



APPARATUS AND METHOD FOR BONDING STRENGTH TESTING

FIELD OF THE INVENTION

5 The present invention relates to an apparatus and method for testing material properties and in particular, it relates to an apparatus and method for testing material bonding strengths.

BACKGROUND OF THE INVENTION

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In a wide variety of industries, it is necessary to measure the bonding strength between two or more materials. For example, during semiconductor fabrication, an epoxy molding compound (EMC) is used to encapsulate an integrated circuit (IC) to protect it from its environment. During the IC encapsulation process, the molding compound tends to adhere to the mold surface. Hence, a layer of coating is usually applied to the mold, which protects the mold against wear and abrasion. In addition, the coating layer also prevents the molding compound from sticking to the mold. In the development of the coating, it is necessary to quantitatively evaluate the bonding strength between the molding compound and the mold. In addition, it is desirable to measure the sticking tendency of different molding compounds to the mold as well as to the IC.

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Various testing methods have been developed to measure the adhesiveness of the molding compound to the coated substrates. The same methods have also often been adapted to test the bonding strength of the adhesives. One method is referred to as a "Shear Test", in which a block of molding compound is molded onto a coated substrate. A gradually increasing force is applied to the substrate and the molding compound in a direction parallel to the bonding surface. The strength of the bond is measured by the shear force required to separate the molding compound and the substrate.



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A major shortcoming of this method is that the test results are affected by the roughness of the surface of the substrate. Therefore, the test results could be more indicative of how rough the surface of the substrate is rather than the true bonding strength between the molding compound and the coated substrate. In addition, removal of the cured compound block from the mold can be quite difficult and the interface may be damaged in the process.

Another method of testing the bonding strength of a material is referred to as "Pull Off" test, in which a handle such as a metal block or a hook is attached to the cured molding compound. A tensile force is then applied to the compound through the handle to separate them. A Tensile Testing Machine is used to apply and record the tensile force. The force is gradually increased until separation occurs, at which the strength of the bond is determined.

While this method is less sensitive to the surface roughness of the coated substrate than the Shear Test, preparation of the test specimen is relatively difficult as debonding or bonding failure often takes place while removing the molded article from the mold as well as during mounting of the test apparatus to the testing machine. Therefore, the interface to be tested may be damaged unknowingly during preparation of the test specimen, and this may yield inconsistent or unreliable test results.

US Patent 5,768,936 to Mann discloses an adhesion and cohesion paint testing system, which measures the bonding strength of a paint to a substrate. A pressurized fluid is applied to the adhesive from the substrate side through an aperture formed on the substrate until separation of the paint from the substrate occurs. A thin film disk is positioned atop the center of the paint layer to be tested and extends beyond the perimeter of the aperture. A plate is fixed on top of the thin film disk by a very high-strength adhesive. During testing, a debond force is applied to the top surface of the paint by the pressurized fluid through the thin film disk and the plate.

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Because a pulling force is applied at the top surface of the paint to be tested, the debond may occur as either a secondary adhesive failure (i.e. at the bonding interface between the paint and the thin disc) or as a cohesive failure (i.e. within the paint itself or "in-layer" failure). As discussed above with regard to the "Pull Off" test, this method may not generate a reliable result of bonding strength between the test substance and the substrate. In addition, the test set up is very complex since it uses a pressurized fluid to apply the testing force and accordingly, it is not suitable for bonding strength test, in particular for the EMC bonding test.

SUMMARY OF THE INVENTION

In accordance with a first aspect of the present invention, there is provided an apparatus for testing the bonding strength between a substrate and a test piece adhered thereon. The substrate has a first bonding portion, the test piece has a second bonding portion to bond onto the first bonding portion of the substrate to form a bonding interface, and a non-bonding portion for receiving a test force to separate the test piece from the substrate. The test force is applied substantially perpendicular to the bonding interface; and both the second bonding portion and the non-bonding portion face the same direction i.e. face the substrate.

Preferably, the non-bonding portion comprises a flat surface for receiving the test force, and both the second bonding portion and the non-bonding portion are located at the same side of the test piece, and between the test piece and the substrate.

Alternatively, the non-bonding portion has a curved profile having a surface component, and both the second bonding portion and the surface component face the substrate.

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Preferably, the substrate further defines a slot to permit contact with the test piece through the substrate.

Preferably, the slot comprises an opening within the first bonding portion.

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Alternatively, the slot comprises a notch partially surrounded by the first bonding portion.

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Preferably, the apparatus further comprises an ejector for applying the test force therethrough and more preferably, the ejector is movable through the slot of the substrate.

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Preferably, the ejector has an enlarged portion to at least partially extend beyond the periphery of the slot.

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Preferably, the apparatus further comprises a cap to cover the slot and the cap is positioned between the substrate and the test piece and preferably, the apparatus further comprises an ejector acting against the cap for applying the test force to separate the test piece from the substrate.

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It should be appreciated that in this context, the term "adhesive" refers to any appropriate material which is initially in a fluid form, and may be injected into a mold and is curable subsequently to be a rigid state, such as Epoxy Molding Compound for IC encapsulation, general purpose adhesive, cement or the like.

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In another embodiment, the test piece is a rigid solid block for bonding onto to the substrate by an adhesive. In this embodiment, the adhesive is the material for which the bonding strength is to be tested.

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In accordance with a second aspect of the present invention, there is provided an apparatus for bonding strength testing, the apparatus comprises a substrate, a test piece and an ejector. The substrate has a first surface and a slot, the test piece has a second surface which includes a bonding portion to bond onto the first surface of the substrate and a non-bonding portion to overlap the slot, and the ejector has a first end to apply a force against the non-bonding portion and a second end extending through the slot. The ejector is movable to break the bonding between test piece and the substrate.

Preferably, the slot comprises an aperture and the ejector is movable within the aperture.

Preferably, the apparatus further comprises a cap positioned between the test piece and the substrate and more preferably, the cap covers the slot and receives the ejector.

In accordance with a third aspect of the present invention, there is provided a method for performing a bonding strength test. The method comprises preparing a test piece having a bonding portion and a non-bonding portion; bonding the test piece with the bonding portion onto a substrate to form a bonding interface, and applying a test force onto the substrate and the non-bonding portion of the test piece to break the bonding interface. The test force is substantially perpendicular to the bonding interface; and the bonding portion and the non-bonding portion face the same direction.

Preferably, the method further comprises determining the test force being applied when the bonding interface is broken.

Preferably, the test force is applied to the non-bonding portion of the test piece through a slot in the substrate.

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Preferably, the test force is applied to the non-bonding portion of the test piece using an ejector.

Preferably, the test piece is a curable adhesive.

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Preferably, the preparation of the test piece further comprises covering the slot of the substrate, and enclosing the substrate to provide a cavity thereabove.

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In one embodiment, the method further comprises injecting the adhesive into the cavity, and curing the adhesive.

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A bonding test performed according to the present invention is able to generate reliable test results which reflect the real bonding strength between the test substance and the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

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Fig. 1A is a cross sectional view showing an apparatus for preparing a test specimen for bonding strength testing according to one embodiment of the present invention;

Fig. 1B is a cross sectional view showing a specimen is ready for bonding strength testing according to one embodiment of the present invention;

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Fig. 1C is a cross sectional view showing the apparatus of Fig. 1B after the test is performed;

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Fig. 2 is a partially cross-sectional front view showing the apparatus of Fig. 1B placed on a test machine for bonding strength testing;

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Figs. 3A and 3B are cross sectional views showing an apparatus for bonding strength testing according to a second embodiment of the present invention;

5 Fig. 4 is a cross sectional view showing an apparatus for bonding strength testing according to a third embodiment of the present invention;

Fig. 5 is a cross sectional view showing an apparatus for bonding strength testing according to a fourth embodiment of the present invention;

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Figs. 6A and 6B are partially top views of the apparatus showing the alternatives of the substrate;

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Fig. 7 is a flow chart showing the method of bonding strength testing according to the present invention;

DETAILED DESCRIPTION OF THE PREFERED EMBODIMENTS

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As shown in Figs. 1A, 1B, and 1C, an apparatus for bonding strength testing according to one embodiment of the present invention comprises a flat substrate 10, a cap 30 and an enclosure, such as a mold 50. The substrate 10 is preferably formed in a cylindrical shape having a first bonding portion 12 and an aperture or a through slot 14 formed thereon, which allows an ejector 40 to move therewithin.

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The ejector 40 includes a first end 42 for engaging the cap 30 and a second end 44 that extends beyond the lower surface of the substrate 10. The mold 50 is supported by the substrate 10 at a sealing surface 70. The cap 30 covers the slot 14 and is supported by the substrate 10 at another sealing surface 80. The shape of the substrate 10, the cap 30, and the mold 50 define a chamber or a cavity 60, such as in a generally cylindrical shape, into which a fluid compound may be injected.

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5 An Epoxy Molding Compound (EMC) 160 is injected into the cavity 60 through an inlet 52 and cured to form a test specimen 20. The test specimen has a second bonding portion 22 contacting the first bonding portion 12 of the substrate 10, and a non-bonding portion 24 contacting the top surface 34 of the cap 30. The non-bonding portion 24 overlaps the slot 14 via the cap 30, and both the second bonding portion 22 and the non-bonding portion 24 face the same direction to the substrate. When the EMC is cured to form the test specimen 20, which is substantially the same shape as the cavity 60, the mold 50 may be removed. It should be appreciated that for the purpose of forming the EMC specimen 20 on the substrate 10, proper anti-sticking agents may be applied on the mold 50 to make the removal of the mold 50 easier without the EMC specimen 20 stuck thereon. Since the EMC is a type of material with certain adhesive properties, it sticks onto the substrate 10 and the apparatus is now ready for testing, as shown in Fig. 1B. The test specimen 20 is now bonded with its second bonding portion 22 onto the first bonding portion 12 of substrate to form a bonding interface 90.

20 Upon start of the testing, a substrate holder in the form of a metal ring 210 is placed on a lower stage 220 of a Tensile Testing Machine 200, as shown in Fig. 2. The test apparatus illustrated in Figure 1B is placed in an up-side-down orientation, with the substrate 10 resting on the metal ring 210 and the ejector 30 placed in the slot 14 and protruding upwardly. A compressive force 100 is then applied on the ejector 30 by an upper stage 230 and on the substrate 10 by the lower stage 220 of the testing machine 200. The force 100 is increased until the test specimen 20 is debonded from the substrate 10. The tensile strength of the test specimen 20 may then be calculated by dividing a separation force by the bonding area between the test specimen and the substrate 10.

30 Fig. 3A shows another embodiment according to the present invention. This embodiment includes an ejector 340a that is generally cone-shaped seated within a corresponding beveled slot 314a of the substrate 310 before preparation

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of the test specimen 320a. It should be appreciated that in this embodiment, the second bonding portion 322 and the non-bonding portion 324 are formed within the same level surface on the test specimen 320. Alternatively, the ejector 340b may be generally cylinder-shaped and seated within a corresponding shaped slot 314b, as shown in Fig. 3B. The dimensions of the ejector 340b and the slot 314b are precisely matched so that the ejector 340b seals the slot 314b and moveable within the slot 314b to eject the test specimen 320b.

Fig. 4 shows a third embodiment according to the present invention. This embodiment includes an ejector 440 having a spherical shaped end portion 442. In addition, a non-bonding portion 424 of a test specimen 420 formed thereon has a corresponding spherical shaped profile. A set of vectors 424a is selected for the purpose of illustration of the orientation of the test specimen 420. The set of vectors 424a has a component 424y, which is perpendicular to the bonding interface and facing the same direction 422y as that of the second bonding surface 422 of the test specimen 420. A test specimen with this type of surface profile enables a test force 400 to be applied directly thereon, which is in a direction opposite to the component 424y to break the bonding interface without the need of forming a secondary bonding interface as the conventional Pull-Off test does.

Fig. 5 shows an apparatus for testing bonding strength according to a fourth embodiment of the present invention. A test specimen 520 made of a rigid solid material such as a metal block is bonded onto a substrate 510 by an adhesive 550 that is to be tested for bonding strength. The apparatus is operated in a similar way as described above by applying a force 500 onto the test specimen 520 through an ejector 540 and a cap 530, until the force 500 reaches the bonding strength limit of the adhesive 550. The force being applied upon failure of the bonding may then be recorded to represent the bonding strength of the adhesive.

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Figs. 6A and 6B are cross sectional top views showing the variations of the substrate of a bonding strength testing apparatus according to further embodiments of the present invention. In one alternative shown in Fig. 6A, the substrate 610 comprises a first bonding region 612 for receiving a test specimen (not shown), a sealing region 680 for receiving a cap (not shown) and a slot 614a through which an ejector 640 is movable for applying a test force to the test specimen. In another alternative shown in Fig. 6B, the substrate 610 comprises a first bonding region 612 for receiving a test specimen (not shown), a sealing region 680 for receiving a cap (not shown) and a notch 614b within which the ejector 640 is movable for applying a test force to the test specimen. It should be appreciated that the substrate may be structured with other variations without departing from the essential features of the present invention. For example, the substrate may have two or more slots and/or notches or the like to meet various testing configurations.

A method 700 for testing bonding strength according to the present invention may be illustrated in Fig. 7. In a first block 710, a test specimen is prepared with a bonding portion and a non-bonding portion. In the next block 720, the test specimen is bonded with its bonding portion on to a substrate to form a bonding interface. In the next block 730, a test force is applied onto the substrate and the non-bonding portion of the test specimen to break the bonding between the test specimen and the substrate. In this method, the test force is applied along a direction substantially perpendicular to the bonding interface, and both the bonding portion and the non-bonding portion of the test specimen face the same direction, i.e. face the substrate so that the test force may be applied directly onto the test specimen at the non-bonding portion.

A bonding strength testing apparatus and method illustrated above has the advantages to enable a testing force to be applied in a direction substantially perpendicular to the bonding surface, which may eliminate the surface roughness problem incurred in the "Shear Test" hence reflects the real bonding strength. In addition, since the testing force is applied to the test specimen onto its force-

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receiving surface which faces the same direction as its bonding surface, the "in-layer" failure of the test piece and the secondary bonding interface failure incurred in the "Pull-Off Test" and US Patent 5,768,936 method are successfully prevented.

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Applying the present invention to the bonding strength test between the EMC and the mold, the possible damage to the bonding interface incurred by conventional method may be minimized. Test specimen may be prepared in a manner similar to the actual IC encapsulating process, therefore the test results obtained are closer to the actual production situation. Test specimen prepared according to the present invention generate no tensile stress across the bonding interface. In the operation, there is no need to clamp the test apparatus onto the test machine as the conventional method such as the "Shear Test" does, which minimizes handling problems, which often lead to premature failure of the test specimen of inconsistent results experienced by the "Pull-Off Test" and the "Shear Test".

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CLAIMS

1. An apparatus for bonding strength testing comprising:
 - a substrate having a first bonding portion;
 - 5 a test piece having a second bonding portion to bond onto the first bonding portion of the substrate to form a bonding interface, and a non-bonding portion for receiving a test force to separate the test piece from the substrate;
 - wherein the test force is substantially perpendicular to the bonding interface;
 - 10 wherein the second bonding portion and the non-bonding portion face the same direction.
 - wherein the substrate further defines a slot to permit contact with the test piece through the substrate; and
 - 15 wherein the apparatus further comprises a cap to cover the slot.
2. The apparatus as claimed in claim 1, wherein the slot comprises an opening within the first bonding portion.
- 20 3. The apparatus as claimed in claim 1, wherein the slot comprises a notch partially surrounded by the first bonding portion.
4. The apparatus as claimed in claim 1, further comprising an ejector for applying the test force therethrough.
- 25 5. The apparatus as claimed in claim 1, further comprising an ejector for applying the test force through the slot.
6. The apparatus as claimed in claim 5, wherein the ejector having an enlarged portion to at least partially extend beyond the periphery of the slot.
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7. The apparatus as claimed in claim 1, wherein the cap is positioned between the substrate and the test piece.
8. The apparatus as claimed in claim 7, further comprising an ejector to applying the test force to the cap to separate the test piece from the substrate.
9. The apparatus as claimed in claim 1, wherein the test piece is a cured adhesive.
10. The apparatus as claimed in claim 1, wherein the test piece is a rigid solid block for bonding onto the substrate by an adhesive which bonding strength is to be tested.
11. The apparatus as claimed in claim 1, further comprising an enclosure for forming on the substrate a chamber into which the test piece is formed by injecting a fluid material.
12. The apparatus as claimed in claim 11, wherein the cap seals the slot.
13. An apparatus for bonding strength testing comprising:
a substrate having a first surface and a slot;
a test piece having a second surface including a bonding portion to bond onto the first surface of the substrate, and a non-bonding portion positioned over the slot; and
an ejector having a first end to apply a force against the non-bonding portion and a second end extending through the slot,
wherein the ejector is movable to break the bonding between test piece and the substrate, and
wherein the apparatus further comprises a cap positioned between the test piece and the substrate.

14. The apparatus as claimed in claim 13, wherein the slot comprises an aperture.
15. The apparatus as claimed in claim 14, wherein the ejector is movable through the aperture.
16. The apparatus as claimed in claim 13, wherein the cap covers the slot and is to contact the first end of the ejector when the force is applied.
17. The apparatus as claimed in claim 13, wherein the ejector having an enlarged portion to at least partially extend beyond the periphery of the slot.
18. A method for bonding strength testing comprising:
covering a slot provided on a substrate;
enclosing the substrate to provide a cavity thereabove;
injecting an adhesive into the cavity, and
curing the adhesive to form a test piece, wherein the test piece having a bonding portion and a non-bonding portion;
bonding the test piece with the bonding portion onto the substrate to form a bonding interface;
applying a test force to the substrate and the non-bonding portion of the test piece to break the bonding interface,
wherein the test force is substantially perpendicular to the bonding interface; and
wherein the bonding portion and the non-bonding portion face the same direction.
19. The method as claimed in claim 18, further comprising determining the test force being applied when the bonding interface is broken.
20. The method as claimed in claim 18, wherein the test force is applied to the non-bonding portion of the test piece through the slot in the substrate.

21. The method as claimed in claim 20, wherein the test force is applied to the non-bonding portion of the test piece using an ejector.
- 5 22. The method as claimed in claim 18, further comprising sealing the cavity.
23. An apparatus for bonding strength testing comprising:
a substrate having a first bonding portion;
a test piece having a second bonding portion to bond onto the first
10 bonding portion of the substrate to form a bonding interface, and a
non-bonding portion for receiving a test force to separate the test
piece from the substrate;
wherein the test force is substantially perpendicular to the bonding
interface;
15 wherein the second bonding portion and the non-bonding portion face
the same direction;
wherein the substrate further defines a slot to permit contact with the
test piece through the substrate; and
wherein the slot comprises a notch partially surrounded by the first
20 bonding portion.
24. The apparatus as claimed in claim 23, further comprising an ejector for applying the test force through the slot.
- 25 25. The apparatus as claimed in claim 24, wherein the ejector having an enlarged portion to at least partially extend beyond the periphery of the slot.
26. The apparatus as claimed in claim 23, further comprising an enclosure for forming on the substrate a chamber into which the test piece is formed by
30 injecting a fluid material.

27. The apparatus as claimed in claim 26, further comprising a cap to seal the slot.

28. An apparatus for bonding strength testing comprising:

5 a substrate having a first bonding portion;

a test piece having a second bonding portion to bond onto the first bonding portion of the substrate to form a bonding interface, and a non-bonding portion for receiving a test force to separate the test piece from the substrate, and

10 an ejector for applying the test force through the slot;

wherein the test force is substantially perpendicular to the bonding interface;

wherein the second bonding portion and the non-bonding portion face the same direction;

15 wherein the substrate further defines a slot to permit contact with the test piece through the substrate, and

wherein the ejector having an enlarged portion to at least partially extend beyond the periphery of the slot.

20 29. An apparatus for bonding strength testing comprising:

a substrate having a first bonding portion;

a test piece having a second bonding portion to bond onto the first bonding portion of the substrate to form a bonding interface, and a non-bonding portion for receiving a test force to separate the test piece from the substrate, and

25 an enclosure for forming on the substrate a chamber into which the test piece is formed by injecting a fluid material

wherein the test force is substantially perpendicular to the bonding interface;

30 wherein the second bonding portion and the non-bonding portion face the same direction; and

wherein the substrate further defines a slot to permit contact with the test piece through the substrate.

30. The apparatus as claimed in claim 29, further comprising a cap to seal the slot.