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Semiconductor devices – Micro-electromechanical devices – Part 31: Four-point bending test method for interfacial adhesion energy of layered MEMS materials

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FOREWORD

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International Standard IEC 62047-31 has been prepared by subcommittee 47F: Micro-electromechanical systems, of IEC technical committee 47: Semiconductor devices.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
47F/326/FDIS	47F/331RVD

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

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SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 31: Four-point bending test method for interfacial adhesion energy of layered MEMS materials

1 Scope

This part of IEC 62047 specifies a four-point bending test method for measuring interfacial adhesion energy of the weakest interface in the layered micro-electromechanical systems (MEMS) based on the concept of fracture mechanics. In a variety of MEMS devices, there are many layered material interfaces, and their adhesion energies are critical to the reliability of the MEMS devices. The four-point bending test utilizes a pure bending moment applied to a test piece of layered MEMS device, and the interfacial adhesion energy is measured from the critical bending moment for the steady state cracking in the weakest interface. This test method applies to MEMS devices with thin film layers deposited on semiconductor substrates. The total thickness of the thin film layers should be 100 times less than the thickness of a supporting substrate (typically a silicon wafer piece).

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.

There are no normative references in this document.

3 Terms, definitions, symbols and designations

3.1 Terms and definitions

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

3.1.1
energy release rate
G
strain energy per unit surface area, which is released during the incremental growth of a crack

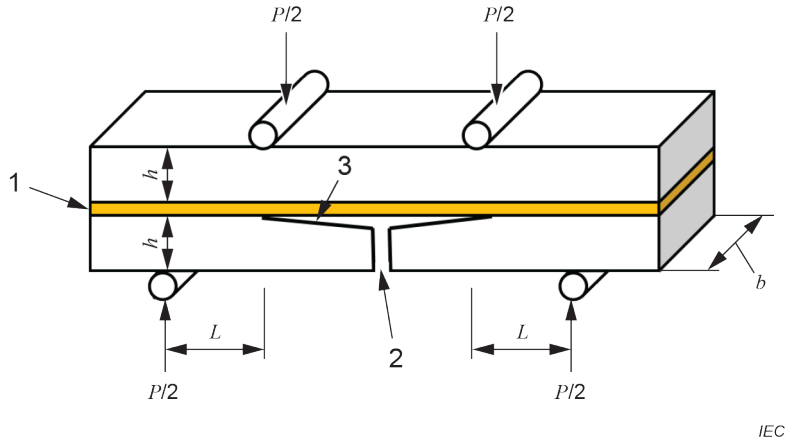
Note 1 to entry: The energy release rate can be regarded as the crack driving force, and its unit is given in J/m^2.

3.1.2
interfacial adhesion energy
G_C
critical energy release rate at the moment of crack extension

Note 1 to entry: Its unit is given in: J/m^2.

3.2 Symbols and designations

The shape of the test piece and the symbols are presented in Figure 1 and Table 1, respectively. The overall shape of the test piece is similar to a sandwiched cantilever beam, and it should have a pre-crack or a notch for crack initiation. After initiation of the crack, the crack follows the weakest interface in the layered materials system.



Key

1 layered material
2 notched pre-crack
3 interfacial crack

Figure 1 – Four-point bending test piece

Table 1 – Symbols and designations of a test piece

Symbol	Unit	Designation
L	mm	Spacing between two adjacent pins
b	mm	Width
h	μm	Thickness of the supporting structure
P	N	Force for driving crack

4 Test piece

4.1 General

The test piece for the layered MEMS materials shall be prepared using the same fabrication process that applies to actual MEMS devices. Machining of the test piece shall be performed to prevent formation of unintended cracks or flaws and delamination in the test piece.

4.2 Shape of a test piece

The overall shape of a test piece is shown in Figure 1. Because the evaluation of the energy release rate relies on several simplifying assumptions, the geometric shape of the test piece should be designed as follows: the thickness of the test piece should be 50 times less than the length and width of the test piece, and the length should be 10 times larger than the width. The total thickness of the layered materials should be 100 times less than the thickness of a supporting substrate. A pre-crack or notch shown in Figure 1 is machined using conventional ways like a diamond saw, laser ablation, or chemical etching. This pre-crack initiates cracking in the supporting substrate under bending, and after that the cracking leads to the introduction

of an interface crack between two adjacent layers of the weakest interface in the layered materials.

4.3 Measurement of dimensions

To analyze the test results, the test piece dimensions shall be accurately measured because the dimensions are used to determine the mechanical properties of test materials. Spacing between the pins (L), width (b), and thickness (h) should be measured with an error of less than ±5 %. Information on thickness measurement can be found in IEC 62047-2:2006, Annex C and in IEC 62047-3:2006, Clause 6.

4.4 Evaluation of energy release rate

The energy release rate (G) is evaluated using the following Equation (1):

$$G = \frac{21(1-\nu^2)P^2L^2}{16Eb^2h^3} \tag{1}$$

where

ν is Poisson's ratio;

E is Young's modulus;

b is the width of a test piece;

h is the thickness of the supporting structure;

L is the spacing between two adjacent pins, and

P is the applied load.

The critical energy release rate or the interfacial adhesion energy is evaluated from the energy release rate when the interfacial crack lying in the interface starts to grow. This formula is valid for brittle fracture.

5 Testing method and test apparatus

5.1 Test principle

The test is performed by applying a pure bending moment to a test piece with a layered material interface as shown in Figure 1. The test consists of two steps: the first is the introduction of an interface crack between two layered materials with the weakest interface. By gradually increasing the four-point bending load applied to the test piece, a crack is initiated from a machined pre-crack. The initiated crack extends in a direction of thickness and then becomes an interface crack when it touches the weakest interface. When the interface crack is formed, the bending load is relaxed. The second step is the extension of the interface crack. By reloading the bending load, the energy release rate at the tip of the interface crack increases, and the interface crack starts to extend. The energy release rate of an interface crack is independent of the crack length when the test piece is under pure bending. For this test method, it is unnecessary to measure the length of the interface crack.