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INTERNATIONAL STANDARD

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Semiconductor devices – Micro-electromechanical devices – Part 27: Bond strength test for glass frit bonded structures using micro-chevron-tests (MCT)

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SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES

Part 27: Bond strength test for glass frit bonded structures using micro-chevron-tests (MCT)

FOREWORD

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International Standard IEC 62047-27 has been prepared by subcommittee 47F: Microelectromechanical systems, of IEC technical committee 47: Semiconductor devices.

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

CDV	Report on voting
47F/230A/CDV	47F/259/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document 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 document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

A bilingual version of this publication may be issued at a later date.

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INTRODUCTION

MEMS devices, e.g. for automotive applications, have to ensure lifecycles of up to 15 years or more. In order to guarantee functionality and reliability of the used interconnection technologies, qualified test methods are required for evaluating the quality and strength of the bonding interfaces. One of the preferred interconnection technologies for MEMS encapsulation is glass frit bonding, using an additional intermediate bond layer.

The micro-chevron-test is an experimental method to determine the fracture toughness of brittle materials or bond interfaces using specifically designed test chips (micro-chevron-samples) under defined load conditions. It was established for characterizing the strength of wafer bonds without additional intermediate bond layers. By analysis of test results from a series of tests at the Fraunhofer Institute for Mechanics of Materials and the Fraunhofer Institute for Electronic Nano Systems with different geometry and layout of the test-probes, the micro-chevron-test was established for the bonding reliability of glass frit bonded devices as well.

SEMICONDUCTOR DEVICES –
MICRO-ELECTROMECHANICAL DEVICES

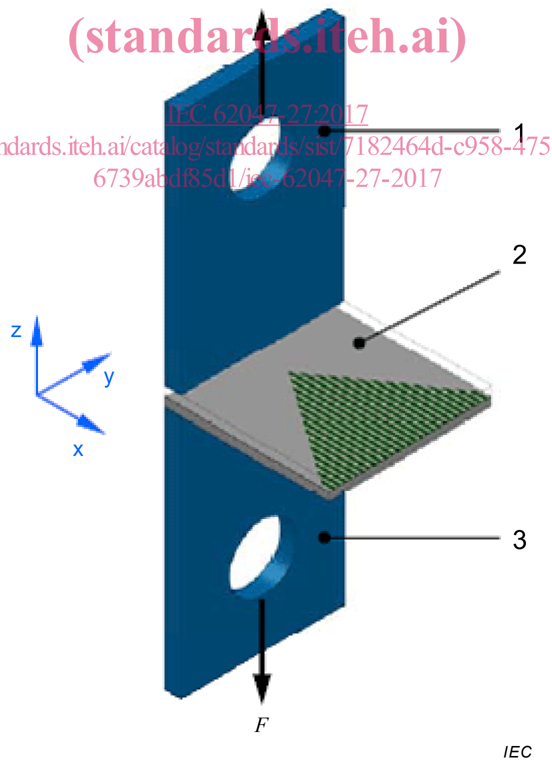
Part 27: Bond strength test for glass frit bonded structures using micro-chevron-tests (MCT)

1 Scope

This part of IEC 62047 specifies a method for assessing the bond strength of glass frit bonded structures using micro-chevron-tests (MCT). It describes suitable sample geometry and provides guidance for the design of deviating sample geometries.

The micro-chevron-test is an experimental method to determine the fracture toughness K_{IC} of brittle materials or bond interfaces using specifically designed test chips (micro-chevron-samples) under defined load conditions (crack opening mode I). Owing to its high precision and low variance, it is suitable for analysing the influence of different process parameters on bond strength as well as for quality assurance.

The exemplary setup of the micro-chevron-test is given in Figure 1.



Key

1 upper glued stud for application of tensile force

2 micro-chevron-test sample with patterned glass-frit-interface

3 lower glued stud for application of tensile force

F applied force

Figure 1 – Test setup of the micro-chevron-test

These operational instructions are applicable for symmetrically glass frit bonded silicon-silicon-stacks, i.e. the joint upper and lower chip of the chevron sample exhibit identical thickness and mechanical properties.

The method is suitable for test samples, which are either produced directly from individual chips in corresponding dimensions, or for integrated samples, which have been singled out from processed wafers using suitable methods.

This document determines preferential dimensions for samples as well as parameters for the test conditions. Deviating geometries can potentially influence the viability of the tests as well as the comparability of the results. On that score, all parameters are determined and documented accurately.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

No terms and definitions are listed in this document.

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

3.2 Symbols and abbreviated terms

Symbols	Unit	Descriptions
A_{Bond}	mm^2	effective bonding surface, represented by the area of the glass frit stripes
A_{Chevron}	mm^2	area of total chevron geometry
a_0	mm	initial crack length
a_{crit}	mm	critical crack length
b	mm	sample width
C_{F}		bond area ratio
$t_{\mathrm{w1}},t_{\mathrm{w2}}$	µm	wafer thickness 1-top wafer / 2-bottom wafer
F_{max}	N	experimentally determined maximum force
g_{s}	mm	width of glass frit bond stripes
K_{IC}	MPa m^{0,5}	fracture toughness of bonding interface
l	mm	sample length
v	µm/s	testing velocity
w_{s}	mm	distance between glass frit bond stripes
Y_{min}		geometry factor

4 Principle

Strength measurement by means of micro-chevron-testing is based on a mode I crack opening within the bonding interlayer. Studs, applied to the surface of the chips, thus transfer a tensile load to the specimen in z-direction (see Figure 1). Special requirements are to be met when aligning specimens in the test setup in order to avoid additional shear stress within the bonding interface, and thus avoiding a mixed mode loading of the bond connection.

The applied force F leads to an increase of the stress intensity factor K_I at the tip of the chevron geometry a_0. If the stress intensity factor exceeds the fracture toughness, self-initiation of a defined crack with subsequent crack growth will start in this area. While the local stress intensity factor increases with growing crack length, the widening of the crack front decreases the stress intensity factor. As a consequence of these two counter-mechanisms, initially a quasi-stable crack propagation occurs in the brittle material. Hence, further crack growth – up to the critical crack length a_crit – requires an increase of the introduced force up to the maximum value F_max. As a result of the insetting instable crack propagation, the critical failure of the specimen occurs. The critical crack length a_crit is solely determined by the geometry of the used specimen and can be calculated using finite element analysis. An additional measurement based determination of the crack length is unnecessary due to the described crack propagation characteristics.

5 Test setup

5.1 General

The test setup should be suitable for transferring small forces and displacements onto glass frit bonded specimens. The setup consists of an actuator, allowing the loading of the specimen, a load cell for measuring the applied force, a controller for setting a constant displacement-controlled loading rate, a positioning system for aligning specimens within the experimental setup, and a recording tool to register force and displacement. Besides a special test setup, universal test equipment adapted for the purposes of this test may be used.

5.2 Actuator

The specimen load requires an actuator, which generates a linear force application at constant loading velocity. A displacement rate between 0,5 µm/s and 10 µm/s is recommended to determine material characteristics.

5.3 Force transducers

The load cell should be able to measure small forces with sufficient accuracy. When using the recommended geometry of the specimen, a 20 N load cell with a category of accuracy of 0,1 % proved adequate.

5.4 Mounting

In order to cause a mode I crack opening in the specimen, accurate positioning of the tested specimen within the experimental setup is necessary. The mounting system should allow rotation around all three axes in order to provide symmetrical loading of the specimens and to minimize shear force effects. The points of force application of the specimen, the actuator and load cell shall be aligned in one axis.

5.5 Data acquisition

A memory unit shall be integrated into the test setup in order to enable a subsequent evaluation of the tests. To accurately map the force-displacement curve, even at test speeds of 10 µm/s, care shall be taken for a sufficient sampling rate. A sampling rate of at least 10 Hz is recommended.

6 Specimens

6.1 Sample design

Specimens for the determination of fracture toughness shall meet the following requirements. The recommended specimen geometry with all associated parameters is given in Figure 2.

- The geometrical dimensions of the chevron geometry (initial crack lengths a_0 and the chevron notch angle φ) have to be inspected, i.e. by using infrared transmission or scanning acoustic microscopy. Deviations significantly influence the geometry factor and lead to inaccuracies within the calculated fracture toughness. Therefore, the geometry given in Figure 2 is required.
- Due to the production process of the glass frit interlayers, for example by means of a screen printing process, the chevron geometry shall be structured as stripe shaped. The stripes should be kept parallel to the direction of the crack propagation (x-direction in Figure 1).
- The widths of the glass frit stripes g_s need to be adapted to the frame widths of the equivalent industrial product to ensure the comparability of the strength properties of the connection.
- The distance between the glass frit stripes w_s shall be set depending on the stripe width g_s within the following range:

  $$0{,}5 \times g_\text{s} \le w_\text{s} \le 1{,}5 \times g_\text{s}$$

  By adapting the distance between the stripes within this range, the maximum measured forces can be adjusted to the available test equipment.
- The stripe structure shall be chosen such that the triangle geometry will be reproduced as homogenously as possible. The number of stripes should be uneven to create a symmetrical design.

  The thickness of the individual silicon chips t_w1 and t_w2 directly influences the geometry factor of the specimens. The thickness of the two composite chips or wafers should be equal (symmetrical design: $t_\text{w1} = t_\text{w2}$).

  Using asymmetrical specimens $t_\text{w1} \neq t_\text{w2}$) will lead to mixed-mode-loading instead of pure mode I crack opening. Thus, the determined strength values are not to be compared to symmetrical specimens and are reflecting variant failure modes of the bond interfaces.