Abstract: The present invention relates to a semiconductor module (10), comprising a substrate (24), in particular formed of a ceramic insulator, and at least one metallic layer (26), in particular formed on the substrate (24), wherein the metallic layer (26) comprises a deepening (40) for placing and fixing a contact element (16), the contact element (16) being at least partially "L"-shaped and comprising a first arm (34) for fixing the contact element (16) at the deepening (40), and a second arm (36) for interconnecting the contact element (16), wherein the deepening (40) has a horizontal dimension which is about 0.5mm bigger than the horizontal dimension of the contact element (16). Semiconductor modules (10) according to the invention exhibit improved reliability and are furthermore producible in a highly reproducible manner.
Description

Semiconductor module and method of manufacturing a semiconductor module

Technical Field

[0001] The Invention relates to a semiconductor module. The invention further relates to a method of manufacturing a semiconductor module.

Background Art

[0002] A variety of semiconductor modules are known and used in many different electronic devices. For forming, or manufacturing, respectively, a semiconductor module, different electric parts of the latter have to be contacted with each other to provide an interlinked internal structure. Additionally, it is required to provide an external contact to connect one or more electric parts of the semiconductor module to an external contact device.

[0003] As an example, to achieve an external electrical contact with the semiconductor module, it is widely known to provide a terminal as a contact element and to solder it on top of a metallization of a ceramic substrate. A major drawback of the known soldering technique is a limited reliability under thermal and mechanical cycling of the soldered connection between terminal and substrate. Therefore, the connection and thus the whole semiconductor module have a limited lifetime only.

[0004] Furthermore, soldered connections only withstand limited operation temperatures. In detail, temperatures of 125 °C should not be exceeded for providing safe and reliable operation conditions in most cases.

[0005] It is therefore known to overcome this problem by replacing the soldered connection between one or more contacts of a semiconductor module by a welded connection. In particular, ultrasonic waves, or energy respectively, are used for forming a welded connection.

[0006] In W. Rusche et al., Ultrasonic Metal Welding, Bodo's Power Magazine, Oct 2008, p. 40-41, for example, it is described to use ultrasonic metal welding for the internal contact within power modules. In detail, it is
described that a welding tool induces pressure and ultrasonic energy in a movable joining partner.

[0007] In case such a technique is used, ultrasonic waves will be generated in the horizontal plane, in an exemplary manner generated by a sonotrode. Due to the horizontal oscillations of the sonotrode, a force parallel to the oscillation amplitude may act on the contact element. Consequently, there may be the risk of the contact element to move in the horizontal plane. This leads to the disadvantage that the position in which the contact element is welded may not be the intended position. Therefore, the formed semiconductor module may be unusable. Additionally, there is a risk of the contact element to be deformed and hence mechanically weakened while it is moving, or slipping, respectively. This, again, leads to the disadvantage of the formed semiconductor module being unusable. Furthermore, the welding process becomes irreproducible.

[0008] To avoid these disadvantages, it may be possible to use stronger welding parameters. In detail, it is possible to use a higher welding energy and/or a higher pressing force. This, however, may lead to damages of the contact region where the contact element is welded to, or to the contact element itself.

[0009] Known from WO 2007/033829 A2 is therefore a power semiconductor module and a method for the production thereof. According to this prior art, contacts are formed via ultrasonic welding by virtue of a sonotrode. The ultrasonic welding operation can also be used for joining the contact regions with the contact ends and consequently for joining the contacts and the foot regions of the power semiconductor module. In detail, a sonotrode is brought to a contact end of a contact element, wherein the latter is pressed to the contact region to be connected. By introducing ultrasonic energy into the interface between the contact element and the substrate, the foot is welded onto the substrate. In carrying out this step, a holding and positioning device holds the contact element in place to avoid the latter to move in a horizontal plane.
Such a holding and positioning element, however, always leads to the process becoming more complex and thus the necessity of rather complex apparatus requirements.

Known from EP 1 711 040 A1 is a circuit device in which a semiconductor and a bus bar are bonded to a ceramic base board. According to this document, a wiring layer is provided on the substrate on a part of which a coating metal layer is formed to provide a region in which the wiring layer is coated. Additionally, an exposing region is provided in which the wiring layer is exposed. The semiconductor is connected to the coated region whereas the bus bar is directly connected to the wiring layer within the exposing region.

According to this document, the exposing region is determined to have an appropriate margin in consideration of variations of a contact area of the end portion of the bus bar. Consequently, this exposing area is adapted for allowing different bus bars with different shapes and dimensions to be fixed.

Summary of invention

It is an object of the present invention to provide an improved semiconductor module which shall obviate at least one of the disadvantages known in the art.

It is a further object of the present invention to provide an improved method of manufacturing a semiconductor module which shall obviate at least one of the disadvantages known in the art.

In particular, it is an object of the present invention to provide a semiconductor module and a method of manufacturing a semiconductor module in which the manufacturing method is easier to perform with higher reproducibility and in which the semiconductor module has an improved reliability.

This object is achieved by a semiconductor module according to claim 1. The object is furthermore achieved by a method of manufacturing a
semiconductor module according to claim 7. Preferred embodiments of the present invention are defined in the dependent claims.

[0017] The invention relates to a semiconductor module, comprising a substrate, in particular formed of a ceramic insulator, and at least one metallic layer, in particular formed on the substrate, wherein the metallic layer comprises a deepening for placing and fixing a contact element, the contact element being at least partially "L"-shaped and comprising a first arm for fixing the contact element at the deepening, and a second arm for interconnecting the contact element, wherein the deepening has a horizontal dimension which is about \( \leq 0.5\)mm bigger than the horizontal dimension of the contact element.

[0018] According to the invention, the contact element may be placed, or aligned and arranged at the intended position, respectively, on the metallic layer at a preformed deepening. As the deepening may be formed before performing the fixing process of the contact element on the metallic layer, the deepening may easily be arranged and located at a well defined position. Therefore, additionally to the deepening as such, the contact element may be located in a well defined and intended position.

[0019] Furthermore, due to the fact that the contact element is precisely located and furthermore held in place by the deepening, the contact element is avoided to slip, or move, respectively, in a horizontal plane on the metallic layer during a fixing process, in particular during a welding process. Therefore, detrimental effects of the welding process are avoided. Consequently, the semiconductor module according to the invention may be manufactured in a well defined and reproducible manner.

[0020] Due to the fact that the contact element is hold in place by the deepening, a further and separate fixture which holds the contact element in place is not required. Especially, a separated holding and positioning device which holds the contact element in place may be omitted. This allows the semiconductor module according to the invention being manufactured in an easy way without the requirement of a highly complex apparatus arrangement thereby being manufactured in a well reproducible manner.
The deepening is thus designed to hold the contact element in place, in particular during a welding process, in the horizontal plane, the latter being particularly defined by the plane of the metallic layer. It thus substantially prevents the contact element from moving in the horizontal plane. However, a limited movability of the contact element in the horizontal plane may be preferred and is not problematic.

In detail, the deepening has a horizontal dimension which is about \(< 0.5\)mm bigger than the horizontal dimension of the contact element, in particular of the part of the contact element being fixed to the metallic layer. This allows a limited and according to the invention acceptable movability of the contact element in a horizontal plane thereby anyhow securing the contact element to be fixed substantially at the intended position. This feature, however, further simplifies placing the contact element in or at the deepening.

Consequently, the deepening is not adapted for a plurality of contact elements each having different sizes. Contrary thereto, providing that the deepening has a horizontal dimension which is about \(< 0.5\)mm bigger than the horizontal dimension of the contact element, the deepening is adapted to the defined contact element, essentially preventing a movability of the contact element, anyway allowing an easy and comfortable fixture of the latter.

Apart from that, the contact element may thus easily be located in the deepening thereby being located at the intended position in a simple manner. Furthermore, a deepening may easily be formed. For example, the deepening may be formed at a deposition step or the like of the metallic layer, or by structuring the metallic layer after deposition. Additionally, a deepening is an easy and in particular secure way to avoid the contact element to move in a horizontal plane, especially during a welding process.

The contact element may thereby be any contact element which is appropriate for contacting said metallic layer. For example, the contact element may be such a contact element for internally contacting different circuits, or electric elements, respectively, of the semiconductor module.
However, it is mostly preferred that the contact element comprises a terminal for externally contacting the metallic layer, or the semiconductor module as such, respectively, to an external contacting device.

Additionally, the contact element is at least partially "L"-shaped and comprises a first arm for fixing the contact element at the deepening, and a second arm for interconnecting the contact element with an external contact device, for example. Such a contact element is especially preferred for welding it at a deepening, or in a deepening, respectively. An at least partly "L"-shaped contact element according to the invention shall thereby mean that at least the bottom part, where it is fixed to the metallic layer, is "L"-shaped. The first arm may thereby easily be located at the deepening and a pressing force may be exercised on the latter in a well defined manner, thereby applying ultrasonic energy to weld the first arm, or the contact element, respectively, to the metallic layer. Due to the "L"-shaped form of the contact element, the second arm is located spaced apart from the metallic layer because of which it may easily be interconnected e.g. with an external contact device.

According to the invention, an L"-shaped form thereby shall mean a design in which the first and second arms are arranged substantially rectangular with respect to each other. However, the contact element may deviate from the rectangular shape if the first arm lies substantially plane on the metallic layer, or at the deepening, respectively, and the second arm proceeds such, that its end is spaced apart from the plane of the metallic layer, so that an interconnection may easily be made.

According to the invention, a metallic layer may be a coating which is deposited on the substrate or on another layer, or it may be a small region of metallization which is deposited on the substrate or on another layer. However, the metallic layer may be any metallic or metallization layer or plate which is arranged in the semiconductor module and which shall be contacted. The metallic layer is preferably made of a material selected from the following materials: copper (Cu), gold (Au), silver (Ag), aluminium (Al) or alloys comprising Cu, Au, Ag and/or Al.
[0029] The semiconductor module may preferably comprise any power semiconductor module known in the art. In particular, a power semiconductor module comprises a power semiconductor device. Examples for power semiconductor devices comprise in a non limiting manner diodes, transistors, like Insulated Gate Bipolar Transistors (IGBT), and integrated circuits.

[0030] According to a embodiment of the present invention, the contact element comprises a cooperation means, in particular at its first arm, for cooperating with the deepening. This furthermore improves the effect of the contact element being placed and hold at the intended position. The cooperation means may be any means suitable, if it is arranged to cooperate, or interact, respectively, with the deepening as will be apparent down below.

[0031] According to a further embodiment the deepening has a depth of \( \geq 100 \mu \text{m} \). Such an arrangement secures that the contact element stays in the deepening, especially at a welding process, and is thus hold in place reliably. It is thus avoided that the contact element slips out of the deepening when fixing it to the metallic layer.

[0032] According to a further embodiment the deepening is at least partially surrounded by bevelled borders. This as well simplifies placing the contact element in or at the deepening.

[0033] In a still further embodiment of the present invention, an intermediate layer is arranged between the metallic layer and the substrate. This arrangement leads to the advantage that the substrate is mechanically and/or thermally protected by the additional intermediate layer. Additionally, a metal layer with a deepening on one side is easier to produce than a deepening in a substrate metallization itself. The additional layer, in particular metal layer, may be attached to the substrate in the same process step in which also the semiconductor chips are attached to the substrate.

[0034] The invention furthermore relates to a method of manufacturing a semiconductor module, comprising the step of bringing in contact a contact element and a metallic layer, the contact element being at least
partially "L"-shaped and comprising a first arm for fixing the contact element at the deepening, and a second arm for interconnecting the contact element, and the metallic layer comprising a deepening for placing the contact element, wherein the deepening has a horizontal dimension which is about \(<0.5\)mm bigger than the horizontal dimension of the contact element, the method comprising the further steps of:
- Pressing the contact element onto the metallic layer at the deepening,
- Applying ultrasonic energy to the interface of the contact element and the metallic layer for welding the contact element onto the metallic layer.

According to the invention, the contact element is thus placed on the metallic layer by a deepening. This leads to the advantages like described above with respect to the semiconductor module according to the invention.

Apart from that, the contact element is connected to the metallic layer by an ultrasonic welding process. A semiconductor module manufactured according to the invention does thus not exhibit disadvantages related to cycling. With respect to the present invention, cycling means an influence of periodically changing conditions, especially with respect to temperature and/or mechanical influence. This as well improves the reliability properties of a semiconductor module according to the invention.

The reliability of a semiconductor module according to the invention is further improved by the fact that a welding connection may sustain temperatures of 200°C or more. This additionally makes a semiconductor module manufactured according to the method according to the invention suitable even for high power applications.

Additionally, a semiconductor module may be manufactured according to the invention without the requirement of consumables like solder or bond wires. Furthermore, the manufacturing process may be performed without further plating or additional cleaning steps. This leads to the advantage that the method according to the invention is advantageous with respect to the environmental point of view. Additionally, traditional working steps may be omitted making the method according to the invention time saving and thus cost saving.
By welding the contact element to the metallic layer, furthermore a highly conductive connection is formed. This makes the semiconductor module according to the invention being particularly suitable for high power applications in which high amounts of electric currents have to be conducted through this connection. Consequently, the semiconductor module according to the invention preferably comprises a high power semiconductor module.

Brief description of drawings

Additional features, characteristics and advantages of the subject-matter of the invention are disclosed in the subclaims, the figures and the following description of the respective figures and examples, which -in an exemplary fashion- shows embodiments and examples of semiconductor modules according to the invention.

In the figures:

Figure 1 shows a sectional side view of an arrangement of a semiconductor module;

Figure 2 shows a partial sectional side view of an embodiment of a semiconductor module according to the invention;

Figure 3 shows a partial sectional side view of a further embodiment of a semiconductor module according to the invention;

Figure 4 shows a partial sectional side view of an embodiment of a semiconductor module not being part of the invention;

Figure 5 shows a partial sectional side view of a further embodiment of a semiconductor module according to the invention;

Figure 6 shows a partial sectional side view of a further embodiment of a semiconductor module according to the invention; and

Figure 7 shows a partial sectional side view of a further embodiment of a semiconductor module not being part of the invention.
Description of embodiments

[0049] In figure 1, an arrangement of a semiconductor module 10 is schematically shown. In detail, the internal structure of said semiconductor module 10 is described. The semiconductor module 10 comprises a housing 12 in which at least one semiconductor device 14 is arranged. The semiconductor device 14 may in a preferred example be a power semiconductor device, such as an insulated gate bipolar transistor (IGBT), a diode, a metal oxide semiconductor field-effect transistor (MOSFET), or the like. According to figure 1, a diode and an IGBT are provided. The semiconductor device 14 or the plurality of semiconductor devices 14 are connectable via contact terminals, or contact elements 16, respectively, and preferably via an auxiliary terminal 18, wherein the semiconductor device 14 is preferably bonded by aluminium bond wires 20.

[0050] As an insulator, a layer of epoxy 22 may be arranged above the semiconductor device 14. The semiconductor device 14 may further be arranged on a substrate 24, or wafer, respectively, which may be formed of a ceramic insulator, in particular of an aluminium nitride ceramic insulator. The contact elements 16 as well as the auxiliary terminal 18 are connected to the substrate 24 via a metallization, or metallic layer 26, respectively, in particular via a copper metallization. Additionally, the substrate 24 is connected to a further metallization 28, in particular a copper metallization, at its bottom side, and to a base plate 32 via a solder 29. The remaining volume inside the housing 12 is filled e.g. with a silicone gel 30.

[0051] The connection between a contact element 16 and a metallic layer 26 is shown in detail in the following figures 2 to 7 in which the same or comparable elements are referenced by the same reference signs.

[0052] In figure 2, the substrate 24 is shown together with the metallic layer 26 and the further metallization 28. To contact the metallic layer 26, a contact element 16 is provided.
[0053] The contact element 16 is at least partially "L"-shaped, i.e. at least at its bottom side. It therefore comprises a first arm 34 for fixing the contact element 16 at the metallic layer 26, and a second arm 36 for interconnecting it, for example, with an external contact device, the external contact device not being shown as such.

[0054] In order to place the contact element 16, or to locate it at the intended position, respectively, according to the invention, the metallic layer 26 comprises a deepening 40 in the metallic layer 26 and may thus comprise a receptacle. Therefore, it is apparent that the contact element 16, or the first arm 34 of the contact element 16, respectively, may be fitted into said deepening 40 to be located at the intended position. The contact element 16, in particular its first arm 34, may be fixed to the metallic layer 26. Therefore, one of the objects of the deepening 40 is to easily find the intended position of the contact element 16 on the metallic layer 26.

[0055] The deepening 40 preferably has a depth of $\geq 100\,\mu$m. This allows a secure fit of the contact element 16 in the deepening 40 to securely be hold in place.

[0056] Even if it is intended that the deepening 40 has as second main objective to hold the contact element 16 in place during a fixing process, in particular at a welding process, it may be appropriate that the deepening 40 has a horizontal dimension which is about $\leq 0,5$mm bigger than the horizontal dimension of the contact element 16, in particular of the horizontal dimension of the first arm 34 of the contact element 16. This improves the step of arranging the contact element 16 in the deepening 40.

[0057] Once the contact element 16 is located in the deepening 40, it has to be fixed on the metallic layer 26. This step is described as follows, wherein it has to be noted that this step may be performed independently from the special arrangement of the contact element 16 and/or deepening 40 and may thus be similarly performed in the embodiments according to the following figures.

[0058] The step of fixing the contact element 16 to the metallic layer 26 is particularly a step of a method of manufacturing a semiconductor module.
After bringing in contact the contact element 16 and a metallic layer 26, the contact element 16 is pressed against the metallic layer 26. In the embodiment like described above, the contact element 16 is pressed against the metallic layer 26 via the first arm 34. This may be performed by pressing a welding tool 42 against the contact element 16, in particular against the first arm 34. This is schematically shown by the arrow 44 shown in figure 2.

[0059] The welding tool 42 preferably comprises a means for generating ultrasonic waves, or ultrasonic energy, respectively. As an example, the welding tool 42 may comprise a sonotrode. Consequently, ultrasonic energy is applied to the interface 46 of the contact element 16 and the metallic layer 26. By virtue of ultrasonic energy, the contact element 16 and the metallic layer 26 are connected to each other in that the contact element 16 is fixed to the metallic layer 26, or the deepening 40, respectively, by an ultrasonic welding process.

[0060] Due to the provision of the deepening 40, the contact element 16 is securely held in place leading to the latter being fixed at the intended position.

[0061] A further embodiment of the present invention is shown in figure 3. According to figure 3, the deepening 40 is at least partially surrounded by bevelled edges, or borders 48, respectively. The amount or degree of bevelling may be chosen according to the desired application. However, to secure the contact element 16 not to slip out of the deepening 40, it is mostly preferred that the bevelling lies in a range of 45° with respect to the horizontal plane, wherein the horizontal plane is defined by the plane of the metallic layer 26. It may furthermore be advantageous that the contact element 16 as well comprises a bevelled edge 50 at one or a plurality of sides. Preferably, these bevelled edges 50 are adapted to the bevelled borders 48, so that the fitting of the contact element 16 on the metallic layer 26, or at the deepening 40, respectively is improved.

[0062] An embodiment not being part of the present invention is shown in figure 4. According to figure 4, a fixing means 38 comprises at least one elevation 52 formed on the metallic layer 26. Preferably, the contact
element 16 is completely surrounded by elevations 52. Therefore, according to this embodiment, the fixing means 38 is formed completely on the metallic layer 26. This has the advantage that the metallic layer 26 is not weakened by the deepening 40 and thus especially advantageous for very thin metallic layers 26. The elevations 52 may in an exemplary manner be formed of at least one in particular flat wire bond forming a stopper for the contact element 16. In this case, the fixing means 38 is very easy to prepare. The elevation may for example be formed at one or several sides of the intended position of the contact element. Additionally, it is possible to form the elevation on a location being located directly at the position of the contact element. In this case it is mostly preferred that the contact element comprises a cooperation means for cooperating, or interacting, respectively, with the elevation. The cooperation means may in this case be realized as a deepening in the contact element being adapted in its size and geometry to the elevation, or the fixing means, respectively. The contact element 16 may comprise one or more bevelled edges 50 and/or one or more rectangular edges 54. Additionally, the elevations 52 may comprise bevelled edges for facilitating placing the contact element 16 at the fixing means.

[0063] A further embodiment according to the invention is shown in figure 5. This embodiment corresponds to the embodiment according to figure 3. However, the embodiment according to figure 5 comprises the further feature, that an intermediate layer 56 is arranged between the metallic layer 26 and the substrate 24. The intermediate layer 56 may be any suitable layer, in particular metal layer, and it may be provided, for example, as a metal plate. The intermediate layer 56 may be attached to the metallic layer 26 by a solder 58 or a low-temperature bonding. It may furthermore be attached to the substrate 24 by any suitable way, e.g. by a deposition process. According to figure 5, the intermediate layer 56 may be formed as a metallization on the substrate 24, whereas the metallic layer 26 comprising the deepening 40 may be formed as a metal plate.

[0064] The embodiment according to figure 6 again may comprise an intermediate layer 56 like described above. Additionally, according to
figure 6, the metallic layer 26 comprises a deepening 40 in the metallic layer 26. Additionally to said deepening 40, the contact element 16 comprises a cooperation means, in particular at its first arm 34, for cooperating with the deepening 40. In detail, according to figure 6, the contact element 16 comprises an elevation 60, preferably at the first arm 34. The elevation 60 and the deepening 40, preferably are adapted to each other with respect to size and geometry. Consequently, the elevation 60 of the contact element 16 serves as a fixing means for cooperating with the deepening 40. This allows the fit of the contact element 16 at the deepening 40 being much closer.

[0065] A further embodiment not being part of the present invention is shown in figure 7. The embodiment according to figure 7 corresponds to the embodiment of figure 6 with the difference, that the metallic layer 26 comprises an elevation 62 as fixing means 38, whereas the contact element 16, in particular the first arm 34 of the contact element 16 comprises a deepening 64 interacting with the fixing means 38. Again, the fixing means 38, i.e. the elevation 62, and the deepening 64 are preferably adapted to each other with respect to size and geometry.

[0066] It has to be noted that the features like described above are not limited to the described embodiments. In particular, the arrangement of the fixing means 38 may be combined with and without an intermediate layer 56. Furthermore, combinations of different arrangements of the fixing means 38 are possible without leaving invention as such.

[0067] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to be disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a
combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting scope.

Reference signs list

[0068] 10 semiconductor module
12 housing
14 semiconductor device
16 contact element
18 auxiliary terminal
20 aluminium bond wires
22 epoxy
24 substrate
26 metallic layer
28 metallization
29 solder
30 silicone gel
32 base plate
34 first arm
36 second arm
38 fixing means
40 deepening
42 welding tool
44 arrow
46 interface
48 bevelled border
50 bevelled edge
52 elevation
54 rectangular edge
56 intermediate layer
58 solder
60 elevation
62 elevation
64  Teepening
Claims

1. Semiconductor module (10), comprising a substrate (24), in particular formed of a ceramic insulator, and at least one metallic layer (26), in particular formed on the substrate (24), wherein the metallic layer (26) comprises a deepening (40) for placing and fixing a contact element (16), the contact element (16) being at least partially "L"-shaped and comprising a first arm (34) for fixing the contact element (16) at the deepening (40), and a second arm (36) for interconnecting the contact element (16), wherein the deepening (40) has a horizontal dimension which is about < 0,5mm bigger than the horizontal dimension of the contact element (16).

2. Semiconductor module according to claim 1, wherein the semiconductor module is a power semiconductor module comprising a power semiconductor device, such as a diode, a transistor, and/or an integrated circuit.

3. Semiconductor module according to claim 1 or 2, wherein the contact element (16) comprises a cooperation means, in particular at its first arm (34), for cooperating with the deepening (40).

4. Semiconductor module according to any of the preceding claims, wherein the deepening (40) has a depth of \( \geq 100 \mu \text{m} \).

5. Semiconductor module according to any of the preceding claims, wherein the deepening (40) is at least partially surrounded by bevelled borders (48).

6. Semiconductor module according to any of the preceding claims, wherein an intermediate layer (56) is arranged between the metallic layer (26) and the substrate (24).

7. Method of manufacturing a semiconductor module (10), comprising the step of bringing in contact a contact element (16) and a metallic layer (26), the contact element (16) being at least partially "L"-shaped and comprising a first arm (34) for fixing the contact element (16) at the deepening (40), and a second arm (36) for interconnecting the contact element (16), wherein the metallic layer (26) comprises a deepening (40) for placing the contact element (16), wherein the deepening (40) has a horizontal dimension which is about \( \leq 0,5 \text{mm} \) bigger than the horizontal dimension of the contact element (16), the method comprising the further steps of:
- Pressing the contact element (16) onto the metallic layer (26) at the deepening,
- Applying ultrasonic energy to the interface of the contact element (16) and the metallic layer (26) for welding the contact element (16) onto the metallic layer (26).