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Brock-Fisher et al.(10) **Pub. No.: US 2016/0296207 A1**(43) **Pub. Date: Oct. 13, 2016**(54) **ULTRASOUND TRANSDUCER ASSEMBLY**(52) **U.S. Cl.**(71) Applicant: **KONINKLIJKE PHILIPS N.V.**,
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2562/12 (2013.01)(72) Inventors: **George Anthony Brock-Fisher**,
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Savord, Andover, MA (US)(57) **ABSTRACT**(21) Appl. No.: **15/035,588**(22) PCT Filed: **Nov. 14, 2014**(86) PCT No.: **PCT/EP2014/074553**

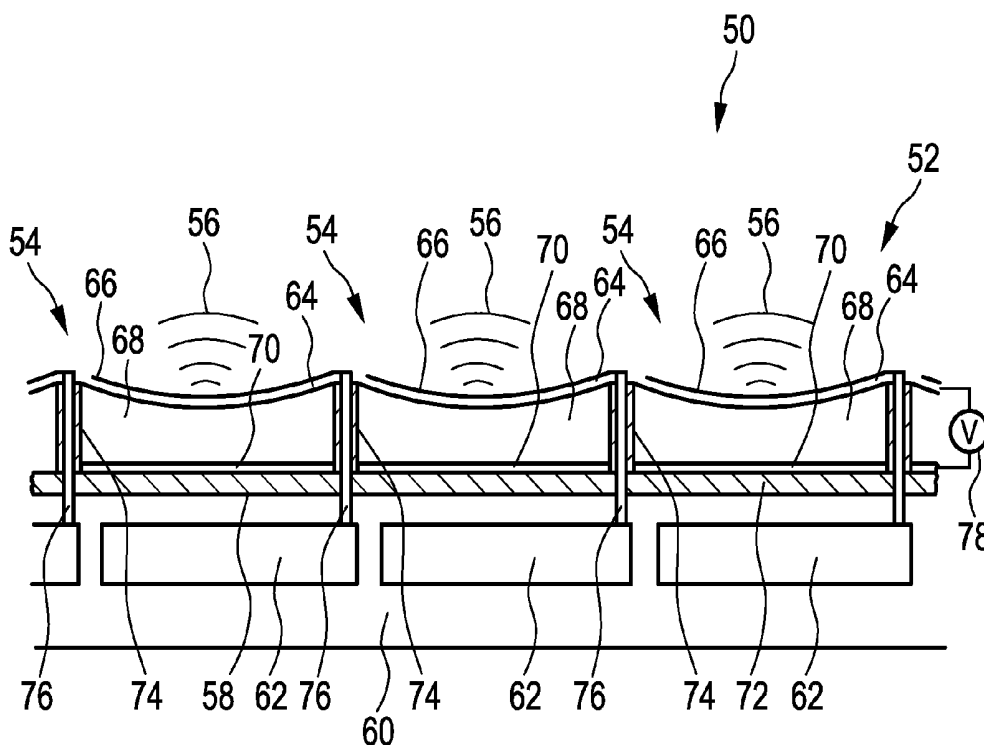
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An ultrasound transducer assembly (50), in particular for ultrasound imaging systems (10), is disclosed, comprising a transducer array (52) including a plurality of transducer elements (54) for emitting and receiving ultrasound waves (56). Each of the transducer elements (54) includes a first electrode (66) connected to a flexible membrane (64) and a second electrode (70). The assembly further comprises an integrated circuit device (60) connected to the transducer array (52) for driving the transducer elements (54), wherein the first electrodes (66) are electrically connected to each other and coupled to the integrated circuit device (60) for providing an alternating drive voltage to each of the transducer elements (54), wherein the second electrodes (70) are connected to a voltage supply for providing a bias voltage to the transducer elements (54), and wherein the first electrodes (66) are each connected by means of a via (76) to the integrated circuit device (60) and the vias (76) are fed through the second electrodes (70).



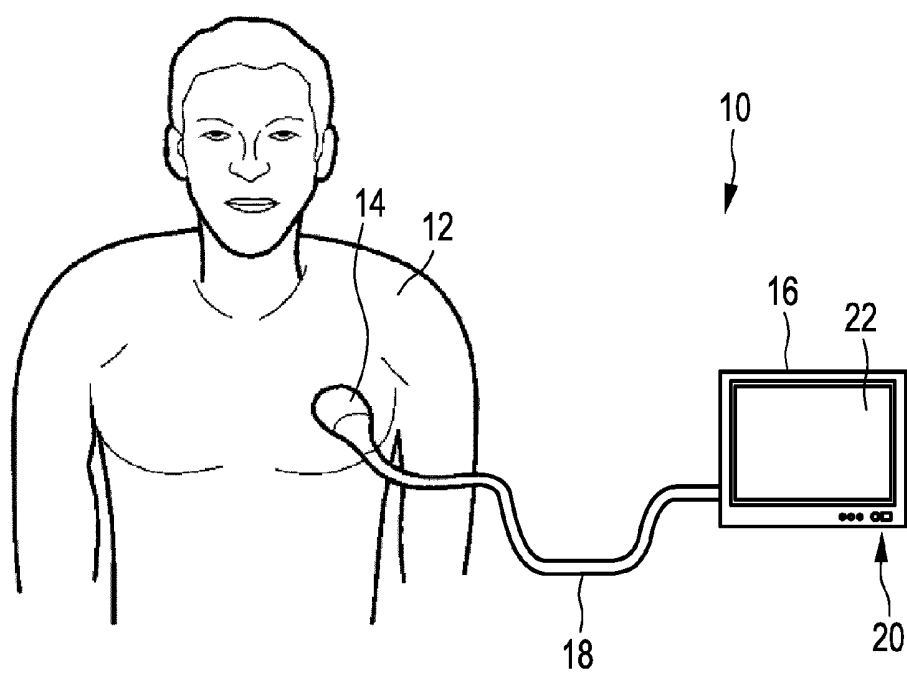


FIG. 1

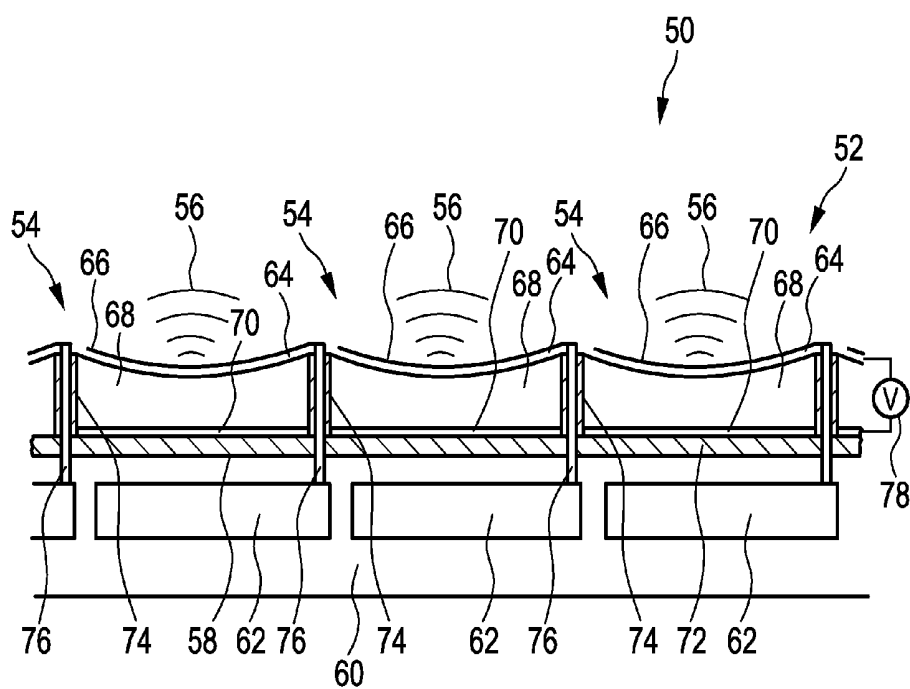


FIG. 3

ULTRASOUND TRANSDUCER ASSEMBLY

FIELD OF THE INVENTION

[0001] The present invention relates to an ultrasound transducer assembly, in particular for ultrasound imaging systems.

BACKGROUND OF THE INVENTION

[0002] In the field of ultrasound transducers and in particular in the field of ultrasound imaging systems, it is generally known to use micro-machined ultrasound transducer elements (CMUTs). Due to the fact that the capacitive micro-machined transducer elements can be fabricated by semiconductor processing techniques, the size of the transducers can be shrunk to very small feature sizes.

[0003] Further, it is generally known to drive the ultrasound transducers including the micro-machined ultrasound transducer arrays by means of application specific integrated circuits, which serve as an electrical interface to each of the transducer elements.

[0004] For integrating the whole transducer assembly, it is further known to fabricate the transducer array directly on a top surface of the application specific integrated circuits or to attach the transducer arrays and the application specific integrated circuits to each other in order to reduce the overall size of the transducer assembly. In order to reduce the technical effort for connecting the electrodes of each of the transducer elements to the application specific integrated circuit, usually the top electrodes, which are attached to the flexible membrane of the transducer elements are each electrically connected to each other and connected to a voltage supply for applying a bias voltage to these electrodes. The second electrodes of the transducer elements, which are disposed at a bottom of a cavity of the transducer elements are each individually connected to the application specific integrated circuit below the transducer array in order to apply individual driving signals to each of the transducer elements and to receive ultrasound signals to be detected and to be evaluated. The disadvantage of the transducer array in combination with the application specific integrated circuit as driver device is that a large parasitic capacitance is formed between the bottom electrode of the transducer elements and the top metal layer of the application specific integrated circuit. This parasitic capacitance can be a significant fraction of the cMUT capacitance itself and must be charged during excitation of the cMUT device resulting in a low overall transmit efficiency. Furthermore, on signal reception, the parasitic capacitance shunts desired receive signals from entering the circuitry. This results in poor signal to noise ratio when receiving signals.

[0005] To reduce the parasitic capacitance between the transducer array and the driver circuit, US 2013/0088118 A1 proposes to include additional floating electrodes between the first and the second electrode of each of the transducer elements within the cavity. The disadvantage of this solution to reduce the parasitic capacitance is that the transducer array has a complicated structure and the technical effort for manufacturing those transducer arrays is increased.

SUMMARY OF THE INVENTION

[0006] It is an object of the present invention to provide an improved ultrasound transducer assembly, in particular for

ultrasound imaging systems having an increased transmit efficiency and an increased receive signal to noise ratio with low technical effort.

[0007] According to one aspect of the present invention, an ultrasound transducer assembly, in particular for ultrasound imaging systems, is provided comprising:

[0008] a transducer array including a plurality of transducer elements for emitting and receiving ultrasound waves, wherein each of the transducer elements includes a first electrode connected to a flexible membrane and a second electrode,

[0009] an integrated circuit device connected to the transducer array for driving the transducer elements,

[0010] wherein the first electrodes are coupled to the integrated circuit device for providing an alternating drive voltage to each of the transducer elements and wherein the second electrodes are electrically connected to each other and coupled to a voltage supply for providing a bias voltage to the transducer elements, and

[0011] wherein the first electrodes are each connected by means of a via to the integrated circuit device and the vias are fed through the second electrodes.

[0012] In a further aspect of the present invention, an ultrasound imaging system is provided including an ultrasound transducer assembly of this kind for emitting and receiving ultrasound waves.

[0013] Preferred embodiments of the invention are defined in the dependent claims. It shall be understood that the claimed method has similar and/or identical preferred embodiments as the claimed device and as defined in the dependent claims.

[0014] The present invention is based on the idea to reduce the parasitic capacitance by inverting the electrical connections to the transducer elements. This is provided by connecting the first electrode of each of the transducer elements which are connected to the flexible membrane to the integrated circuit device by means of vias through the second electrodes for driving each of the first electrodes individually and by connecting the second electrodes of the transducer elements to each other and to a common voltage supply in order to provide a necessary bias voltage to these second electrodes. Hence, the first electrode is used as the active electrode and is connected to the driver and/or receiver device of the integrated circuit device so that the second electrode is the passive electrode. This configuration reduces the parasitic capacitance of the connection to the active electrode since the active electrodes are top electrodes and the driver and/or receiver device is connected to the active electrodes by means of vias fed through the second electrodes. Hence, the overall transmit efficiency and the signal to noise ratio of the transducer array can be significantly improved. Additionally, the overall size of the transducer assembly is reduced.

[0015] In a preferred embodiment, the first electrodes are top electrodes of the transducer array. This is a possibility to transmit and receive ultrasound waves with low attenuation, since the ultrasound waves are directly emitted and received so that the overall signal strength is increased.

[0016] It is further preferred that the first electrodes are each coupled to a top surface of the flexible membranes. This is a possibility to reduce the technical effort for manufacturing the transducer elements, since the electrodes can be formed on the flexible membranes, e.g. by means of a deposition process.

[0017] In a preferred embodiment, the second electrodes are bottom electrodes attached to an isolation layer. This is a simple possibility to provide a bias electrode isolated from the integrated circuit device.

[0018] In a preferred embodiment, the vias are fed through the isolation layer. This is a possibility to directly contact the first electrodes to driver elements of the integrated circuit disposed below the respective transducer element.

[0019] In a preferred embodiment, the second electrodes are rigid electrodes. This is a possibility to provide the second electrodes as bias electrodes with low technical effort, since the rigid electrodes can be manufactured with low technical effort, e.g. by means of a deposition method.

[0020] In a preferred embodiment, the cavity is formed between each of the first electrodes and each of the second electrodes, respectively. This is a possibility to easily transmit and receive ultrasound waves since the flexible membrane can be deflected into the cavity.

[0021] In a preferred embodiment, the flexible membranes of the transducer elements are each supported by means of a spacer. This is a simple possibility to form the flexible membranes in a distance to the second electrode so that the flexible membranes and the first electrodes can easily be deflected into the cavity.

[0022] It is preferred that the vias for connecting the first electrode to the integrated circuit device are integrated in the spacer. This is a further possibility to reduce the overall size of the transducer array.

[0023] In a preferred embodiment, the transducer elements are capacitive micro-machined ultrasound transducer elements. This is a possibility to form the transducer array with low technical effort and with a small overall size since the transducer array can be manufactured in an IC process in/on a silicon wafer.

[0024] In a preferred embodiment, the integrated circuit device is an application specific integrated circuit. This is a possibility to connect the transducer array directly to a specific driving element, since the application specific integrated circuit is designed to drive the transducer elements and to receive signals according to the received ultrasound waves.

[0025] In a preferred embodiment, the transducer elements are monolithically formed on the integrated circuit device. This is a possibility to manufacture the ultrasound transducer assembly with low technical effort and with reduced feature sizes.

[0026] In a further preferred embodiment, the integrated circuit device and the transducer elements are monolithically integrated on a substrate. This is a further possibility to reduce the manufacturing time and effort since almost the whole device can be formed monolithically e.g. by means of micro-electronic process technology. An additional advantage of this embodiment is that the transducer elements can be manufactured on a pre-manufactured integrated circuit device. As mentioned above, by connecting the top electrode to the integrated circuit for providing AC driving signals to the respective transducer element and by connecting the bottom electrode to a common DC power supply for providing a DC bias voltage to the transducer array, the parasitic capacitance between the driven or excited electrode of the transducer elements can be significantly reduced so that the transmit efficiency and receive signal to noise ratio of the transducer array can be significantly improved and the

quality of the analytic information received from the ultrasound transducer assembly e.g. the image data can be improved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] 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

[0028] FIG. 1 shows a schematic illustration of an ultrasound imaging system;

[0029] FIG. 2 shows a schematic sectional view of an ultrasound transducer array and an integrated circuit device according to the state of the art; and

[0030] FIG. 3 shows a schematic sectional view of an ultrasound transducer array and an integrated circuit according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0031] FIG. 1 illustrates a principle design of an ultrasound imaging system generally denoted by 10. This figure is used to explain the background of the ultrasound imaging. It shall be understood that the claimed ultrasound transducer assembly is not restricted to such kind of applications.

[0032] The ultrasound imaging system 10 is used for scanning an area or a volume of a body, e.g. of a patient 12. It shall be understood that the ultrasound system 10 may also be used for scanning other areas or volumes, e.g. body parts of animals or other living beings.

[0033] For scanning the patient, an ultrasound probe 14 is provided. In the embodiment shown in FIG. 1, the ultrasound probe 14 is connected to a console device 16. The console device 16 is shown as a mobile console. This console 16 may however also be realized as a stationary device. The console device 16 is connected to the probe 14 via an interface 18 formed as a via. Further, the console device 16 comprises an input device 20 to enable the user to control the ultrasound imaging system 10 and may comprise a display 22 to display data and images generated by the ultrasound imaging system 10. By this, the volume within the patient 12 that is scanned via the ultrasound probe 14 can be viewed on the console device 16 by the user of the ultrasound imaging system 10.

[0034] The ultrasound probe 14 usually comprises an ultrasound transducer array driven by a driver device as described in the following in order to transmit and receive ultrasound waves and to provide ultrasound image data from the received ultrasound waves.

[0035] FIG. 2 shows an ultrasound transducer assembly as known from the state of the art, which is generally denoted by 24. The ultrasound transducer assembly 24 comprises a transducer array 26 of a plurality of transducer elements 28, which are formed as capacitive micro-machined ultrasound transducer (CMUT) elements. The transducer array 26 is connected to a top surface of an application specific integrated circuit 30. The transducer elements 28 comprises a flexible membrane 32, a cavity 34 and a top electrode 36 and a bottom electrode 38. The top electrode 36 is formed on or embedded in the flexible membrane 32 and the bottom electrode 38 is formed at a bottom of the cavity 28 on top of or embedded in an isolation layer 40 isolating the transducer array 26 from the application specific integrated circuit 30.

[0036] The top electrodes 36 are connected to each other and are connected to a DC power supply 41 for providing a DC bias voltage to the transducer elements 28. The bottom electrodes 38 are each individually connected to a driving element 42 of the application specific integrated circuit 30 in order to provide an individual AC signal to each of the transducer elements 28 and to drive the transducer elements 28 individually. Hence, by applying the AC signal to the bottom electrode 38 and by receiving a signal from the bottom electrode 38, the application specific integrated circuit can transmit and receive ultrasound waves by each of the transducer elements 28.

[0037] The bottom electrodes 38, which are connected by vias to the application specific integrated circuit 30, and the isolation layer 40—have parasitic capacitances parallel to the bottom electrodes 38 and the input of the application specific integrated circuit 30. The parasitic capacitances of the transducer elements 28 can be in the order of 0.5 pF, so that the transmit efficiency and receive signal to noise ratio degradation may be in the range of 2 db. These parasitic capacitances reduce the transmit efficiency and receive signal to noise ratio of the signals received from the transducer elements 28 so that the signal quality of the transducer assembly 24 is reduced.

[0038] In FIG. 3, an ultrasound transducer assembly according to the present invention is shown in a schematic sectional view and generally denoted by 50. The ultrasound transducer assembly 50 comprises an ultrasound transducer array 52 having a plurality of transducer elements 54, which are preferably formed as capacitive micro-machined ultrasound transducer elements (CMUT) for emitting and receiving ultrasound waves 56. The ultrasound transducer array 52 is formed on a top surface 58 of an integrated circuit 60, which is preferably an application specific integrated circuit 60. The ultrasound transducer array 52 is preferably formed monolithically on the top surface 58 by a micro manufacturing process. The integrated circuit 60 comprises a plurality of driving and receiving elements 62 for driving the transducer elements 54 and for receiving signals from the transducer elements 54 as described in the following. The so formed ultrasound transducer assembly 50 may be used in the ultrasound probe 14 for transmitting and receiving ultrasound waves 56.

[0039] The transducer elements 54, which are formed as capacitive micro-machined ultrasound transducer element and the integrated circuit 60, which is preferably formed as an application specific integrated circuit 60 are formed or manufactured monolithically on a substrate which is preferably a semiconductor substrate by means of a micro manufacturing method e.g. a microelectronic manufacturing technology. This is a possibility to reduce the size of the ultrasound transducer assembly 50 and to reduce the technical effort for manufacturing the ultrasound transducer assembly.

[0040] The transducer elements 54 each comprise a flexible membrane 64 each including a first electrode 66, which is preferably attached to a top surface of the flexible membrane 64 or embedded in to the membrane 64. A cavity 68 is formed below the flexible membrane 64 so that the flexible membrane 64 can be deflected or excited in order to emit the ultrasound waves 56. At a bottom of the cavity 68, each transducer element 54 comprises a second electrode 70, which is coupled or embedded in to an isolation layer 72 which isolates the ultrasound transducer array 52 from the

integrated circuit 60. The first electrode 66 is formed either as a flexible electrode 66 or as the rigid electrode which is coupled to the flexible membrane 64 and the second electrode 70 is formed as a rigid electrode 70. The flexible membrane 64 is separated from the second electrode 70 and the isolation layer 72 by means of support elements 74 or spacers 74.

[0041] The first electrodes are isolated from each other and each individually electrically connected to the drive elements 62 of the integrated circuit 60 by means of a via 76. The via 76 is formed within the support elements 74. Alternatively, the vias 76 may be connected laterally to the support elements 74.

[0042] The vias 76 are further fed through the isolation layer 72 and the second electrodes 70 in order to connect the first electrodes 66 individually to the integrated circuit 60. The second electrodes 70 are connected to each other and connected to a DC power supply 78 for providing a DC bias voltage to the transducer elements 54. The second electrodes 70 are preferably formed as a single metal layer deposited on a top surface of the isolation layer 72. Hence, the first electrodes 66 as the top electrodes 66 form the active electrodes and the second electrodes, which are formed as bottom electrodes, are the passive electrodes. By means of this inverse connection with the active electrode as the top electrode 66, the parasitic capacitances between the active electrode 66 and the integrated circuit 60 in general can be reduced so that the transmit efficiency and receive signal to noise ratio of the transducer elements 54 can be improved and the signal and image quality can be increased.

[0043] The cavity 68 may be a vacuum gap. The flexible membrane 64 may be deflected down to the second electrode 70 by means of the DC bias voltage in order to use the transducer elements 54 in a collapsed mode to increase the sensitivity of the ultrasound transducer assembly 50 in general. In a certain embodiment, the second electrode 70 may be covered by an additional isolation layer.

[0044] 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.

[0045] 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.

[0046] Any reference signs in the claims should not be construed as limiting the scope.

1. An ultrasound transducer assembly, comprising:
 - a transducer array including a plurality of transducer elements for emitting and receiving ultrasound waves, wherein each of the transducer elements includes a first electrode connected to a flexible membrane and a second electrode,
 - an integrated circuit device connected to the transducer array for driving the transducer elements,

wherein the first electrodes are coupled to the integrated circuit device for providing an alternating drive voltage to each of the transducer elements and wherein the second electrodes are electrically connected to each other and coupled to a voltage supply for providing a bias voltage between the first and second electrodes of the transducer elements, and

wherein the first electrodes are each connected by a via to the integrated circuit device and the vias are fed through the second electrodes.

2. The ultrasound transducer assembly as claimed in claim 1, wherein the first electrodes are top electrodes of the transducer array.

3. The ultrasound transducer assembly as claimed in claim 2, wherein the first electrodes are each coupled to a top surface of the flexible membranes.

4. The ultrasound transducer assembly as claimed in claim 1, wherein the second electrodes are bottom electrodes attached to an isolation layer.

5. The ultrasound transducer assembly as claimed in claim 4, wherein the isolation layer is attached to a surface of the integrated circuit device.

6. The ultrasound transducer assembly as claimed in claim 1, wherein the second electrodes are rigid electrodes.

7. The ultrasound transducer assembly as claimed in claim 1, wherein a cavity is formed between each of the first electrodes and each of the second electrodes, respectively.

8. The ultrasound transducer assembly as claimed in claim 1, wherein the flexible membranes of the transducer elements are each supported by a spacer.

9. The ultrasound transducer assembly as claimed in claim 8, wherein the vias for connecting the first electrodes to the integrated circuit are fed through the spacers.

10. The ultrasound transducer assembly as claimed in claim 4, wherein the vias are fed through the isolation layer.

11. The ultrasound transducer assembly as claimed in claim 1, wherein the transducer elements are capacitive micro-machined ultrasound transducer elements.

12. The ultrasound transducer assembly as claimed in claim 1, wherein the integrated circuit device is an application specific integrated circuit.

13. The ultrasound transducer assembly as claimed in claim 1, wherein the transducer elements are monolithically formed on the integrated circuit device.

14. The ultrasound transducer assembly as claimed in claim 1, wherein the integrated circuit device and the transducer elements are monolithically integrated on a substrate.

15. An ultrasound imaging system including an ultrasound transducer assembly as claimed in claim 1 for emitting and receiving ultrasound waves.

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专利名称(译)	超声换能器组件		
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[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.		
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发明人	BROCK-FISHER, GEORGE ANTHONY SAVORD, BERNARD JOSEPH		
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摘要(译)

公开了一种超声换能器组件 (50)，特别是用于超声成像系统 (10)，包括换能器阵列 (52)，包括多个换能器元件 (54)，用于发射和接收超声波 (56)。每个换能器元件 (54) 包括连接到柔性膜 (64) 的第一电极 (66) 和第二电极 (70)。该组件还包括连接到换能器阵列 (52) 的集成电路装置 (60)，用于驱动换能器元件 (54)，其中第一电极 (66) 彼此电连接并耦合到集成电路器件 (60) 以提供每个换能器元件的交流驱动电压 (54)，其中第二电极 (70) 连接到电压源，用于向换能器元件提供偏置电压 (54)，并且其中第一电极 (66) 各自通过通孔 (76) 连接到集成电路器件 (60) 并且通孔 (76) 通过第二电极供给 (70 的)。

