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## **Characterization of Interfacial Adhesion in Semiconductor Packages**

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# CHARACTERIZATION OF INTERFACIAL ADHESION IN SEMICONDUCTOR PACKAGES

## Contents

|                                                                       |           |
|-----------------------------------------------------------------------|-----------|
| <b>Introduction.....</b>                                              | <b>ii</b> |
| <b>1 Scope .....</b>                                                  | <b>1</b>  |
| <b>2 Terms and definitions .....</b>                                  | <b>1</b>  |
| <b>3 References.....</b>                                              | <b>2</b>  |
| <b>4 Die adhesion.....</b>                                            | <b>2</b>  |
| 4.1 Molded wire bond package .....                                    | 3         |
| 4.2 Flip chip package .....                                           | 4         |
| <b>5 Characterization methods .....</b>                               | <b>6</b>  |
| 5.1 Die shear test.....                                               | 6         |
| 5.2 Button shear test.....                                            | 8         |
| 5.3 (Leadframe) pull test.....                                        | 9         |
| 5.4 Stud pull test .....                                              | 9         |
| 5.5 Laser spallation technique.....                                   | 10        |
| 5.6 Flip chip tensile pull test for bumps.....                        | 11        |
| 5.7 Peel test .....                                                   | 12        |
| 5.8 Wedge test.....                                                   | 13        |
| 5.9 Cantilever beam test.....                                         | 14        |
| 5.10 Three-point bend test .....                                      | 14        |
| 5.11 Mixed-mode bend test.....                                        | 15        |
| <b>6 Comparison and assessment of methods.....</b>                    | <b>16</b> |
| 6.1 Scope and application range of the method .....                   | 16        |
| 6.1.1 Failure characterization techniques.....                        | 17        |
| 6.1.2 Methods for interface characterization .....                    | 18        |
| 6.1.3 Methods for measurement of adhesion strength .....              | 19        |
| 6.2 Failure mechanisms .....                                          | 19        |
| <b>7 Summary and recommendations.....</b>                             | <b>20</b> |
| <b>Annex A (informative) Flip – chip package interfaces .....</b>     | <b>21</b> |
| <b>Annex B (informative) Molded leadframe-package interfaces.....</b> | <b>21</b> |
| <b>Annex C (informative) Bibliography.....</b>                        | <b>22</b> |

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## Introduction

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Delamination of the interfaces between the die, lead frame and the ambient materials is one of the major issues of IC reliability. There are several methods described in the literature how to characterize the adhesion of the die at these interfaces. Some of them are standardized. This publication gives guidance which method to choose for material selection, qualification or monitoring.

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## CHARACTERIZATION OF INTERFACIAL ADHESION IN SEMICONDUCTOR PACKAGES

(From JEDEC Board Ballot JCB-20-33 and JCB-20-33A, formulated under the cognizance of the JC-14.1 Subcommittee on Reliability Test Methods for Packaged Devices.)

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### 1 Scope

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This document identifies methods used for the characterization of die adhesion. It gives guidance which method to apply in which phase of the product or technology life cycle.

**NOTE** Inclusion in this directory of methods does not imply applicability to all die-package configurations.

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### 2 Terms and definitions

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**die adhesion:** Steady or firm attachment between die and an adhesive material e.g. mold compound

**adhesion strength:** the force needed to separate two materials by an defined method like shear or pull.

**creep:** the tendency of a solid material to slowly and permanently deform under stress.

**Mode I (crack failure mode):** An opening or tensile crack caused by loading normal to the crack

**Mode II (crack failure mode):** A sliding or in-plane shear crack caused by loading parallel to the crack surface sliding direction.

**NOTE** The crack surfaces slide over one another in direction perpendicular to the leading edge of the crack.

**Mode III (crack failure mode):** A tearing or out-of-plane shear crack caused by loading coplanar to the crack surface and perpendicular to the crack propagation direction.

**wear:** The erosion of material from a solid surface caused by interaction with another material.

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### 3 References

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ASTM D3165, Standard Test Method for Strength Properties of Adhesives in Shear by Tension Loading of Single-Lap-Joint Laminated Assemblies

ASTM D3433, Standard Test Method for Fracture Strength in Cleavage of Adhesives in Bonded Metal Joints

ASTM D3762, Standard Test Method for Adhesive-Bonded Surface Durability of Aluminum (Wedge Test)

ASTM D903, Standard Test Method for Peel or Stripping Strength of Adhesive Bonds

ASTM F459, Standard Test Methods for Measuring Pull Strength of Microelectronic Wire Bonds

JESD22-B109, Flip Chip Tensile Pull

JESD22-B115, Solder Ball Pull

MIL-STD-883 Meth 2012.7, Radiography

MIL-STD-883 Meth 2019, Die Shear Strength

MIL-STD-883 Meth 2027, Substrate Attach Strength

MIL-STD-883 Meth 2030, Ultrasonic Inspection of Die Attach

MIL STD 883 Meth 2031.1, Flip Chip Pull off test

SEMI G63-95, Test Method for Measurement of Die Shear Strength

SEMI G69-0996, Test Method for Measurement of Adhesive Strength between Leadframes and Molding Compounds

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### 4 Die adhesion

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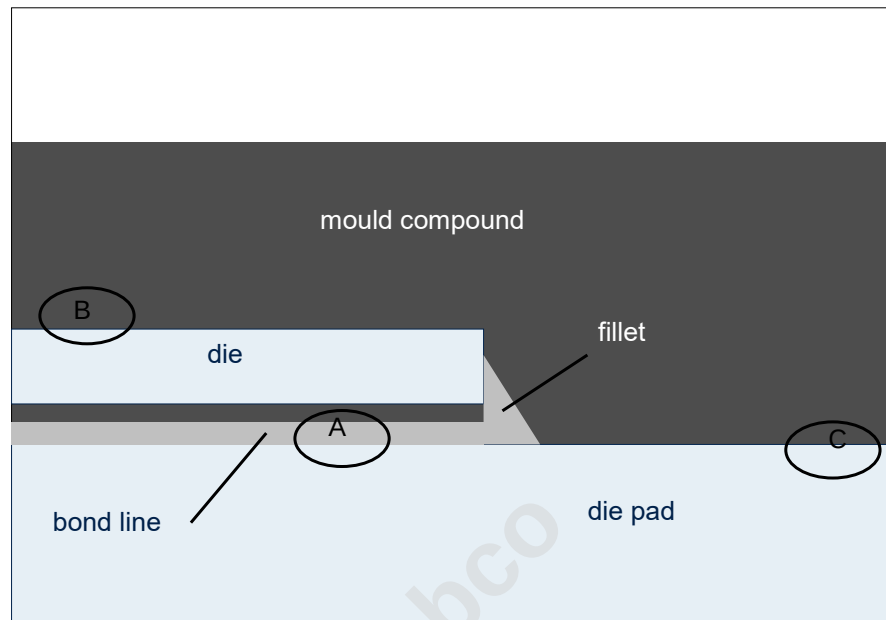
Failure mechanisms directly or indirectly affecting die adhesion are

- fatigue mechanisms,
- creep,
- wear,
- Interfacial fracture, and
- nonwetting due to contamination or residues.

The effect on time to failure depends very much on design and construction of the package.

#### 4.1 Molded wire bond package

There are two major techniques for attaching a die to a die pad, adhesive or solder. For adhesives polyimide, epoxy or silver filled glass is used. A sketch of the three critical interfaces of this type of package is shown in Figure 1.



A) die – adhesive – pad, B) die – mould compound,  
C) mould compound – die pad/leadframe

**Figure 1 — Die adhesion interface**

Delamination at C does not directly affect a die-related interface, but it should be taken into account because of its influence on delamination and related failure modes at die-related interfaces.

The attach process with adhesives has two potential failure causes:

- excessive die attach fillet resulting in die attach contamination and problems when performing die shear tests;
- too little die attach fillet resulting in die delamination or die cracking.

The eutectic process typically uses alloys Sn-Ag, Sn-Ag-Cu, Au-Si, Au-Sn, Pb-Sn or Au. Here voiding especially large voids are the main risk. These voids change the stress situation and therefore are the cause of die cracking.

Table 1 gives an overview of the cause-failure correlation at die interfaces. Delamination failures are covered by the column “die lifting”.

#### 4.1 Molded wire bond package (cont'd)

**Table 1 — Cause failure correlation, examples**

| <b>Failure Cause</b>                                         | <b>Die to mold separation</b> | <b>Die Lifting from LF</b> | <b>Die Cracking</b> | <b>Adhesive Shorting</b> | <b>Bond Lifting</b> |
|--------------------------------------------------------------|-------------------------------|----------------------------|---------------------|--------------------------|---------------------|
| contamination                                                | <b>X</b>                      | <b>X</b>                   |                     |                          |                     |
| excessive die attach voids                                   |                               | <b>X</b>                   | <b>X</b>            |                          |                     |
| incomplete die attach coverage                               |                               | <b>X</b>                   | <b>X</b>            |                          |                     |
| inadequate die attach curing                                 | <b>X</b>                      | <b>X</b>                   |                     |                          |                     |
| die overhang                                                 |                               |                            | <b>X</b>            |                          |                     |
| insufficient bond line thickness                             |                               |                            | <b>X</b>            |                          |                     |
| excessive die ejection force                                 |                               |                            | <b>X</b>            |                          |                     |
| absence of voids                                             |                               |                            | <b>X</b>            |                          |                     |
| incorrect die attach material viscosity                      |                               |                            |                     | <b>X</b>                 |                     |
| incorrect adhesive dispensation                              |                               |                            |                     | <b>X</b>                 |                     |
| Out gassing from D/A cure                                    | <b>X</b>                      |                            |                     |                          | <b>X</b>            |
| resin bleeding of the die attach material into the bond pads |                               |                            |                     |                          | <b>X</b>            |

#### 4.2 Flip chip package

Flip chip packages have many interfaces which could delaminate or break (see Figure 2. Cohesive failure modes are not covered in this publication. Stress related failures due to thermal load have been studied for the interfaces

bump – underfill [6]  
die – mold compound [7]  
die – underfill [7].

Interface underfill-solder mask is not discussed here.

Especially the adhesion of the underfill is the most important factor affecting reliability of flip chip assemblies. An example of a detailed reliability analysis of a flip-chip-package can be found at reference [8].