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(54) Title: ULTRASOUND TRANSDUCER ASSEMBLY AND METHOD OF MANUFACTURING THE SAME

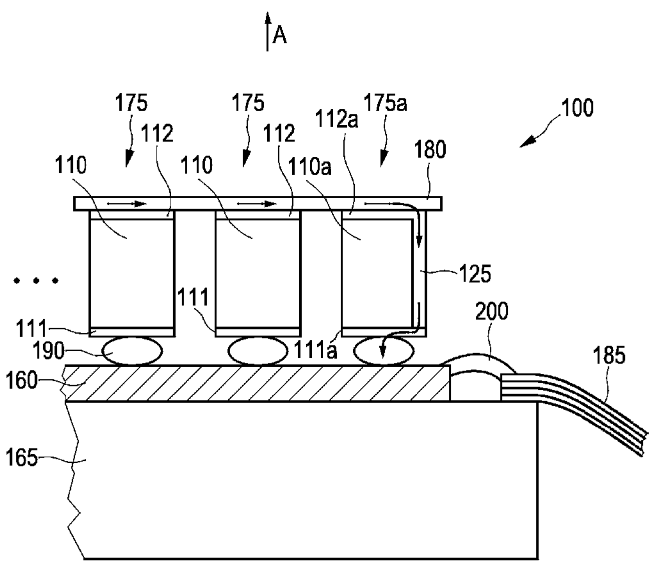

FIG. 1

(57) Abstract: The present invention relates to an ultrasound transducer assembly (100) comprising ultrasound transducer elements (175, 175a) for transmitting ultrasound waves in a general transmission direction (A). Each of, or each of part of, the ultrasound transducer elements (175, 175a) comprises a piezoelectric layer (110, 110a) having a top surface, a bottom surface and a side surface with respect to the general transmission direction (A), as well as a bottom electrode layer (111, 111a) and a top electrode layer (112, 112a). A conductive layer (125) is applied at least partly on the side surface of at least one specific one (110a) of the piezoelectric layers, such that the conductive layer (125) is connected to the top electrode layer (112a) and the bottom electrode layer (111a) of said specific piezoelectric layer (110a).

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Ultrasound transducer assembly and method of manufacturing the same

FIELD OF THE INVENTION

The present invention relates to an ultrasound transducer assembly comprising ultrasound transducer elements for transmitting ultrasound waves in a general transmission direction. The present invention further relates to a method of manufacturing such ultrasound transducer assembly.

BACKGROUND OF THE INVENTION

US 2008/0315331 A1 discloses a transducer assembly having a ground connection routed through a via formed in a cMUT array and through an ASIC. A transducer module comprises a cMUT transducer subarray formed on a semiconductor substrate with a front electrode positioned over a membrane and with the membrane suspended over insulating supports. The individual cells include bottom electrodes for receiving signals from ASIC circuit cells. A conductive via is formed within the insulating support between adjacent transducer cells to connect the front electrode to a contact on the cMUT substrate. However, the transducer assembly disclosed in US 2008/0315331 A1 is quite complex and thus not easy in manufacturing.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an ultrasound transducer assembly and corresponding method of manufacturing that provides an easier manufacturing and thus a cheaper ultrasound transducer assembly.

In a first aspect of the present invention an ultrasound transducer assembly is presented that comprises ultrasound transducer elements for transmitting ultrasound waves in a general transmission direction. Each of, or each of part of, the ultrasound transducer elements comprises a piezoelectric layer having a top surface, a bottom surface and a side surface with respect to the general transmission direction, as well as a bottom electrode layer and a top electrode layer. Further, a conductive layer is (directly) applied at least partly on the side surface of at least one specific one of the piezoelectric layers, such that the conductive layer is connected to the top electrode layer and the bottom electrode layer of said specific piezoelectric layer.

In a further aspect of the present invention a method of manufacturing an ultrasound transducer assembly is presented, the assembly comprising ultrasound transducer elements for transmitting ultrasound waves in a general transmission direction. The method comprises, for each of, or each of part of, the ultrasound transducer elements, providing a piezoelectric layer having a top surface, a bottom surface and a side surface with respect to the general transmission direction. The method further comprises, for each of, or each of part of, the ultrasound transducer elements, arranging or applying a bottom electrode layer, and arranging or applying a top electrode layer. The method further comprises (directly) applying a conductive layer at least partly on the side surface of at least one specific one of the piezoelectric layers, such that the conductive layer is connected to the top electrode layer and the bottom electrode layer of said specific piezoelectric layer.

In another aspect a method of manufacturing an ultrasound transducer assembly is presented, the assembly comprising ultrasound transducer elements for transmitting ultrasound waves in a general transmission direction. The method comprises providing a common layer of piezoelectric material having a top, surface, a bottom surface and a side surface. The method further comprises applying a common bottom electrode layer on the bottom surface of the common piezoelectric layer, applying a common top electrode layer on the top surface of the common piezoelectric layer, and applying a conductive layer on each of the side surfaces of the common piezoelectric layer, such that the conductive layer is connected to the common top electrode layer and the common bottom electrode layer. The method further comprises cutting or dicing the ultrasound transducer elements out of the coated common layer of piezoelectric material.

With general transmission direction a general direction is meant in which the ultrasound waves are transmitted from the ultrasound transducer element(s). In particular, the top surface or top electrode layer is arranged further in front in the general transmission direction than the bottom surface or bottom electrode layer. The general transmission direction can be in particular perpendicular to a surface formed by the tops of the ultrasound transducer elements. The bottom surface and the top surface of the piezoelectric layer can each be arranged perpendicular to the general transmission direction and/or the side surface can be arranged parallel to the general transmission direction. When a voltage is applied between the top electrode layer and the bottom electrode layer, ultrasound waves are transmitted from the piezoelectric layer in the general transmission direction. The bottom electrode layer acts as a bottom electrode for the piezoelectric layer or transducer element. The top electrode layer acts as a top electrode for the piezoelectric layer or transducer element.

Preferably, the bottom electrode layer is applied on the bottom surface of the piezoelectric layer, and the top electrode layer applied on the top surface of the piezoelectric layer. Alternatively, there can also be intermediate layers between the piezoelectric layer and the electrodes.

The basic idea of the invention is to provide a short electrical path between the top electrode(s) and an external electrical connection, in particular to ground. A conductive layer is (directly) applied at least partly, in particular on all of, the side surface of at least one specific one of the piezoelectric layers, such that the conductive layer is connected to the top electrode layer and the bottom electrode layer of said specific piezoelectric layer. With (directly) applying the conductive layer it is meant that there is or are no intermediate layer(s) between the piezoelectric layer and the applied conductive layer. The conductive layer provides electrical connection between the top electrode layer and the bottom electrode layer of said specific piezoelectric layer for external electrical connection, in particular for external electrical connection to ground. Alternatively, also external electrical connection to a voltage potential can be provided. By providing an electrical path from the top electrode layer to the bottom electrode layer of that specific piezoelectric layer, or corresponding ultrasound transducer element, a short electrical path, in particular for ground return current, is provided and at the same time the manufacturing process is easy.

Preferred embodiments of the invention are defined in the dependent claims. It shall be understood that the claimed method of manufacturing has similar and/or identical preferred embodiments as the claimed ultrasound transducer assembly and as defined in the dependent claims. In the same way it shall be understood that the claimed ultrasound transducer assembly has similar and/or identical preferred embodiments as the claimed method of manufacturing and as defined in the dependent claims.

In one embodiment the ultrasound transducer element having the specific piezoelectric layer is a dummy element not operable to transmit or receive ultrasound waves. By providing an electrical path between the top electrode layer and the bottom electrode layer of that specific piezoelectric layer or corresponding ultrasound transducer element, the piezoelectric layer is not functional any more. Thus, that specific ultrasound transducer element is a dummy element not operable to transmit or receive ultrasound waves. Therefore, that specific transducer element is sacrificed, as it is not functioning as a transducer element any more. However, even though that specific ultrasound transducer element is sacrificed, the manufacturing of the ultrasound transducer assembly is significantly simplified, thus providing a cheaper ultrasound transducer assembly.

In a further embodiment the ultrasound transducer element having the specific piezoelectric layer is the outermost ultrasound transducer element in a (one-dimensional) row or an (two-dimensional) array of the ultrasound transducer elements. In this way the conductive layer is applied to the outermost ultrasound transducer assembly, thus providing an easy way of applying the conductive layer. In a variant of this embodiment the side surface to which the conductive layer is applied is the side surface facing outward in the row or the array of the ultrasound transducer elements.

In a further variant of this embodiment, the ultrasound transducer elements having the specific piezoelectric layers are the outermost ultrasound transducer elements at the ends of a (one-dimensional) row or an (two-dimensional) array of ultrasound transducer elements. In this way, part of or all of the ultrasound transducer elements at the two ends of the (one-dimensional) row or the edges of the (two-dimensional) array of ultrasound transducer elements can be dummy elements not operable to transmit or receive ultrasound waves. With one-dimensional row an arrangement of transducer elements in only one direction is meant (arranged one next to the other in a row). With two-dimensional array an arrangement of the transducer elements in two directions is meant (arranged in rows and columns).

In a further embodiment the assembly further comprises a conductive connection layer which electrically connects the top electrode layers of the ultrasound transducer elements. This is an easy way of providing a common top electrode for external electrical connection, in particular to ground. In one example, the conductive connection layer can be (directly) applied to the top electrode layers or it can form the top electrode layers. In another example, there can be additional conductive layers between the top electrode layer and the conductive connection layer.

In a further embodiment, the assembly further comprises at least one matching layer applied to the top electrode layer and/or at least one de-matching layer applied to the bottom electrode layer. In this way, the performance of the ultrasound transducer assembly can be improved. By providing at least one matching layer, in particular multiple matching layers, to the top electrode impedance matching to the body of the user (patient), on which the ultrasound transducer assembly can be placed, is achieved. By providing at least one de-matching layer, in particular exactly one de-matching layer, to the bottom electrode reflection of basically all of the transmitted energy of the ultrasound waves in the general transmission direction can be achieved. The matching layer and/or de-matching layer can in particular be made of a conductive material. In one example, the matching layer(s) can be made of graphite and/or the de-matching layer(s) can be made of Tungsten or Tungsten carbide.

In a variant of this embodiment the conductive layer is further applied on the side surface of the at least one matching layer and/or de-matching layer. As it may be difficult to apply the conductive layer on only part of the specific ultrasound transducer element (stack of layers), applying the conductive layer also on the side surface of the matching layer(s) and/or de-matching layer(s) provides an easier way of manufacturing. The whole side surface of the stack of layers can thus be coated with one conductive layer.

In a variant of this variant a top conductive layer applied to the topmost matching layer and/or a bottom conductive layer applied to the bottommost de-matching layer. As it may be difficult to apply the conductive layer on only a side surface of the specific ultrasound transducer element, applying also a top conductive layer and/or a bottom conductive layer to the stack of layers provides an easier way of manufacturing.

In yet a further embodiment each of or part of the bottom electrode layers of the ultrasound transducers elements are connected to at least one semiconductor chip. The semiconductor chip can for example be an ASIC or the like. The semiconductor chip can be used to control the transmission and/or reception of the ultrasound transducer elements, for example using beamforming in order to steer the ultrasound waves at an angle with respect to the general transmission direction. In particular, external electrical connection, in particular, to ground, can be provided via the semiconductor chip.

In a further embodiment the bottom electrode layer of the ultrasound transducer element having the specific piezoelectric layer is connected to a flexible circuit for external electrical connection. In this way external electrical connection can be provided, in particular to ground. Thus, an electrical path for the ground return current can be provided. In a variant of this embodiment, the bottom electrode layer of the specific ultrasound transducer element is connected to the semiconductor chip, which is connected to the flexible circuit. Thus, the electrical path for the ground return current can be provided.

In a further embodiment, the conductive layer is applied by metallization. In this way an easy way of manufacturing, in particular coating of the conductive layer, is provided. In an example, the conductive layer can be made of gold or any other suitable conductive material that can be applied by metallization.

In a variant of this embodiment the metallization is performed by sputtering or applying conductive epoxy. Sputtering or applying conductive epoxy are particularly suitable manufacturing methods.

In another embodiment the bottom electrode layers, the top electrode layers, and the conductive layer are applied in one common metallization step to a common layer of piezoelectric material. In a variant of this embodiment the ultrasound transducer elements are cut out or diced out of the common layer of piezoelectric material after the common metallization step has been performed. By providing a common layer of piezoelectric material on which a common top electrode layer and a common bottom electrode layer and the conductive layer on the side surface is applied, the manufacturing process is simplified. The ultrasound transducer elements then only need to be cut out or diced out of the common metalized layer of piezoelectric material. In this way, also less variability in the electrical connection is provided, as there is a common top electrode layer and a common bottom electrode layer.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiment(s) described hereinafter. In the following drawings

Fig. 1 shows a cross sectional view of an ultrasound transducer assembly according to an embodiment;

Figs. 2a to 2e show subsequent manufacturing steps of a method of manufacturing according to an embodiment; and

Figs. 3a to 3g each show a cross sectional view of an ultrasound transducer assembly according to different embodiments.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 shows a cross sectional view of an ultrasound transducer assembly 100 according to an embodiment. The ultrasound transducer assembly 100 comprises ultrasound transducer elements 175, 175a for transmitting ultrasound waves in a general transmission direction A. The ultrasound transducer elements 175, 175a can be arranged in a (one-dimensional) row or an (two-dimensional) array. For simplification purposes, in the cross sectional view of Fig. 1 only three of those ultrasound transducer elements are illustrated. It will be understood that there can be any number of additional ultrasound transducer elements arranged in the row or the array.

In the embodiment of Fig. 1, each of the ultrasound transducer elements 175, 175a comprises a piezoelectric layer 110, 110a having a top surface, a bottom surface and a side surface with respect to the general transmission direction A. The top surface and the bottom surface of the piezoelectric layer 110, 110a are each arranged perpendicular to the general transmission direction A. The side surface is arranged parallel to the general transmission direction A. Each of the ultrasound transducer elements 175, 175a further comprises a bottom electrode layer 111, 111a arranged on the bottom surface of the piezoelectric layer 110, 110a and a top electrode layer 112, 112a arranged on the top surface of the piezoelectric layer 110, 110a. With general transmission direction a general direction is meant in which the ultrasound waves are transmitted from the ultrasound transducer elements 175, 175a. As can be seen in Fig. 1, the top surface or top electrode layer 112, 112a of the piezoelectric layer 110, 110a is arranged further in front in the general transmission direction A than the corresponding bottom surface or bottom electrode layer 111, 111a of the piezoelectric layer 110. The general transmission direction A is here perpendicular to a surface formed by the tops of the ultrasound transducer elements 175, 175a. When a voltage is applied between the top electrode layer 112 and the bottom electrode layer 111 of a transducer element 175, ultrasound waves are transmitted from the piezoelectric layer 110 of that ultrasound transducer element 175 in the general transmission direction A.

A conductive layer 125 is (directly) applied at least partly on the side surface of at least one specific piezoelectric layer 110a of the piezoelectric layers, in particular on the entire side surface. The ultrasound transducer element having that specific piezoelectric layer 110a is the transducer element 175a in the embodiment of Fig. 1. As can be seen in Fig. 1, there are no intermediate layers between the piezoelectric layer 110a and the applied conductive layer 125, thus the conductive layer 125 is (directly) applied. The conductive layer 125 is applied, such that the conductive layer 125 is connected to the top electrode layer 112a and the bottom electrode layer 111a of said specific piezoelectric layer 110a of the specific transducer element 175a. In this way, a short electrical path between the top electrode 112a and an external electrical connection (via the bottom electrode 111a), in particular to ground, can be provided. Such electrical path is schematically indicated by arrows in Fig. 1. By providing this electrical path from the top electrode layer 112a to the bottom electrode layer 111a of that specific piezoelectric layer 110a of the specific ultrasound transducer element 175a, a short electrical path, in particular for ground return current, is provided and at the same time the manufacturing process is easy.

In this way, the specific ultrasound transducer element 175a having the specific piezoelectric layer 110a is created to be a dummy element not operable to transmit or receive ultrasound waves. Thus, the specific transducer element 175a is sacrificed, as is it not functioning as an ultrasound transducer element any more. However, even though this specific ultrasound transducer element 175 is sacrificed, the manufacturing of the ultrasound transducer assembly 100, which will be explained in more detail further on, is significantly simplified.

As can be seen in the embodiment of Fig. 1, the specific ultrasound transducer element 175a having the specific piezoelectric layer 110a (dummy element) is the outermost ultrasound transducer element 175a in the row or array of ultrasound transducer elements. In particular, the side surface to which the conductive layer 125 is applied is the side surface facing outward in the row or the array.

In the embodiment of Fig. 1 the ultrasound transducer assembly 100 further comprises a conductive connection layer 180 which electrically connects the top electrode layers 112, 112a. In this embodiment, the conductive connection layer 180 is (directly) applied to the top electrode layers 112, 112a. Alternatively, it can also form the top electrode layers 112, 112a. The conductive connection layer 180 connects the top electrode layers 112, 112a in order to provide a return current path, indicated by the arrows in Fig. 1, as previously explained.

As can be seen in the embodiment of Fig. 1, each of the bottom electrode layers 111, 111a of the ultrasound transducer elements 175, 175a are connected to a semiconductor chip 160. This electrical connection is provided using electrically conductive stud bumps 190. However, the electrical connection can also be provided in any other suitable way. The semiconductor chip 160 can for example be an ASIC or the like. The semiconductor chip 160 can be used to control the transmission and/or reception of the ultrasound transducer elements 175, 175a, for example using beamforming in order to steer the ultrasound waves at an angle with respect to the general transmission direction A. The semiconductor chip 160 is arranged on a backing 165 in the embodiment of Fig. 1. The backing 165 provides support for the transducer assembly. External electrical connection (to ground) is provided via the semiconductor chip (e.g. ASIC).

The semiconductor chip 160 is connected to a flexible circuit 185 using a connector 200. In this way, also the bottom electrode layer 111a of the specific ultrasound transducer element 175a having the specific piezoelectric layer 110a is connected to the flexible circuit 185 for external electrical connection. Thus, the ground return current path can be provided. More particularly, the bottom electrode layer 111a of the specific ultrasound transducer element 175a is connected to the semiconductor chip 160, which in turn is connected to the flexible circuit 185, thus providing the ground return current path.

The flexible circuit 185 can comprise a ground wire for such electrical connection. The flexible circuit 185 can further comprise system channel lines and semiconductor chip control lines (e.g. ASIC control lines). The system channel lines each transmit a data signal between a respective one of the transducer elements 175 and an external ultrasound computation system (not shown) (e.g. an ultrasound imaging system). Each data signal can for example control the transmission and/or reception of the respective transducer element 175. The semiconductor chip control lines (e.g. ASIC control lines) control functionality of the semiconductor chip (e.g. ASIC). A coaxial cable (not shown) can for example be joined to the flexible circuit 185 for external electrical connection, in particular to the ultrasound computation system. A ground or voltage and/or current source, for ground connection or connection to voltage potential, can be located in the ultrasound computation system. Alternatively, the ground or voltage and/or current source can also be located at any other suitable position, for example attached to or arranged next to the ultrasound transducer assembly.

Figs. 2a to 2e show subsequent manufacturing steps of a method of manufacturing an ultrasound transducer assembly according to an embodiment, in particular for manufacturing the ultrasound transducer assembly 100 of the embodiment of Fig. 1. In a first step, shown in Fig. 2a, the method comprises providing a common layer 110' of piezoelectric material having a top surface, a bottom surface and a side surface. Using this common piezoelectric layer 100', for each of the ultrasound transducer elements 175, 175a a piezoelectric layer 110, 110a having a top surface, a bottom surface and a side surface with respect to the general transmission direction A can be provided.

In a subsequent step, as shown in Fig. 2b, a common bottom electrode layer 111' is applied on the bottom surface of the common piezoelectric layer 100', a common top electrode layer 112' is applied on the top surface of the common piezoelectric layer 110', and the conductive layer 125 is applied on each of the side surfaces of the common piezoelectric layer 100', such that the conductive layer 125 is connected to the common top electrode layer 112' and the common bottom electrode layer 111'. The conductive layer 125 and/or the electrode layers can be applied by metallization, such for example by sputtering or applying conductive epoxy. As can be seen in Fig. 2b, the bottom electrode layers 111, 111a, the top electrode layers 112, 112a, and the conductive layer 125 are applied in one common metallization step to the common layer 110' of piezoelectric material.

In a subsequent step, as shown in Fig. 2c, the ultrasound transducer elements 175, 175a are cut out or diced out of the coated or metalized common layer 110' of piezoelectric material after the common metallization step (as explained with reference to Fig. 2b) has been performed.

In this way it can be achieved that for each of the ultrasound transducer elements 175, 175a, a bottom electrode layer 111, 111a is arranged on the bottom surface of the piezoelectric layer 110, 110a, and a top electrode layer 112, 112a is arranged on the top surface of the piezoelectric layer 110, 110a. Further, a conductive layer 125 is (directly) applied on the side surface(s) of the specific piezoelectric layer(s) 110a, such that the conductive layer 125 is connected to the top electrode layer 112a and the bottom electrode layer 111a of that specific piezoelectric layer(s) 110a.

In Fig. 2c the specific ultrasound transducer elements 175a having the specific piezoelectric layers 110a are the two outermost ultrasound transducer elements at the two ends of the (one dimensional) row of ultrasound transducer elements. Similarly, if the ultrasound transducer elements are arranged in an (two-dimensional) array, these are the ultrasound transducer elements at the edges of the array.

In a further step, with reference to Fig. 2d, a conductive connection layer 180 which electrically connects the top electrode layers 112, 112a can be provided. In this example, the conductive connection layer 180 is (directly) applied on the top electrode layers 112, 112a.

A final step for providing the ultrasound transducer assembly 100 is shown in Fig. 2e. The connected transducer elements 175, 175a can be connected to at least one semiconductor chip 160, which is for example arranged on a backing 165. As can be seen in Fig. 2e, this can for example be done by using conductive stud bumps 190. Finally, the semiconductor chip 160 can then be connected to a flexible circuit 185 using a connector 200. It will be understood that the step of Fig. 2e could also be performed before the step of Fig. 2d.

Figs. 3a to 3g each show a cross sectional view of an ultrasound transducer assembly 100 according to different embodiments. Fig. 3a shows the basic embodiment as explained with reference to Fig. 1 or Figs. 2a to 2e. Fig. 3b shows an embodiment which differs from the basic embodiment of Fig. 3a by an additional first matching layer 120 applied to the top electrode 112, 112a of each ultrasound transducer element 175, 175a. The embodiment of Fig. 3c differs from the basic embodiment of Fig. 3a by a first matching layer 120 applied to the top electrode 112, 112a of each transducer element 175, 175a and a second matching layer 130 applied to the first matching layer 120 of each transducer element 175, 175a. By providing the matching layer(s) 120, 130, impedance matching to the body of the user (patient), on which the ultrasound transducer assembly 100 can be placed, is achieved. The matching layer(s) 120, 130 can in particular be made of a conductive material (e.g. graphite). In this way, electrical connection from the top electrode 112 to the conductive connection layer 180, as previously described, can be provided.

The embodiment of Fig. 3d differs from the embodiment of Fig. 3c by an additional de-matching layer applied to the bottom electrode layer 111, 111a of each transducer element 175, 175a. By providing the de-matching layer 140 to the bottom electrode, reflection of basically all of the transmitted energy of the ultrasound waves in the general transmission direction A can be achieved. The de-matching layer 140 can in particular be made of a conductive material (e.g. a metal, such as Tungsten, or a carbide, such as Tungsten carbide).

The embodiment of Fig. 3e differs from the embodiment of Fig. 3d in that the conductive layer 125 is further (directly) applied on the side surface of the first matching layer 120a, the second matching layer 130a and the de-matching layer 140a for the specific transducer element 175a. Applying the conductive layer 125 on the whole side surface of the specific ultrasound transducer element 175a (stack of layers) is easier than applying it on only part of the side surface. Thus, the whole side surface of the stack of layers is coated with the conductive layer 125 in the embodiment of Fig. 3e.

The embodiment of Fig. 3f differs from the embodiment of Fig. 3e, for each transducer element, by an additional top conductive layer 114, 114a applied to the upmost matching layer 130, 130a and an additional bottom conductive layer 113, 113a applied to the bottom most de-matching layer 140, 140a. Thus, the top conductive layer 114, 114a and the bottom conductive layer 113, 113a are applied on the top surface and the bottom surface of the stack of layers. Thus, the stack of layers can be coated on all sides, providing an easier way of manufacturing.

In the embodiment of Fig. 3g the top electrode is not (directly) applied to the top surface of the piezoelectric layer, but there are intermediate layers between the piezoelectric layer and the top electrode layer. Each of the ultrasound transducer elements 175, 175a comprises a piezoelectric layer 110, 110a having the top surface, the bottom surface and the side surface. Each of the ultrasound transducer elements 175, 175a comprises a bottom electrode layer 111, 111a arranged on the bottom surface of the piezoelectric layer 110, 110a. A first matching layer 120, 120a is applied on the top surface of each transducer element 175, 175a, and a second matching layer 130 is applied on the first matching layer 120. The top electrode layer 112, 112a is then applied on the second matching layer 130. Thus, in this embodiment of Fig. 3g, contrary to the embodiments of the previous figures, the top electrode layer 112, 112a is not (directly) applied on the top surface of the piezoelectric layer 110, 110a, but there are intermediate layers in between. However, as the matching layers 120, 130 are conductive, the top electrode layer 112, 112a can still act as a top electrode for the piezoelectric element 110, 110a. It will be understood that any number (e.g. one) of intermediate layers (e.g. matching layer(s)) can be arranged in between. In the same way (not shown in Fig. 3g), the bottom electrode layer could not be (directly) applied to the bottom surface of the piezoelectric layer, as shown in Fig. 3g, but could be applied on the bottom surface of a de-matching layer 140 which is applied on the bottom surface of the piezoelectric layer.

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 the 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. A single element or other unit may fulfill the functions of several items recited in the claims. 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 the scope.

CLAIMS:

1. An ultrasound transducer assembly (100) comprising ultrasound transducer elements (175, 175a) for transmitting ultrasound waves in a general transmission direction (A), each of, or each of a part of, the ultrasound transducer elements (175, 175a) comprising:

- a piezoelectric layer (110, 110a) having a top surface, a bottom surface and a side surface with respect to the general transmission direction (A);
- a bottom electrode layer (111, 111a); and
- a top electrode layer (112, 112a);

wherein a conductive layer (125) is applied at least partly on the side surface of at least one specific one (110a) of the piezoelectric layers, such that the conductive layer (125) is connected to the top electrode layer (112a) and the bottom electrode layer (111a) of said specific piezoelectric layer (110a).

2. The ultrasound transducer assembly of claim 1, wherein the ultrasound transducer element (175a) having the specific piezoelectric layer (110a) is a dummy element not operable to transmit or receive ultrasound waves.

3. The ultrasound transducer assembly of claim 1, wherein the ultrasound transducer element (175a) having the specific piezoelectric layer (175a) is the outermost ultrasound transducer element in a row or an array of the ultrasound transducer elements.

4. The ultrasound transducer assembly of claim 3, wherein side surface to which the conductive layer (125) is applied is the side surface facing outward in the row or the array of the ultrasound transducer elements (175, 175a).

5. The ultrasound transducer assembly of claim 1, further comprising a conductive connection layer (180) which electrically connects the top electrode layers (112, 112a) of the ultrasound transducer elements (175, 175a).

6. The ultrasound transducer assembly of claim 1, further comprising at least one matching layer (120, 130) applied to the top electrode layer (112, 112a) and/or at least one de-matching layer (140) applied to the bottom electrode layer (111, 111a).

7. The ultrasound transducer assembly of claim 6, wherein the conductive layer (125) is further applied on the side surface of the at least one matching layer (120a; 130a) and/or de-matching layer (140a).

8. The ultrasound transducer assembly of claim 7, further comprising a top conductive layer (114, 114a) applied to the topmost matching layer and/or a bottom conductive layer (113, 113a) applied to the bottommost de-matching layer.

9. The ultrasound transducer assembly of claim 1, wherein each of or part of the bottom electrode layers (111, 111a) of the ultrasound transducers elements (175, 175a) are connected to at least one semiconductor chip (160).

10. The ultrasound transducer assembly of claim 1, wherein the bottom electrode layer (111a) of the ultrasound transducer element (175a) having the specific piezoelectric layer (110a) is connected to a flexible circuit (185) for external electrical connection.

11. A method of manufacturing an ultrasound transducer assembly (100) comprising ultrasound transducer elements (175, 175a) for transmitting ultrasound waves in a general transmission direction (A), the method comprising, for each of, or each of a part of, the ultrasound transducer elements (175, 175a):

- providing a piezoelectric layer (110, 110a) having a top surface, a bottom surface and a side surface with respect to the general transmission direction (A);
- applying a bottom electrode layer (111, 111a); and
- applying a top electrode layer (112, 112a);

the method further comprising applying a conductive layer (125) at least partly on the side surface of at least one specific one (110a) of the piezoelectric layers, such that the conductive layer (125) is connected to the top electrode layer (112a) and the bottom electrode layer (111a) of said specific piezoelectric layer (110a).

12. The method of claim 11, wherein the conductive layer (125) is applied by metallization.

13. The method of claim 12, wherein the metallization is performed by sputtering or applying conductive epoxy.

14. The method of claim 11, wherein bottom electrode layers (111, 111a), the top electrode layers (112, 112a), and the conductive layer (125) are applied in one common metallization step to a common layer (110′) of piezoelectric material.

15. The method of claim 14, wherein the ultrasound transducer elements (175, 175a) are cut out or diced out of the common layer (110′) of piezoelectric material after the common metallization step has been performed.

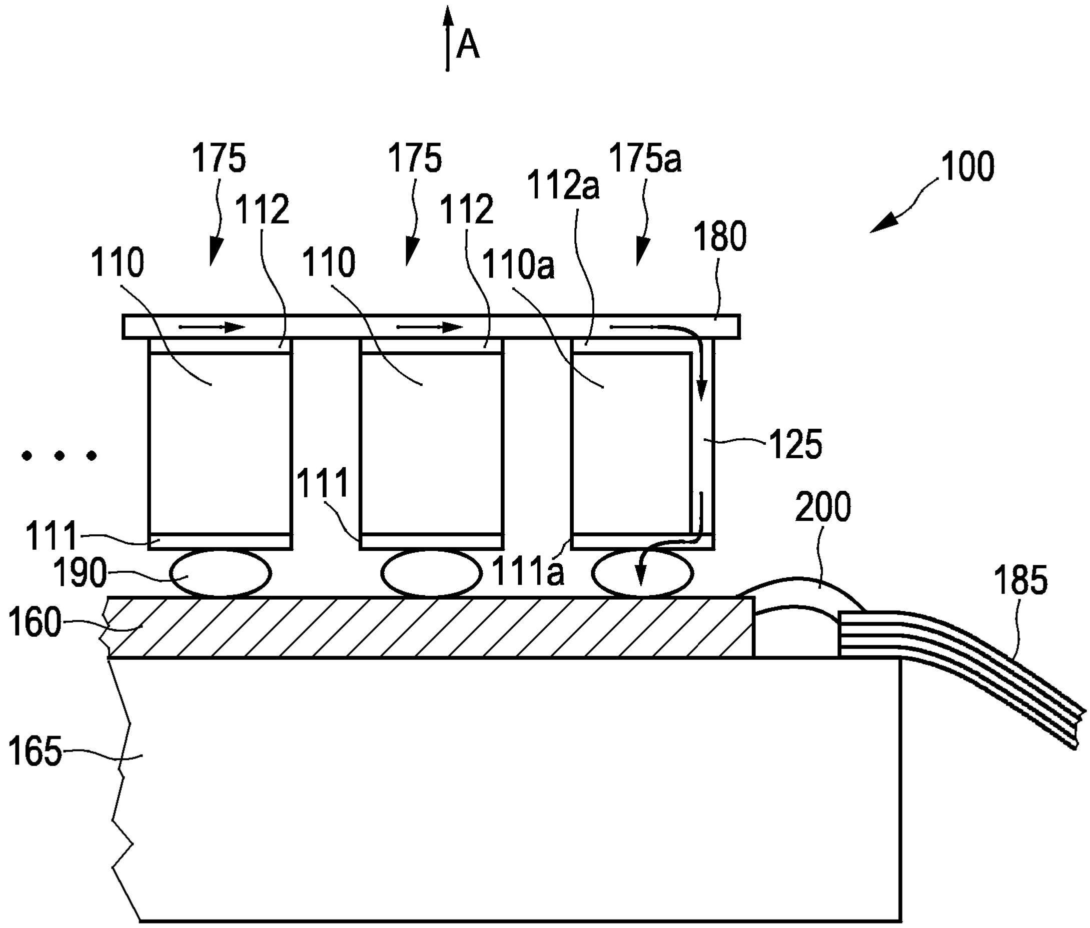

A
175
175
175a
100
112
112
112a
180
110
110
110a
125
111
111
111a
190
200
185
160
165

FIG. 1

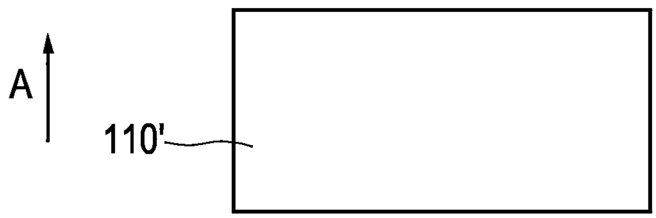


FIG. 2a

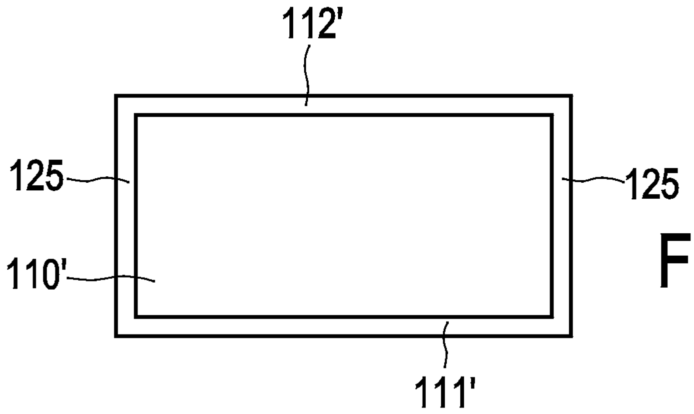


FIG. 2b

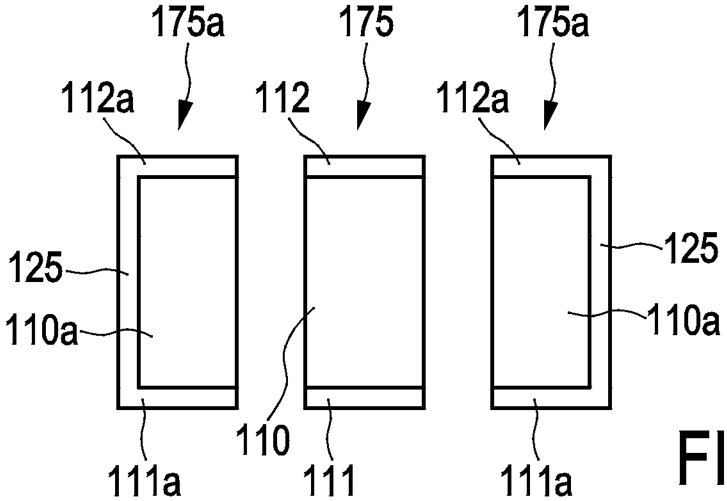


FIG. 2c

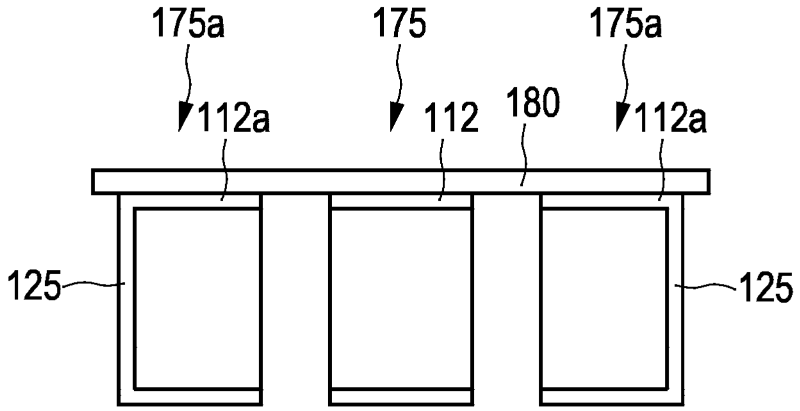

175a
175
175a
112a
112
180
112a
125
125

FIG. 2d

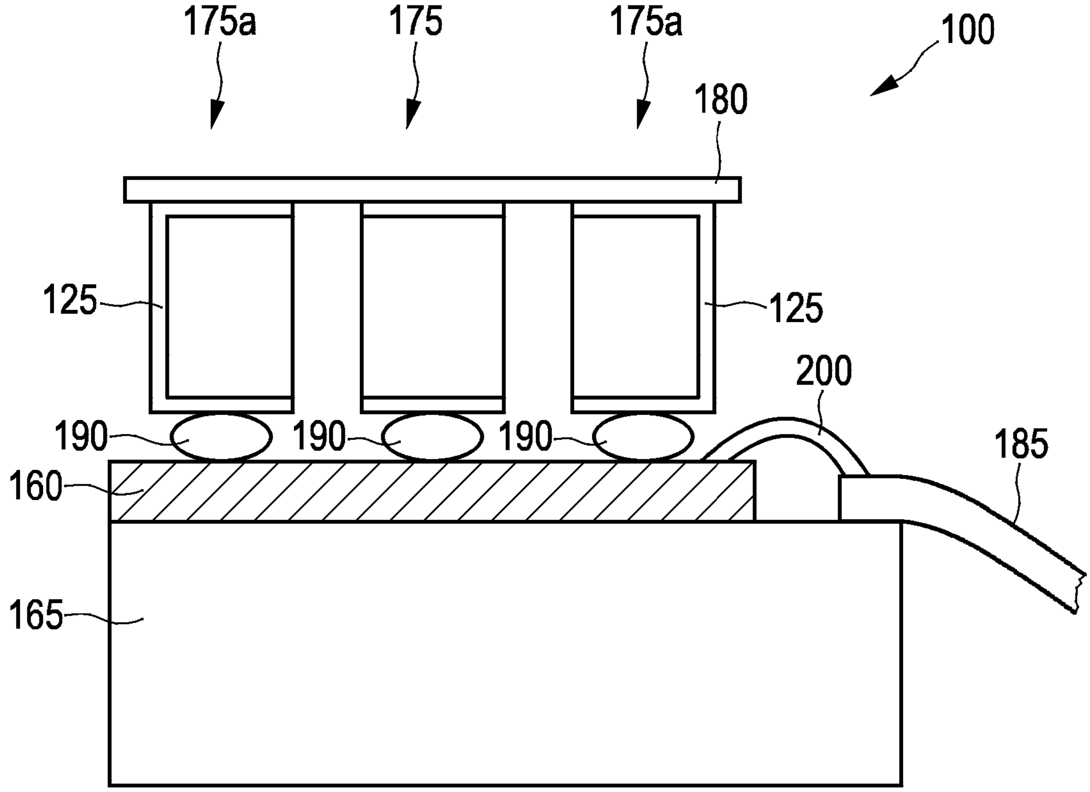

175a
175
175a
100
180
125
125
200
190
190
190
185
160
165

FIG. 2e

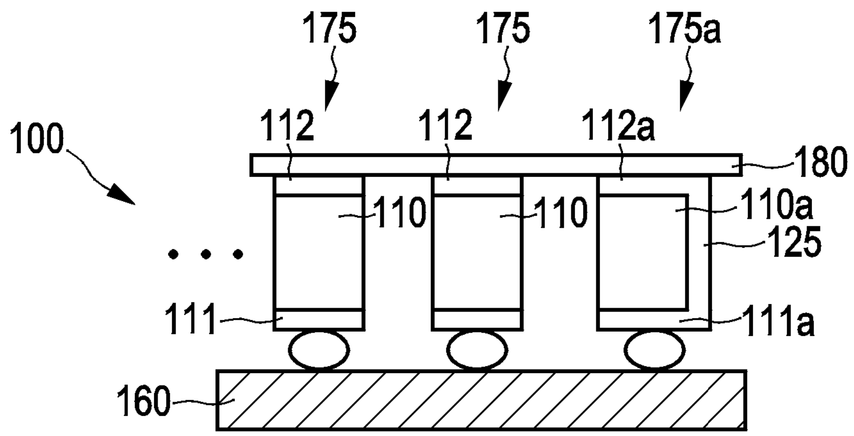


FIG. 3a

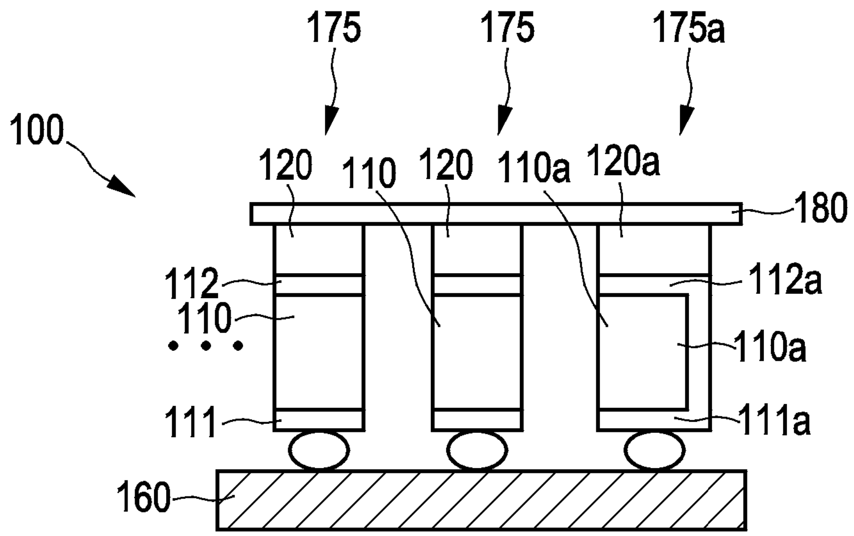


FIG. 3b

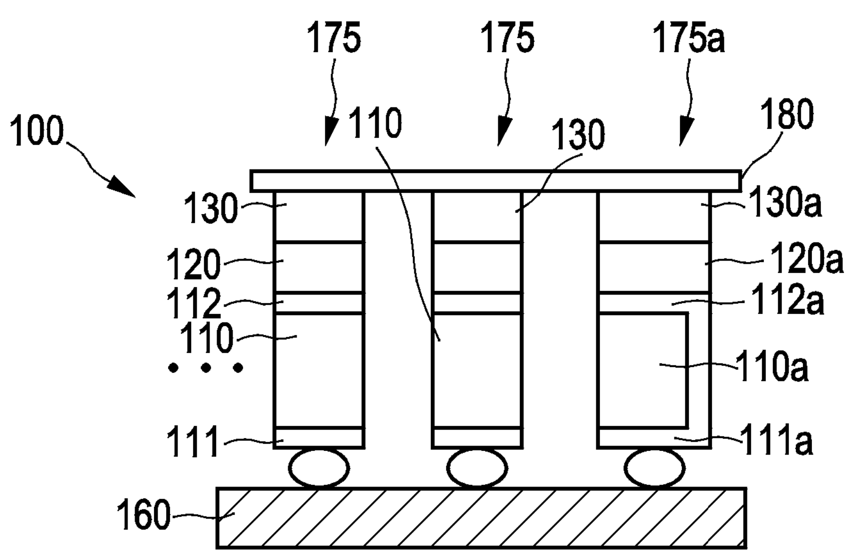


FIG. 3c

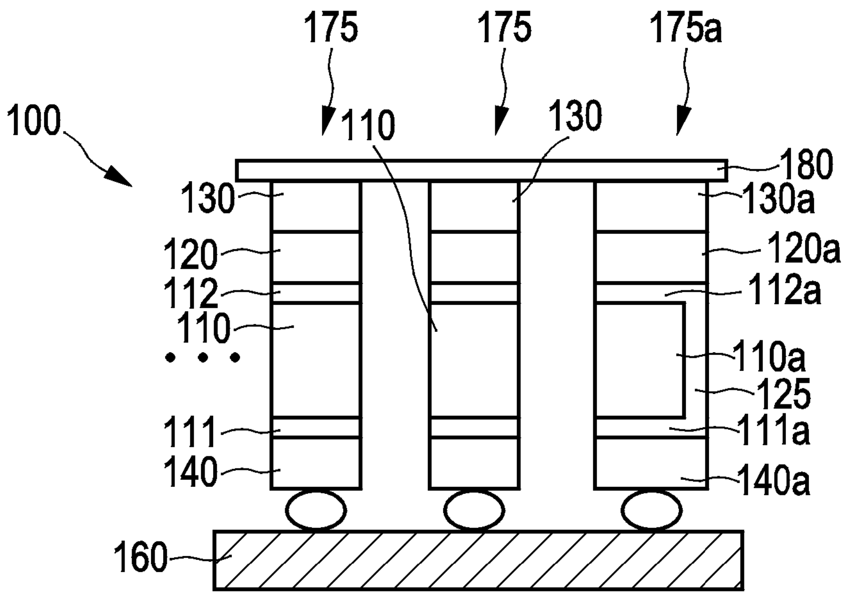
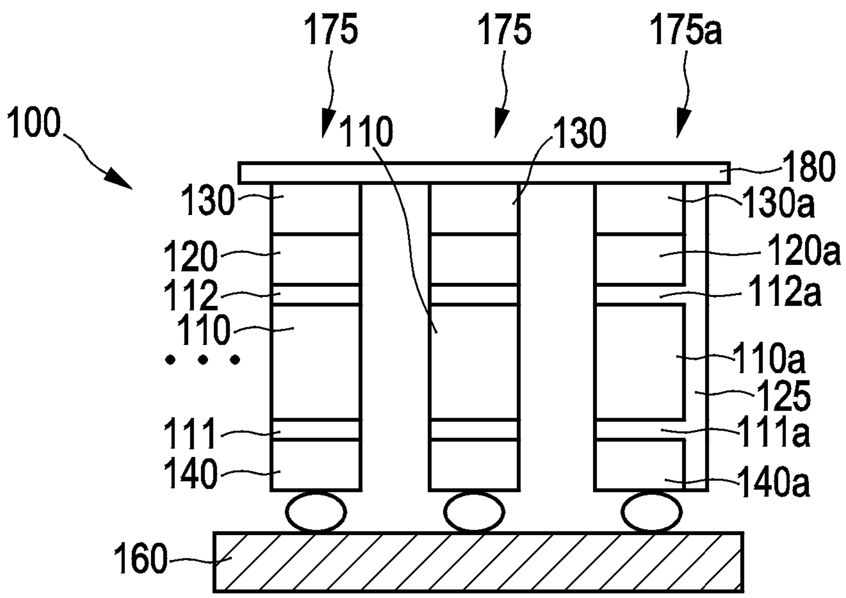

175
175
175a
100
110
130
180
130
130a
120
120a
112
112a
110
110a
125
111
111a
140
140a
160

FIG. 3d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175
175a
100
110
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180
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130a
120
120a
112
112a
110
110a
125
111
111a
140
140a
160

FIG. 3e

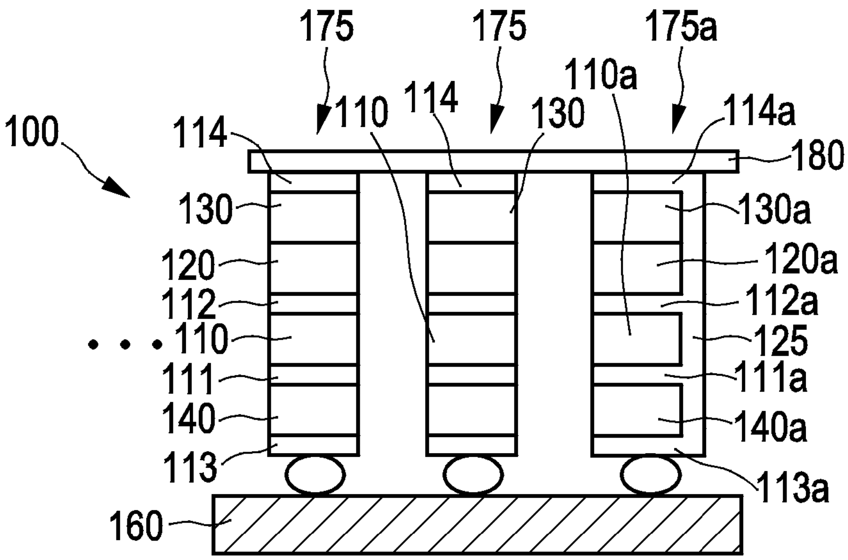
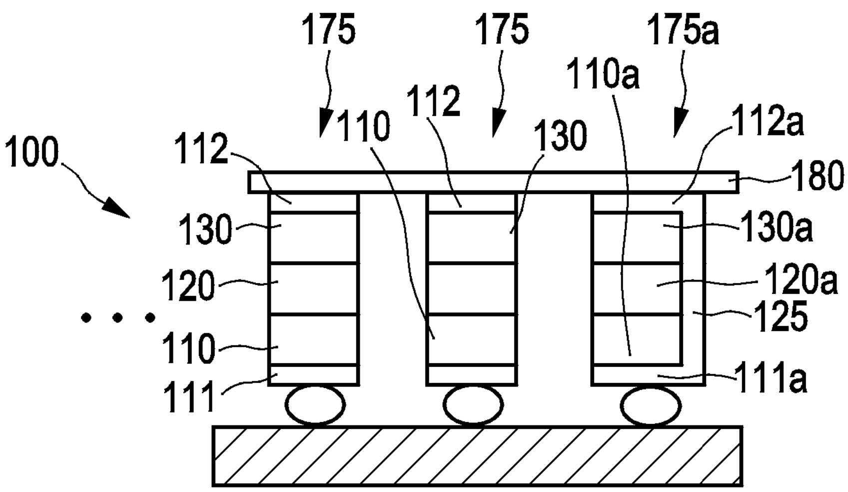

175
175
175a
110a
110
114
130
114a
100
114
180
130
130a
120
120a
112
112a
110
125
111
111a
140
140a
113
113a
160

FIG. 3f


175
175
175a
110a
110
112
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112a
100
112
180
130
130a
120
120a
125
110
111a
111

FIG. 3g

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/053216

A. CLASSIFICATION OF SUBJECT MATTER
INV. B06B1/06 H01L41/047
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)
B06B 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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 774 960 A (DE FRAGUIER SIXTE [FR] ET AL) 7 July 1998 (1998-07-07) column 1, lines 5-16 column 4, line 36 - column 5, line 38; figures 13-15 -----	1-15
X	US 6 726 631 B2 (HATANGADI RAM [US] ET AL) 27 April 2004 (2004-04-27) column 6, line 40 - column 8, line 23; figures 3-4 -----	1-15
X	EP 0 785 826 B1 (PARALLEL DESIGN INC [US]) 3 February 1999 (1999-02-03) paragraphs [0014] - [0025]; figures 1-5 -----	1-15
X	US 5 793 149 A (THIEL WOLFGANG [DE] ET AL) 11 August 1998 (1998-08-11) column 4, lines 53-64; figures 1-3 column 5, lines 18-41; figure 5 -----	1-4,11,12,14,15

☐ 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

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"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	Date of mailing of the international search report
26 November 2012	04/12/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Trique, Michael

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2012/053216

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5774960 A	07-07-1998	FR 2702309 A1	09-09-1994
		US 5774960 A	07-07-1998
		WO 2004073892 A1	02-09-2004
US 6726631 B2	27-04-2004	CN 1568230 A	19-01-2005
		EP 1429870 A1	23-06-2004
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		WO 03024625 A1	27-03-2003
EP 0785826 B1	03-02-1999	CN 1162937 A	22-10-1997
		DE 69507705 D1	18-03-1999
		DE 69507705 T2	17-06-1999
		DK 785826 T3	20-09-1999
		EP 0785826 A1	30-07-1997
		JP H10507600 A	21-07-1998
		US 5511550 A	30-04-1996
		WO 9611753 A1	25-04-1996
US 5793149 A	11-08-1998	NONE	

patsnap

专利名称(译)	超声换能器组件及其制造方法		
公开(公告)号	[EP2723506A1](EP2723506A1)	公开(公告)日	2014-04-30
申请号	EP2012748535	申请日	2012-06-26
[标]申请(专利权)人(译)	皇家飞利浦电子股份有限公司		
申请(专利权)人(译)	皇家飞利浦N.V.		
当前申请(专利权)人(译)	皇家飞利浦N.V.		
[标]发明人	SUDOL WOJTEK		
发明人	SUDOL, WOJTEK		
IPC分类号	B06B1/06 H01L41/047 A61B8/00		
CPC分类号	H01L41/29 A61B8/4494 B06B1/0607 B06B1/0622 H01L41/0475 Y10T29/42		
代理机构(译)	STEFFEN，THOMAS		
优先权	61/501307 2011-06-27 US		
其他公开文献	EP2723506B1		
外部链接	Espacenet		

摘要(译)

超声换能器组件技术领域本发明涉及一种超声换能器组件（100），其包括用于在一般传输方向（A）上发射超声波的超声换能器元件（175,175a）。超声换能器元件（175,175a）中的每一个或每个部分包括压电层（110,110a），其具有顶表面，底表面和相对于一般传输方向（A）的侧表面，以及底部电极层（111,111a）和顶部电极层（112,112a）。导电层（125）至少部分地施加在压电层的至少一个特定的一个（110a）的侧表面上，使得导电层（125）连接到顶部电极层（112a）和底部所述特定压电层（110a）的电极层（111a）。