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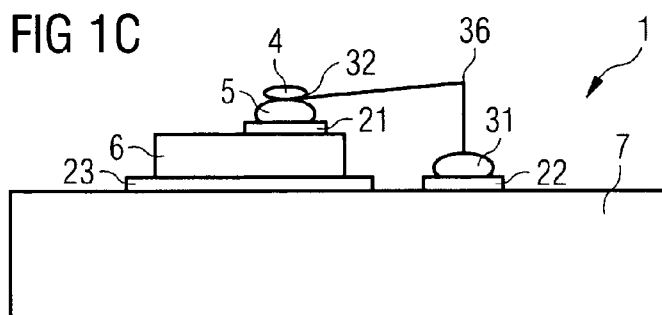
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(54) Title: ELECTRONIC DEVICE AND METHOD FOR FORMING AN ELECTRICAL CONNECTION



(57) Abstract: An electronic device (1) comprising a first contact area (21), a second contact area (22) and a wire bond connection (3) between the first contact area and the second contact area is specified. The wire bond connection extends between a first end (31) of the wire bond connection and a second end (32) of the wire bond connection, wherein an additional bond ball (4) is arranged on top of the wire bond connection. Furthermore, a method for forming an electrical connection is specified.

Description

Electronic device and method for forming an electrical connection

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The present application relates to an electronic device and to a method for forming an electrical connection.

Electronic components such as semiconductor chips may be electrically connected by means of wire bonding, for example. Mechanical stress, for instance, may result in a breakage of the bond connection, which in turn typically leads to failure of the component. In particular, the reliability of a wire bond connection may be reduced if the loop height needs to be reduced due to space constraints.

One object to be solved is to specify an electronic device that exhibits a highly reliable connection. A further object is to specify a method that allows for providing a highly reliable electrical connection.

In accordance with at least one aspect of the electronic device, the electronic device comprises a first contact area. The first contact area may be an area provided on a semiconductor chip, said area being intended for external electrical connection of the semiconductor chip.

The term "electronic device" includes electronic devices such as diodes or transistors as well as optoelectronic devices. For instance, the electronic device may comprise at least one optoelectronic semiconductor chip such as a luminescence diode or a radiation detector.

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The term "wire bond connections" includes all types of connections that use a bond wire. The wire bond connection may be formed by any kind of wire bonding, for instance by ball bonding. Heat, pressure or ultrasonic energy as well as combinations thereof may be applied during fabrication of the wire bond connection.

In accordance with at least one aspect of the electronic device, the electronic device comprises a second contact area. The second contact area may be an area provided on a submount of a semiconductor chip, on a lead frame or on a connection carrier such as a printed circuit board. Alternatively, the second contact area may be provided on a semiconductor chip, said area being intended for external electrical connection of the semiconductor chip.

In accordance with at least one aspect of the electronic device, a wire bond connection is formed between the first contact area and the second contact area. The wire bond connection electrically conductively connects the first contact area with the second contact area. The wire bond connection extends between a first end of the wire bond connection and a second end of the wire bond connection. A wire part of the wire bond connection extends between the first end and the second end. Preferably, a cross section of the wire part is constant along the wire bond connection. In particular, the cross section of the wire part is of circular shape.

Preferably, the first end is a bond ball. The second end preferably is a wedge bond. The wedge bond is formed without making a bond ball. The wedge bond is also referred to as tail bond or as second bond. The term wedge bond does not

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necessarily imply that the shape of the second end is of a geometric wedge shape. During production of the wedge bond, pressure is applied on the bond wire, so that the wire is compressed. For instance, the wire may be crushed between a capillary the wire is fed in and the surface to be bonded. Compared to the wire part, the height of the wedge bond is decreased and a lateral extension of the wedge bond is increased. It has turned out that the additional bond ball arranged on top of the bond ball or on top of the wedge bond improves the reliability of the wire bond connection.

In accordance with at least one aspect of the electronic device, an additional bond ball is arranged on top of the wire bond connection. The additional bond ball may be provided on top of the first end or on top of the second end of the wire bond connection. The wire part preferably extends beyond the additional bond ball.

In accordance with at least one aspect of the electronic device, a main plane of extension of the first contact area is arranged in an elevated manner with respect to a main plane of extension of the second contact area, so that the wire bond connection extends only on a side of the main plane of extension of the second contact area that faces the first contact area. In other words, the first contact area is arranged on a higher level than the second contact area. Alternatively, the first and second contact areas may be arranged on an equal level.

In accordance with at least one aspect of the electronic device, the first contact area is a bond pad of a semiconductor chip. Alternatively or in addition, the second contact area may be a bond pad of a semiconductor chip.

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In accordance with at least one aspect of the electronic device, the additional bond ball is arranged on top of the first contact area. By means of the additional bond ball, a highly reliable wire bond connection having a low loop height
5 may be obtained in a simplified manner.

In accordance with at least one aspect of the electronic device, the additional bond ball is formed on top of the wedge bond. The wedge bond is arranged between the additional
10 bond ball and the contact area on which the wedge bond is arranged.

In accordance with at least one aspect of the electronic device, the additional bond ball is formed on top of the bond
15 ball. The bond ball is arranged between the additional bond ball and the contact area on which the bond ball is arranged. In particular, a maximum extension of the additional bond ball may be smaller than a maximum extension of the bond ball. During production, the diameter of the additional bond
20 ball is smaller than the diameter of the bond ball. Using an additional bond ball of reduced diameter allows for reducing the overall height of the wire bond connection without negatively affecting the reliability of the wire bond connection.

25

In accordance with at least one aspect of the electronic device, the first end is a bond ball, said bond ball being arranged on the first contact area, wherein the first contact area preferably is arranged in an elevated manner with
30 respect to the second contact area and wherein the additional bond ball is arranged on top of the bond ball.

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In accordance with at least one aspect of the electronic device, the second end is a wedge bond, said wedge bond being arranged on the first contact area, wherein the first contact area preferably is arranged in an elevated manner with
5 respect to the second contact area and wherein the additional bond ball is formed on the wedge bond.

In accordance with at least one aspect of the electronic device, an underlying bond ball is arranged between the wedge
10 bond and the contact area on which the wedge bond is arranged, for instance on the first contact area. By means of the underlying bond ball, a mechanically stable connection between the contact area and the wedge bond may be obtained in a simplified manner. In particular, the wedge bond may be
15 arranged between the underlying bond ball and the additional bond ball.

In accordance with at least one aspect of the electronic device, a wedged part of the wedge bond overlaps a center of
20 the underlying bond ball in top view. In other words, a center of the wedge bond is offset with respect to a center of the underlying bond ball. In the wedged part, the height of the wire bond connection decreases as seen from the wire part towards the wedge bond. The additional bond ball
25 preferably covers the center of the underlying bond ball.

In accordance with at least one aspect of the method, a first contact area and a second contact area are provided. A wire bond connection is formed between the first contact area and
30 the second contact area, wherein the wire bond connection extends between a first end and a second end.

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In accordance with at least one aspect of the method, an additional bond ball is formed on top of the wire bond connection. By means of the additional bond ball, the wire bond connection formed prior to the formation of the additional bond ball is pressed against the contact area on which the additional bond ball is formed.

In accordance with at least one aspect of the method, the additional bond ball is thinned or removed after its formation. By means of this step, the overall height of the wire bond connection above the contact area may be reduced. Alternatively, the additional bond ball may entirely remain on the contact area.

In accordance with at least one aspect of the method, a kink is formed in the wire bond connection. In particular, the kink may overlap the first contact area in top view. This means that the wire part may extend vertically or substantially vertically with respect to the first contact area from the first end to the kink. The additional bond ball may be formed on top of the kink. Using the additional bond ball, the wire extending between the first end and the kink is compressed, so that the vertical extension of the wire bond connection may be reduced.

The method described is particularly suited for the production of the electronic device. Thus, features described in connection with the device may also apply to the method and vice versa.

The device and the method for forming an electrical connection are described in greater detail below on the basis of exemplary embodiments and the corresponding figures.

In the figures:

Figures 1A through 1D show method steps of an exemplary embodiment of the method for forming an electrical connection in an electronic device, wherein Figure 1C represents an exemplary embodiment of the electronic device. In Figure 1D, a magnified representation of a section of Figure 1B is depicted.

Figures 2A through 2C show method steps of a further exemplary embodiment of the method for forming an electrical connection in an electronic device, wherein Figure 2C represents a further exemplary embodiment of the electronic device.

Elements which are identical, of identical type or act identically are marked with the same reference symbols in the figures.

The figures and the proportions of the individual elements illustrated in the figures should not be regarded as drawn to scale. Rather, individual elements - for example layer thicknesses - may be illustrated in an exaggerated size in order to allow for better demonstration and/or a better understanding.

An exemplary embodiment for a method for forming an electrical connection is shown in Figures 1A through 1D in sectional view, wherein Figure 1C shows an exemplary embodiment of an electronic device.

As shown in Figure 1A, a first contact area 21 and a second contact area 22 are provided. The first contact area is a

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bond pad of a semiconductor chip 6. The bond pad is provided for an external electrical connection of the semiconductor chip via a wire bonding connection. The term "wire bonding" includes all types of bond connections that use a bond wire, for instance ball bonding.

The first contact area 21 and the second contact area preferably comprise gold. However, other metals, such as aluminum, silver, copper or tin, may be used alternatively or in addition.

The semiconductor chip 6 is mounted on a further contact area 23.

The further contact area 23 and the second contact area 22 are provided on a surface of a carrier 7. The carrier may be a submount or a printed circuit board, for instance. Unlike in the present embodiment, the carrier 7 may be a lead frame which provides the first contact area 21 and the second contact area 22.

The first contact area 21 is vertically spaced apart from the second contact area 22. A vertical direction is understood to be a direction running perpendicularly with respect to a main plane 210 of extension of the first contact area 21. The first contact area 21 is arranged in an elevated manner with respect to a main plane of extension 220 of the second contact area 22. In other words, a distance between the carrier 5 and the first contact area 21 is larger than a distance between the carrier 5 and the second contact area 22. This means that the wire bond connection 3 extends on only one side of the second contact area 22 that faces the first contact area. As seen from the first contact area, the

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wire bond connection 3 comprises a region that extends away from the second contact area 22 and a region that extends towards the second contact area 21.

5 An underlying ball 5 is formed on the first contact area 21. In particular, the underlying ball is in direct physical contact with the first contact area. In top view, the underlying ball 5 is arranged entirely within the first contact area 21, so that the underlying ball does not extend
10 beyond the first contact area in a lateral direction.

As shown in Figure 1B, a wire bond connection 3 is formed between the first contact area 21 and the second contact area 22. The wire bond connection 3 extends between a first end 31
15 and a second end 32. The second contact area 22 is connected first. Subsequently, the first contact area 21 is provided with the second end 32 of the wire bond connection.

The wire bond connection 3 further comprises a wire part 35
20 extending between the first end 31 and the second end 32. The wire part 35 comprises a kink 36. By means of the kink 36, the wire part 35 is divided into a region extending essentially parallel to the vertical direction between the first end 31 and the kink 36 and a further region running
25 perpendicularly or essentially perpendicularly with respect to the vertical direction. The kink 36 may help to reduce the overall vertical extension of the wire bond connection 3. However, the kink may also be dispensed with.

30 In the embodiment shown, the first end 31 is a bond ball and the second end 32 is a wedge bond. The wedge bond is formed by pressing the wire of the wire bond connection 3 against the underlying bond ball 5 so that the first end 31 comprises

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a flat part 33 and a wedged part 34. Preferably, ultrasonic energy is applied with a transducer during formation of the wedge bond.

5 The formation of the wedge bond is shown in Figure 1D in more detail. The second end 32 is formed such that the wedged part 34 which extends between the flat part 33 and the wire part 35 overlaps a center of the underlying bond ball 5. In Figure 1D, a center line 51 running through the center of the
10 underlying bond ball 5 is shown.

Subsequently, an additional bond ball 4 is formed on top of the wire bond connection 3 (Figure 1C). By means of the additional bond ball, the mechanical strength of the wire
15 bond connection 3 is improved. In particular, the connection between the second end 32 and the underlying bond ball 5 is enhanced. The diameter of the additional bond ball 4 is preferably smaller than the diameter of the underlying bond ball 5. This helps to reduce the overall bump height on top
20 of the first contact area 21. Simulations have shown that the maximum mechanical stress occurs in the wedged part 34 of the wire bond connection 3. As the additional bond ball 4 covers the wedged part 34, the risk of a wire breakage at the position of the wedged part 34 may be avoided or at least
25 significantly reduced.

Preferably, the wire bond connection comprises gold or consists of gold. Alternatively, the wire bond connection may comprise some other metal, for instance aluminum or copper or
30 a metallic alloy comprising at least one of said materials.

Unlike in the exemplary embodiment shown, the underlying bond ball 5 may also be dispensed with. In this case, the second

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end 32 may be in direct physical contact with the first contact area 21.

5 A finished electronic device 1 according to a first exemplary embodiment is shown in Figure 1C. The semiconductor chip 6 may be an electronic chip such as a transistor or a diode or an optoelectronic chip. For instance, the optoelectronic semiconductor chip 6 may be a luminescence diode chip, such as a light emitting diode chip, or a laser diode chip. The
10 semiconductor chip 6 may also be a radiation detector, such as a photodiode.

The diameter of the wire used for the fabrication of the wire bond connection 3 preferably is between 30 μm , inclusively,
15 and 60 μm , inclusively. Thinner wires may be used as well in order to further reduce the device height. However, the current that may be fed through a thin wire is restricted, so that thin wires are not suitable for high-power applications.

20 Of course, thicker wires may also be used. However, thicker wires may result in an increased vertical extension of the wire bond connection 3.

The loop height of the wire bond connection 3 preferably is
25 less than 100 μm . The loop height is the maximum vertical extension of the wire bond connection with respect to the level of the elevated contact area. For instance, with a wire of 38 μm in diameter, a loop height of between 60 μm , inclusively, and 100 μm , inclusively, may be obtained.

30

A further exemplary embodiment for a method for forming an electrical connection is shown in Figures 2A through 2C, wherein Figure 2C shows a finished electronic device

according to a further exemplary embodiment. The method and the device essentially correspond to the previously described first embodiments for a method and a device, respectively.

Unlike in the first embodiment, the wire bond connection 3 is produced such that the first end 31 is formed on the first contact area 21 and the second end 32 is formed on the second contact area 22. Starting from the first contact area 21, the wire part 35 extends vertically to a kink 36 of the wire bond connection 3. The kink 36 overlaps the first contact area 21 in top view.

As shown in Figure 2B, an additional bond ball 4 is formed on top of the kink 36 so that the wire part extending between the first end and the kink 36 is compressed. Arrow 8 indicates the direction of movement during fabrication of the additional bond ball 4.

It has turned out that such a wire bond connection with the kink 36 being pressed into the bond ball of the first end 31 has an improved reliability as compared to a wire bond connection having a sharp kink slightly above the bond ball of the first end 31. Furthermore, the overall vertical extension of the wire bond connection 3 may be reduced by means of the additional bond ball 4.

Preferably, the size of the additional bond ball 4 is smaller than the size of the bond ball of the first end 31, so that the height of the bond bump formed on the first contact area 21 may be kept small.

In order to further reduce the overall height, part of the additional bond ball 4 or even the entire additional bond ball 4 may be removed. This may be done mechanically, for

instance. It has turned out that, even if the additional bond ball 4 is not present in the finished electronic device, the reliability of the wire bond connection 3 may be improved. However, the additional bond ball 4 may also remain in the finished device. Even with the additional bond ball 4 remaining in the device, the overall bump height formed on the first contact 21 may be smaller than 80 μm , for instance between 40 μm and 70 μm .

10 The methods described allow for producing electronic devices having a wire bond connection that is highly reliable and at the same time of reduced vertical extension. This allows for reducing the overall height of the electronic device.

15 In the embodiments shown, the additional bond ball 4 is formed on the contact area which is elevated with respect to the second contact area. It has turned out that the end of the wire bond connection 3 that is arranged on the elevated contact area, i.e. the first contact area 21 in the exemplary
20 embodiments, may be significantly strengthened by means of the additional bond ball 4, irrespective of whether the end of the wire bond connection is the first end 31 or the second end 32. However, the method is also suitable for making electrical connections between contact areas being arranged
25 on an equal level.

Furthermore, a further additional bond ball may be arranged on the second contact area 22, so that both ends of the wire bond connection 3 are provided with an additional bond ball.

30

The invention is not restricted to the exemplary embodiments by the description on the basis of said exemplary embodiments. Rather, the invention encompasses any new

feature and also any combination of features which in particular comprises any combination of features in the patent claims and any combination of features in the exemplary embodiments, even if this feature or this
5 combination itself is not explicitly specified in the patent claims or exemplary embodiments.

Claims

1. An electronic device (1) comprising a first contact area (21), a second contact area (22) and a wire bond connection (3) between the first contact area and the second contact area, wherein the wire bond connection extends between a first end (31) of the wire bond connection and a second end (31) of the wire bond connection and wherein an additional bond ball (4) is arranged on top of the wire bond connection.

10

2. The device as claimed in claim 1, wherein a main plane (210) of extension of the first contact area is arranged in an elevated manner with respect to a main plane of extension (220) of the second contact area, so that the wire bond connection only extends on a side of the main plane of extension of the second contact area that faces the first contact area.

15

3. The device as claimed in claim 2, wherein the first contact area is a bond pad of a semiconductor chip (6).

20

4. The device as claimed in claim 2 or 3, wherein the additional bond ball is arranged on top of the first contact area.

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5. The device as claimed in any of the preceding claims, wherein the first end is a bond ball and the second end is a wedge bond.

30

6. The device as claimed in claim 5, wherein the additional bond ball is formed on top of the wedge bond.

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7. The device as claimed in claim 5,
wherein the additional bond ball is formed on top of the bond
ball.

5 8. The device as claimed in claim 2 or 3,
wherein the first end is a bond ball, said bond ball being
arranged on the first contact area, and wherein the
additional bond ball is arranged on top of the bond ball.

10 9. The device as claimed in claim 8,
wherein a maximum extension of the additional bond ball is
smaller than a maximum extension of the bond ball.

10. The device as claimed in claim 2 or 3,
15 wherein the second end is a wedge bond, said wedge bond being
arranged on the first contact area, and wherein the
additional bond ball is formed on the wedge bond.

11. The device as claimed in claim 10,
20 wherein an underlying bond ball (5) is arranged between the
first contact area and the wedge bond.

12. The device as claimed in claim 11,
wherein a wedged part (34) of the wedge bond overlaps a
25 center of the underlying bond ball in top view.

13. A method for forming an electrical connection comprising
the steps:

a) providing a first contact area (21) and a second contact
30 area (22),

b) forming a wire bond connection (3) between the first
contact area and the second contact area, said wire bond

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connection extending between a first end (21) and a second end (22); and

c) forming an additional bond ball (4) on top of the wire bond connection.

5

14. The method as claimed in claim 13, wherein the additional bond ball is thinned or removed subsequent to step c).

10

15. The method as claimed in claim 13 or 14, wherein a kink (36) is formed in the wire bond connection such that the kink overlaps the first contact area in top view and wherein the additional bond ball is formed on top of the kink.

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FIG 1A

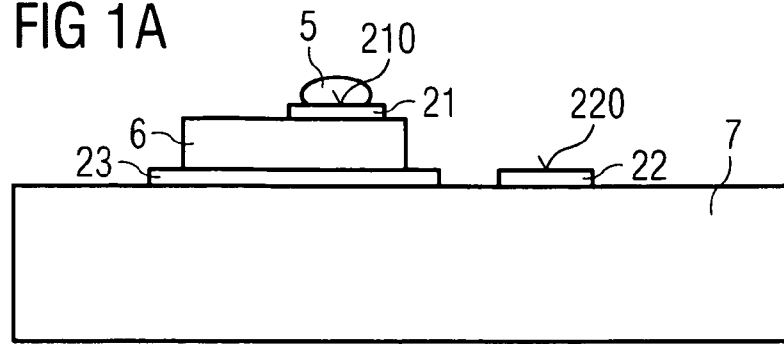


FIG 1B

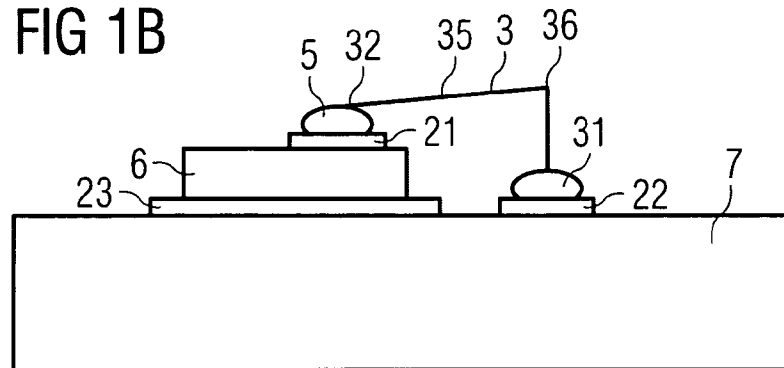


FIG 1C

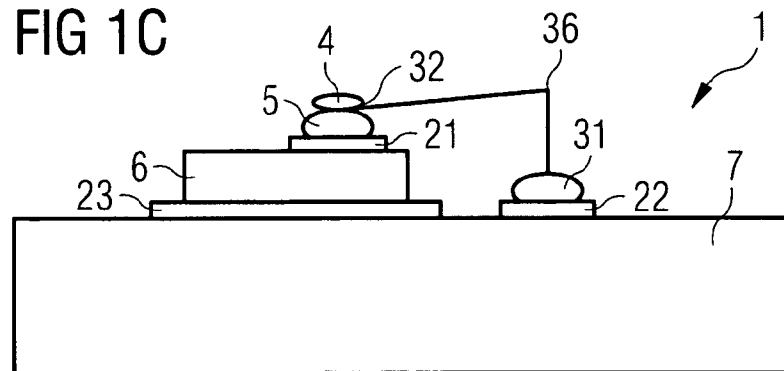
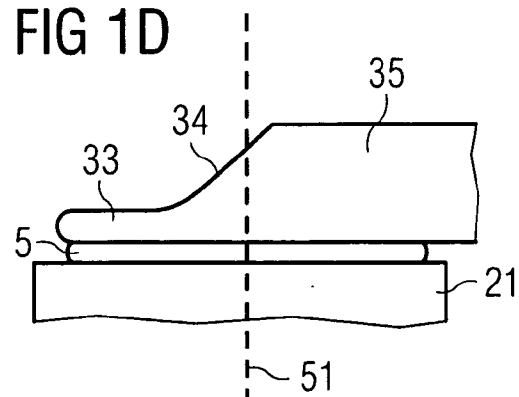


FIG 1D



2/2

FIG 2A

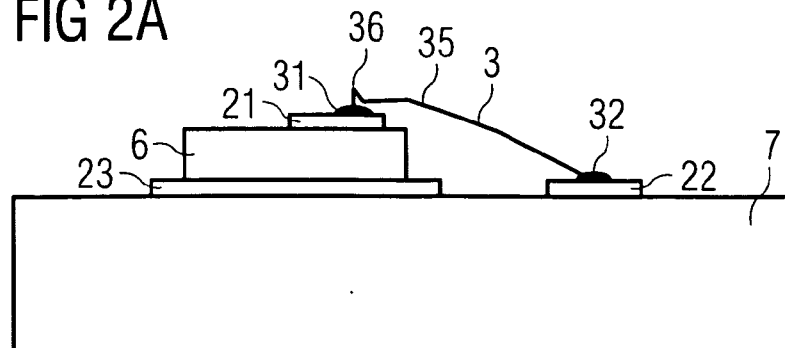


FIG 2B

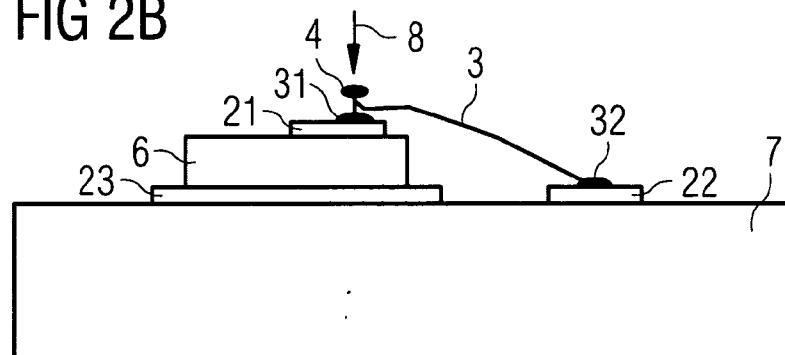
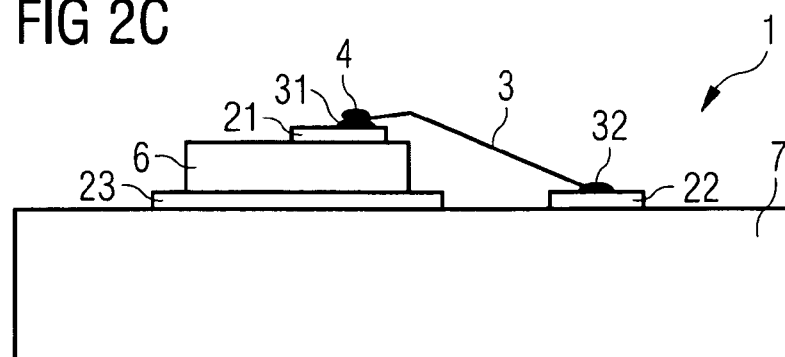


FIG 2C



INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2012/068854

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-8, 10-13

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2012/068854

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01L21/60 H01L23/49
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/070729 A1 (KURITA ISAO [JP]) 24 March 2011 (2011-03-24) paragraphs [0006], [0039], [0073] - [0080]; claims 17-19; figures 10-12 -----	1-5,7,8, 13
X	US 2008/105459 A1 (HORIO TOMOHARU [JP]) 8 May 2008 (2008-05-08) paragraphs [0007] - [0012], [0044] - [0063]; figures 2-21 -----	1-6, 10-13
X	US 2005/242159 A1 (YAJIMA KAORU [JP]) 3 November 2005 (2005-11-03) paragraphs [0002], [0020] - [0033]; figures 3A-3I,4 -----	1-5,7,8, 13
X	US 2002/079354 A1 (LEE CHUN-CHI [TW]) 27 June 2002 (2002-06-27) paragraphs [0008], [0009], [0012], [0023] - [0026]; figures 5,6 -----	1-6, 10-13



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

30 November 2012

Date of mailing of the international search report

28/01/2013

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Fax: (+31-70) 340-3016

Authorized officer

Ahlstedt, Mattias

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2012/068854

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-8, 10-13

directed to that the additional bond ball is formed on a wedge bond.

2. claim: 9

directed to that a maximum extension of the additional bond ball is smaller than a maximum extension of the bond ball.

3. claim: 14

directed to that the additional bond ball is thinned or removed subsequent to step c).

4. claim: 15

directed to that a kink is formed in the wire bond connection such that the kink overlaps the first contact area in top view and wherein the additional bond ball is formed on top of the kink.
