whole testing structure should be present in the field of views under an optical microscopy. When the arm contacts with the bottom surface (or the fracture occurs in the testing structure), the loading process should be stopped and the needle should be raised slowly until it is separated from the testing structure.

5.2.3 Pull-press testing method result process

During the testing structure arm design process, a table, about the maximum compressive and tensile stress value at the bonding area when every testing structure arm in the design deforms to contact with the bottom surface, should be built. After the testing operation, the bonding strength can be referred to the table according to the arm length with which the anchor is broken.

In case that the stress cannot be obtained, the testing structure parameters in Annex A can be used. And the reference stress tables are listed from Table A.2 to Table A.16.

If the arm length is not listed in the reference tables, the relative stress can be interpolated from the table content.

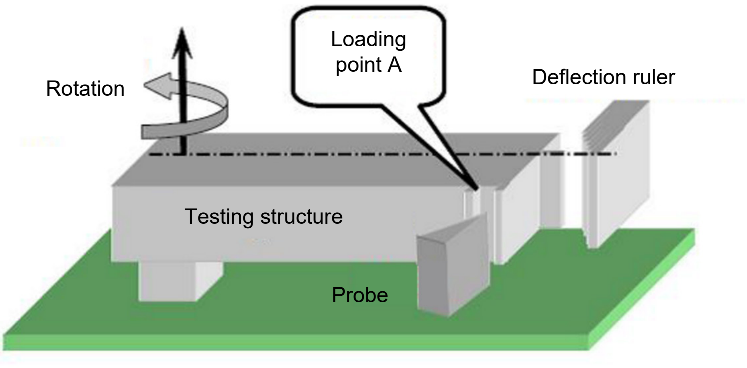
If the fracture occurs in the bulk silicon structure first, the bonding strength can be known as bigger than the bulk silicon strength.

5.3 Shearing testing method

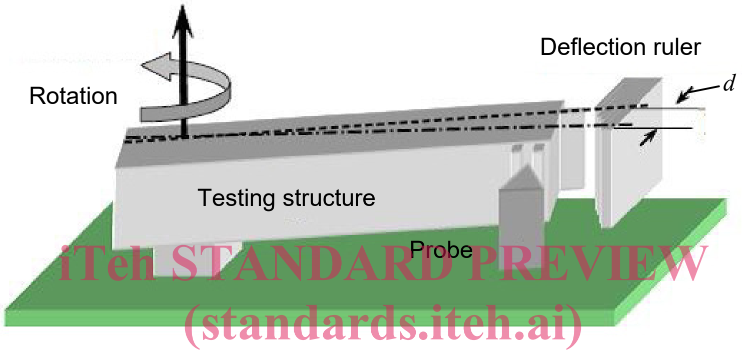
5.3.1 Shearing testing method operation process

The shearing testing method operation process is as follows:

a) During the operation process, the chip with testing structure is fixed on the probe station. The loading force is imposed laterally at the loading point on the structure arm by the station needle (A) and the deformation is monitored by the microscopy, see Figure 4. The rotation deflection can be read out from the ruler located at the end of the arm.



a) Before probe loading



b) Dimension of the rotation deflection at a monitoring length by the deflection ruler

Figure 4 – Shearing testing method operation process

b) The loading should be parallel with the bottom surface and the loading process should be slow and stable. The needle and whole testing structure should be present in the field of views under the optical microscopy. When the fracture occurs in the testing structure or at the bonding area, the loading process should be stopped and the needle should be retracted slowly until it is separated with the testing structure.

c) According to various bonding areas, the recommended testing structure dimensions are calculated in order to get a reasonable resolution and operation needle pressure, as listed in Table 1.

Table 1 – Dimensions for shearing testing structure

$a \times a$ (μm^2)	$w \times h_2$ (μm^2)	l (μm)
13 × 13	33 × 80	243
17 × 17	37 × 80	241
20 × 20	40 × 80	240
25 × 25	45 × 80	238
30 × 30	50 × 80	240
40 × 40	100 × 80	565
50 × 50	150 × 80	607
60 × 60	200 × 80	596
70 × 70	250 × 80	605
80 × 80	250 × 80	614
90 × 90	300 × 80	1 456
100 × 100	400 × 80	1 423
110 × 110	400 × 80	1 444
120 × 120	400 × 80	1 449

5.3.2 Shearing testing method result process

The shearing stress τ_{max} can be calculated as:

$$\tau_{max} = 0{,}14 \times \frac{h_2 w^3}{a^3 l^2} d$$

where

h_2 thickness of the testing structure arm

a side length of the bonding area

l length of the testing structure arm

w width of the testing structure arm

d rotation deflection

If the fracture occurs in the bulk silicon structure first, the bonding strength can be known as bigger than the bulk silicon strength.

Annex A
(informative)

Dimensions for testing structure and tensile/compressive strength

A.1 Dimensions for testing structure

Ranges of dimensions for testing structure are described as Table A.1.

Table A.1 – Dimensions for testing structure

Dimensions in μm

l	*a*	h_2	*w*	h_1	*d*
300 to 2 000	10 to 150	20 (a <= 70) 70 (a > 70)	200	80 (a <= 70) 80 (a > 70)	100

A.2 Tensile strength and compressive strength

Tensile strength $\sigma_{L,T}$ and compressive strength $\sigma_{L,C}$ are described in the following tables, from Table A.2 to Table A.16.

Table A.2 – Tensile strength and compressive strength (bonding area: 10 μm × 10 μm)

l (μm)	$\sigma_{L,T}$ (MPa)	$\sigma_{L,C}$ (MPa)
800	1 072,1	-1 135,8
850	1 008,3	-1 067,9
900	951,6	-1 007,6
950	900,7	-953,5
1 000	855,1	-905,0
1 050	813,7	-861,0
1 100	776,0	-821,0
1 150	741,6	-784,4
1 200	710,0	-750,9
1 250	680,9	-720,0
1 300	654,2	-691,7
1 350	629,3	-665,3
1 400	606,2	-640,8