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(54) **ULTRASONIC TRANSDUCER UNIT**

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G01S 7/521 (2006.01)
(Continued)

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(58) **Field of Classification Search**
CPC combination set(s) only.
See application file for complete search history.

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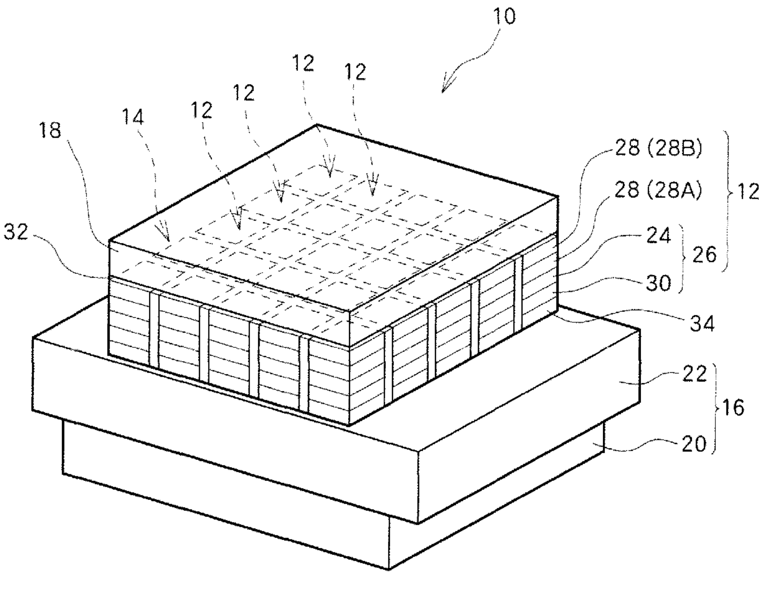
(57) **ABSTRACT**

A resonance layer (**30**) and an acoustic separation layer (**34**) are arranged adjacent to each other between a piezoelectric element (**24**) and a circuit board (**16**) provided with an electronic circuit for driving the piezoelectric element. The acoustic impedance of the resonance layer (**30**) is higher than that of the piezoelectric element (**24**), and the acoustic impedance of the acoustic separation layer (**34**) is lower than that of the circuit board (**16**). An ultrasonic wave is reflected at the interface between the resonance layer (**30**) and the acoustic separation layer (**34**) where the difference in acoustic impedance is large, and the ultrasonic wave propagating to the circuit-board (**16**) side is reduced.

7 Claims, 3 Drawing Sheets



(51) **Int. Cl.**

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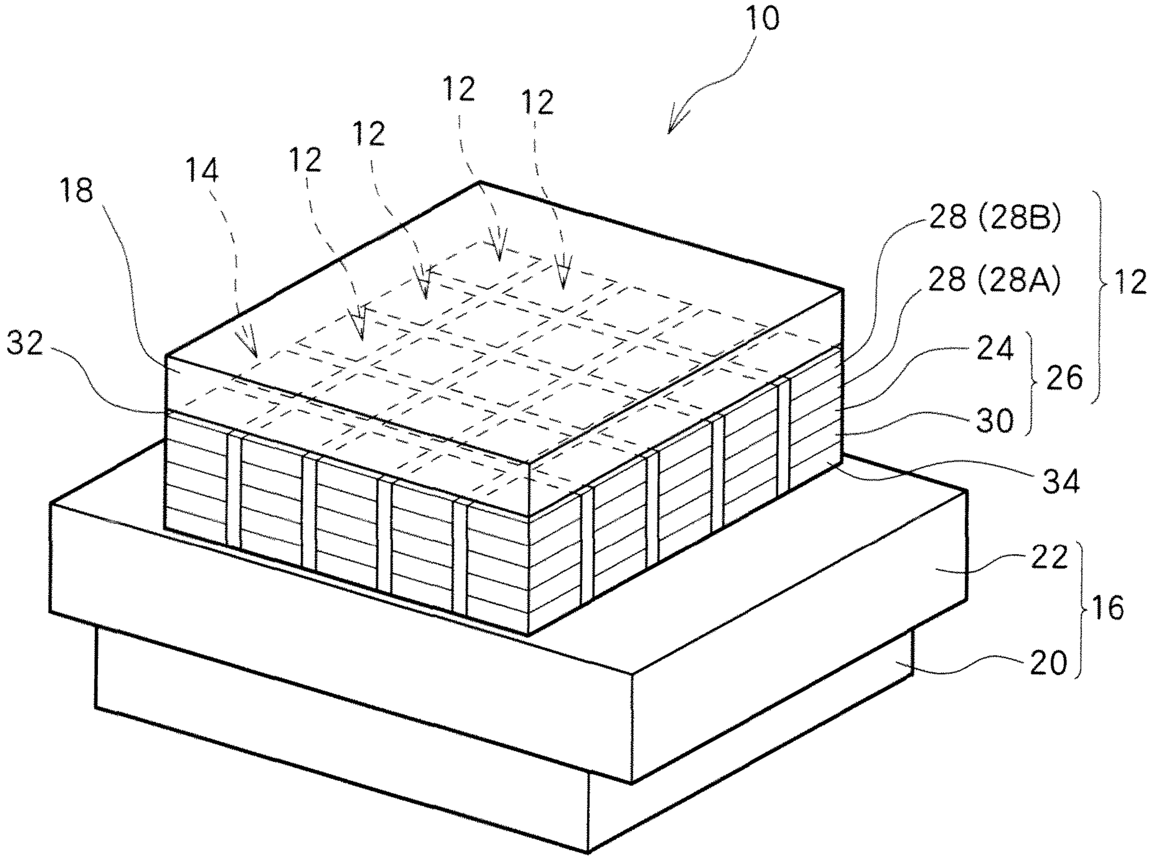

FIG. 1

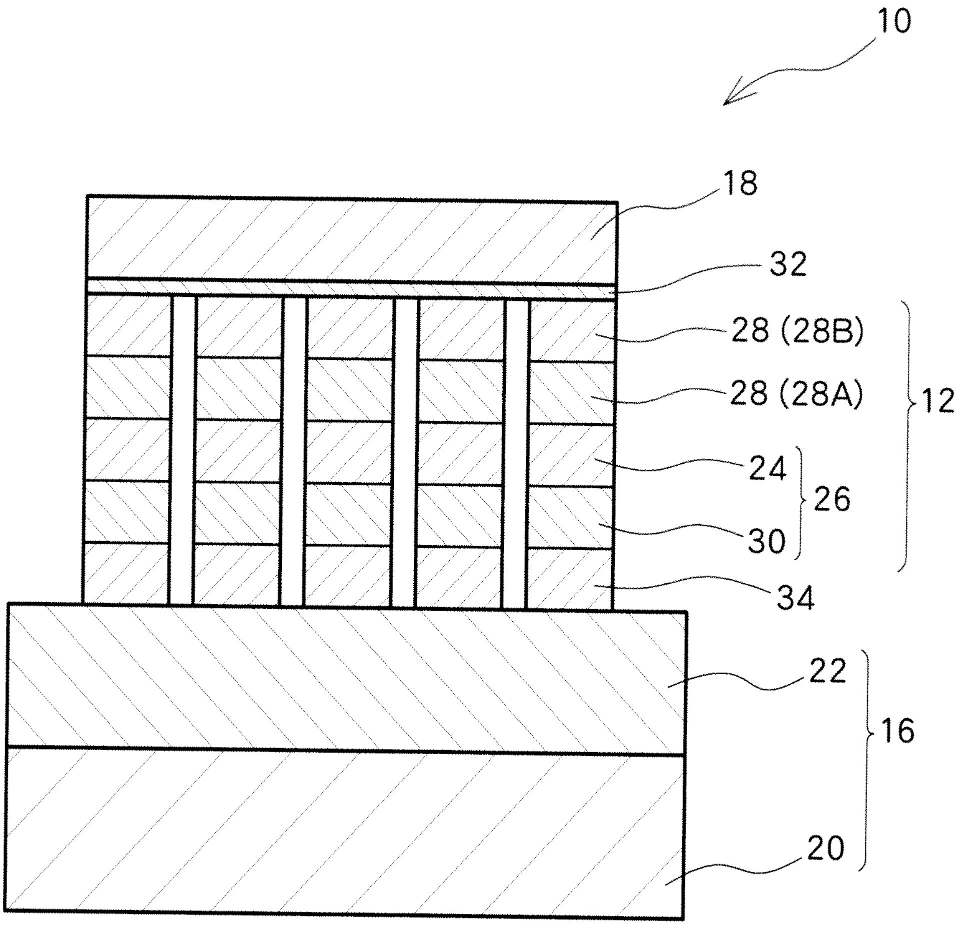

FIG. 2

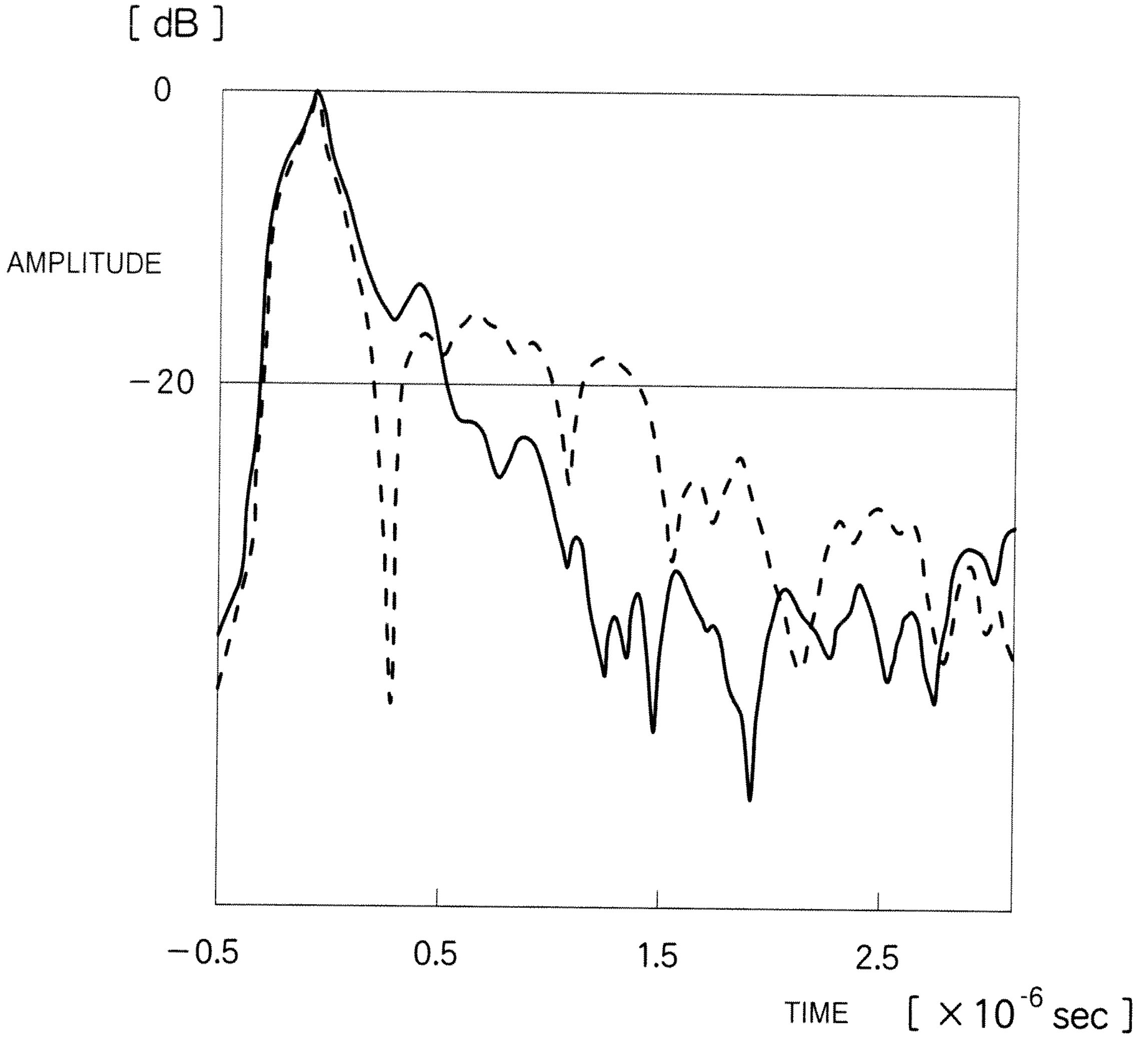

FIG. 3

ULTRASONIC TRANSDUCER UNIT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a national phase claiming the benefit of and priority to International Patent Application No. PCT/JP2016/051286, entitled “ULTRASONIC TRANSDUCER UNIT”, filed Jan. 18, 2016 which claims priority to Japanese Patent Application No. 2015-038544, filed Feb. 27, 2015, which are hereby incorporated by reference in their entireties.

TECHNICAL FIELD

The present disclosure relates to an ultrasound transducer unit used for an ultrasound probe, and in particular, to a structure of the ultrasound transducer unit.

BACKGROUND

Ultrasound diagnostic apparatuses are used in the medical field. An ultrasound diagnostic apparatus is an apparatus which transmits and receives ultrasound to and from a living body, and forms an ultrasound image based on a reception signal obtained by the transmission and reception of the ultrasound. The transmission and reception of the ultrasound to and from the living body are executed by an ultrasound probe (probe). The probe includes a transducer including a piezoelectric element, and ultrasound is transmitted and received by driving the piezoelectric element.

The transducer includes a matching layer placed on a living body side of the piezoelectric element. The matching layer is a layer for acoustically matching the piezoelectric element and the living body, by gradationally reducing an acoustic impedance from the piezoelectric element toward the living body. In addition, the transducer may include a resonance layer placed adjacent to a back surface of the piezoelectric element; that is, a surface opposite from the living body side. An acoustic impedance of the resonance is higher than that of the piezoelectric element, and is useful for resonating with the piezoelectric element to effectively transmit the ultrasound toward the living body. On a back surface of the transducer, a circuit board having an electronic circuit which drives the piezoelectric element is placed. Patent Document 1 shows an example of the ultrasound probe.

CITATION LIST

Patent Literature

Patent Document 1: JP 2005-507581 A

SUMMARY

Technical Problem

When the ultrasound transmitted from the transducer propagates to the circuit board, the ultrasound is reflected within the circuit board, and a part of the ultrasound returns to the transducer and is further transmitted into the living body. The ultrasound reflected in the circuit board is transmitted in a delayed manner from the ultrasound which is directly transmitted. Due to the delay, the ultrasound may form noise, resulting in a possible degradation of the ultrasound image.

An advantage of the present disclosure lies in reduction of the ultrasound propagating from the transducer to the circuit board side.

Solution to Problem

According one aspect of the present disclosure, there is provided an ultrasound transducer unit comprising: a piezoelectric element; a circuit board having an electronic circuit which drives the piezoelectric element; a resonance layer placed between the piezoelectric element and the circuit board, and being higher in acoustic impedance than the piezoelectric element; and an acoustic separation layer placed on a circuit board side of the resonance layer and adjacent to the resonance layer, and being lower in acoustic impedance than the circuit board.

Due to the difference in the acoustic impedance between the resonance layer and the acoustic separation layer, the ultrasound may be reflected at a boundary surface between these layers, and, consequently, propagation of the ultrasound to the circuit board side can be suppressed.

According to another aspect of the present disclosure, the acoustic separation layer may comprise a porous material, in particular, porous carbon.

According to another aspect of the present disclosure, the acoustic impedance of the resonance layer may be greater than or equal to 2.3 times the acoustic impedance of the piezoelectric element, and the acoustic impedance of the acoustic separation layer may be less than or equal to 1/20 of the acoustic impedance of the circuit board. According to another aspect of the present disclosure, the acoustic impedance of the acoustic separation layer may be 1/70 the acoustic impedance of the resonance layer.

Advantageous Effects of Invention

According to various aspects of the present disclosure, the ultrasound can be reflected at the boundary surface between the acoustic separation layer and the resonance layer and propagation of the ultrasound to the circuit board can be suppressed. Consequently, the noise due to ultrasound reflected within the circuit board can be reduced.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a perspective diagram schematically showing a structure of an ultrasound transducer unit according to an embodiment of the present disclosure.

FIG. **2** is a cross-sectional diagram schematically showing a structure of an ultrasound transducer unit according to an embodiment of the present disclosure.

FIG. **3** is a diagram showing an effect of an acoustic separation layer.

DESCRIPTION OF EMBODIMENTS

An embodiment of the present disclosure will now be described with reference to the drawings. FIG. **1** is a perspective diagram showing an ultrasound transducer unit **10** according to an embodiment of the present disclosure. FIG. **2** is a cross sectional diagram of the ultrasound transducer unit **10**. The ultrasound transducer unit **10** is built in a probe of an ultrasound diagnostic apparatus, and transmits and receives ultrasound to and from a living body which the probe contacts. A transmission direction of the ultrasound in FIG. **1** is upward. In the following description, the terms related to an up-and-down relationship such as “upper” and “lower” merely describe the up-and-down relationship in the figures, and do not mean the up-and-down relationship in usage or the like.

The ultrasound transducer unit **10** includes a two-dimensional array transducer **14** in which individual transducers **12** are arranged vertically and horizontally. In the array transducer **14** shown in the figure, the same number of individual transducers **12** are arranged vertically and horizontally, to form an approximate square as a whole. In the figures, for the purpose of description, the number of the individual transducers **12** is set to 5×5=25, but the actual array transducer **14** includes many more individual transducers **12**, for example, thousands of individual transducers **12**. In this structure, an ultrasound beam can be scanned in an arbitrary angle. From data within a three-dimensional space captured by scanning of an arbitrary angle, a three-dimensional ultrasound image representing the three-dimensional space can be formed. Alternatively, from the data, an ultrasound image at an arbitrary cross section may be formed. Alternatively, the array transducer may be a one-dimensional array in which the individual transducers **12** are arranged in a straight line. Alternatively, the array transducer may be an approximate rectangular array in which different numbers of individual transducers **12** are arranged in the vertical direction and the horizontal direction.

The ultrasound transducer unit **10** has a circuit board **16** having an electronic circuit which drives the array transducer **14**, and a protection layer **18** which covers and protects the array transducer **14**. In the case of the ultrasound transducer unit **10**, the circuit board **16** has an electronic circuit board **20** on which an electronic circuit is formed, and a relay board **22** having a wiring or a circuit for connecting the electronic circuit and the individual transducer **12**. The relay board **22** may have a function to switch a connection between terminals on the electronic circuit and the individual transducers **12**.

The individual transducer **12** includes a transducer element **26** including a piezoelectric element **24**, and an acoustic matching layer **28**. The transducer element **26** includes a resonance layer **30** in addition to the piezoelectric element **24**. The resonance layer **30** is placed on a back side of the piezoelectric element **24**; that is, on a side opposite from the direction of transmission and reception of the ultrasound. The resonance layer **30** is also higher in acoustic impedance than the piezoelectric element **24**, and forms a hard back layer, and the piezoelectric element **24** and the resonance layer **30** as a whole transmit and receive the ultrasound. The acoustic impedances of the piezoelectric element **24** and the resonance layer **30** are, for example, 30 MRayl and 70 to 100 MRayl, respectively. The acoustic impedance of the resonance layer **30** is greater than or equal to 2.3 times the acoustic impedance of the piezoelectric element **24**. A material of the resonance layer **30** is a resin material including a conductive filler such as carbon and tungsten, a metal, an alloy, a sintered structure of metal, a sintered structure of metal and an inorganic material, or a composite of these. The resonance layer **30** is useful in effectively transmitting the ultrasound to the living body by resonating with the piezoelectric element **24**. The acoustic impedance of the circuit board **16**, in particular, the relay board **22**, is about 20 MRayl.

The acoustic matching layer **28** is a layer for acoustically matching the piezoelectric element **24** and the living body by gradationally reducing the acoustic impedance from the piezoelectric element **24** toward the living body. The acoustic matching layer **28** may be formed from only one layer, or may include a plurality of layers, in order to smoothly reduce the acoustic impedance toward the living body. In the example structure shown in the figures, the acoustic matching layer **28** includes two layers, a first acoustic matching layer **28**A and a second acoustic matching layer **28**B.

On a surface of the individual transducer **12** facing the protection layer **18**, a ground electrode **32** common for all individual transducers **12** is joined. The acoustic matching layer **28** has conductivity, and electrically connects the ground electrode **32** and the transducer element **26**. In the acoustic matching layer **28**, in order to introduce conductivity, there may be used a resin to which glass-form carbon, carbon, a graphite material, or a conductive filler is mixed. The resin may be, for example, an epoxy resin.

On a back side of the resonance layer **30**; that is, on the side of the circuit board **16**, an acoustic separation layer **34** is placed adjacent to the resonance layer **30**. The acoustic separation layer **34** is lower in acoustic impedance than the piezoelectric element **24** and the circuit board **16**. The relay board **22** and the electronic circuit board **20** included in the circuit board **16** are approximately equal in acoustic impedance. However, when these impedances differ from each other, the acoustic impedance of the acoustic separation layer **34** is set lower than the acoustic impedance of the relay board **22** placed on the side of the acoustic separation layer **34**. When there is no relay board **22**, the acoustic impedance of the acoustic separation layer **34** is set lower than the acoustic impedance of the electronic circuit board **20**. By placing the resonance layer **30** being higher in acoustic impedance than the piezoelectric element **24** and the acoustic separation layer **34** being lower in acoustic impedance than the circuit board **16** adjacent to each other, a large difference in acoustic impedance is created at the boundary between the resonance layer **30** and the acoustic separation layer **34**. With such a configuration, the ultrasound reflects at the boundary surface between the resonance layer **30** and the acoustic separation layer **34**, and the amount of ultrasound propagating to the circuit board **16** is reduced. By setting the acoustic impedance of the resonance layer **30** to be higher than that of the piezoelectric element **24**, and the acoustic impedance of the acoustic separation layer **34** to be lower than that of the relay board **22**, the difference in acoustic impedance between the resonance layer **30** and the acoustic separation layer **34** can be increased.

The individual transducer **12** is connected to an electrode provided on a surface of the circuit board **16** via the acoustic separation layer **34**. The resonance layer **30** and the acoustic separation layer **34** are set to be conductive, and the piezoelectric element **24** and the electrode of the circuit board **16** are electrically connected. The relay board **22** has a function to connect the individual transducer **12** and the electrode provided on an upper surface of the electronic circuit board **20**, and, for example, the connection between the individual transducer **12** and the electrode is realized by a through via provided on the relay board **22**. Placement of the wiring in the relay board **22** enables matching of differences in arrangement and a pitch between the electrode on the electronic circuit board **20** and the individual transducer **12**. Alternatively, a circuit for switching the connection relationship between the electrode on the electronic circuit board **20** and the individual transducer **12** may be provided in the relay board **22**.

As described above, the acoustic separation layer **34** is a layer for causing the ultrasound to be reflected at the boundary surface with the resonance layer **30** by the difference in the acoustic impedance with the resonance layer **30**, and thus, must be formed from a material having a large difference in acoustic impedance from the resonance layer **30**. As described above, the acoustic impedance of the resonance layer **30** is high, and thus, it is desirable to reduce the acoustic impedance of the acoustic separation layer **34**, to achieve a large acoustic impedance difference. In addition, because electricity supplied from the circuit board **16** flows in the acoustic separation layer **34**, a high conductivity is required for the acoustic separation layer **34**. Further, because the acoustic separation layer **34** connects the individual transducer **12** and the circuit board **16**, a high structural strength is also required. Thus, the acoustic separation layer **34** must have a low acoustic impedance, a high conductivity, and a high structural strength.

As a material which satisfies the above-described characteristics required for the acoustic separation layer **34**, a porous material can be exemplified. For example, in production of a sintered conductive member, a pore ratio of 80 percent or greater can be achieved by mixing a binder or the like, and, with this process, the acoustic impedance can be set to be less than or equal to 1 MRayl. More specifically, as the material, a porous metal and porous carbon may be exemplified. Characteristics of a certain porous carbon are: an acoustic impedance of 0.7~1.0 MRayl, a specific resistance of about 2 to 20×10^{-2} Ω cm, and a bending modulus of elasticity of 2 to 15 GPa, which satisfy the above-described required characteristics.

FIG. **3** is a diagram showing an effect of the acoustic separation layer **34** made of porous carbon having the above-described characteristics. A horizontal axis shows elapsed time and a vertical axis shows an amplitude of ultrasound. A broken line shows a graph in a case where the acoustic separation layer **34** is not provided, and a solid line shows a graph in a case where the acoustic separation layer **34** is provided. FIG. **3** shows that a pulse width of the ultrasound at −20 dB became about 50 percent, indicating that the influence due to multiple reflections in a back layer of the acoustic separation layer **34** has been reduced. In the actual ultrasound image also, reduction of acoustic noise due to the multiple reflection is observed.

The acoustic impedance of the acoustic separation layer **34** made of the porous carbon is 1/20 that of the circuit board **16**, and 1/100 to 1/70 that of the resonance layer **30**. It is suggested that, with values lower than these values, the pulse width of the ultrasound may be reduced to 50 percent or less, and the image quality of the ultrasound image can be improved.

Employment of a configuration where the ultrasound is reflected at the boundary surface between the resonance layer **30** and the acoustic separation layer **34** enables improvement in the degree of freedom for selection of materials for the layers placed on the back side of the acoustic separation layer **34**. In the structure of the related art having no acoustic separation layer **34**, the noise has been suppressed by attenuating the ultrasound entering the layers behind the transducer element **26**, such as the circuit board **16**, within such layers. Thus, it has been necessary to select a material having a high attenuation for the material of these layers. By providing the acoustic separation layer **34**, the ultrasound propagating to the layers behind the acoustic separation layer **34** can be reduced, and thus, it becomes possible to select a material with small attenuation.

REFERENCE SIGNS LIST

10 ULTRASOUND TRANSDUCER UNIT; **12** INDIVIDUAL TRANSDUCER; **16** CIRCUIT BOARD; **20** ELECTRONIC CIRCUIT BOARD; **22** RELAY BOARD; **24** PIEZOELECTRIC ELEMENT; **26** TRANSDUCER ELEMENT; **28** ACOUSTIC MATCHING LAYER; **30** RESONANCE LAYER; **34** ACOUSTIC SEPARATION LAYER.

The invention claimed is:

1. An ultrasound transducer unit comprising:

a piezoelectric element;

a circuit board having an electronic circuit which drives the piezoelectric element;

a resonance layer placed between the piezoelectric element and the circuit board, and being higher in acoustic impedance than the piezoelectric element;

an acoustic separation layer placed on a circuit board side of the resonance layer and adjacent to the resonance layer, and being lower in acoustic impedance than the circuit board, wherein

the acoustic impedance of the acoustic separation layer is less than or equal to 1/70 of the acoustic impedance of the resonance layer; and

an acoustic matching layer adjacent to the piezoelectric element and opposite the circuit board for gradationally reducing acoustic impedance from the piezoelectric element.

2. An ultrasound transducer unit comprising:

a piezoelectric element;

a circuit board having an electronic circuit which drives the piezoelectric element, and being lower in acoustic impedance than the piezoelectric element;

a resonance layer placed between the piezoelectric element and the circuit board, and being higher in acoustic impedance than the piezoelectric element;

an acoustic separation layer placed on a circuit board side of the resonance layer and adjacent to the resonance layer, and being lower in acoustic impedance than the circuit board, wherein

the acoustic separation layer comprises a porous material; and

an acoustic matching layer adjacent to the piezoelectric element and opposite the circuit board for gradationally reducing acoustic impedance from the piezoelectric element.

3. The ultrasound transducer unit according to claim **2**, wherein

the acoustic impedance of the acoustic separation layer is less than or equal to 1/70 of the acoustic impedance of the resonance layer.

4. An ultrasound transducer unit comprising:

a piezoelectric element;

a circuit board having an electronic circuit which drives the piezoelectric element, and being lower in acoustic impedance than the piezoelectric element;

a resonance layer placed between the piezoelectric element and the circuit board, and being higher in acoustic impedance than the piezoelectric element; and

an acoustic separation layer placed on a circuit board side of the resonance layer and adjacent to the resonance layer, and being lower in acoustic impedance than the circuit board, wherein

the acoustic separation layer comprises porous carbon; and

an acoustic matching layer adjacent to the piezoelectric element and opposite the circuit board for gradationally reducing acoustic impedance from the piezoelectric element.

5. The ultrasound transducer unit according to claim **4**, wherein the acoustic impedance of the acoustic separation layer is less than or equal to 1/70 of the acoustic impedance of the resonance layer.

6. An ultrasound transducer unit comprising:

a piezoelectric element;

a circuit board having an electronic circuit which drives the piezoelectric element, and being lower in acoustic impedance than the piezoelectric element;

a resonance layer placed between the piezoelectric element and the circuit board, and being higher in acoustic impedance than the piezoelectric element;

an acoustic separation layer placed on a circuit board side of the resonance layer and adjacent to the resonance layer, and being lower in acoustic impedance than the circuit board, wherein

the acoustic impedance of the resonance layer is greater than or equal to 2.3 times the acoustic impedance of the piezoelectric element, and the acoustic impedance of the acoustic separation layer is less than or equal to 1/20 of the acoustic impedance of the circuit board; and

an acoustic matching layer adjacent to the piezoelectric element and opposite the circuit board for gradationally reducing acoustic impedance from the piezoelectric element.

7. The ultrasound transducer unit according to claim **6**, wherein

the acoustic impedance of the acoustic separation layer is less than or equal to 1/70 of the acoustic impedance of the resonance layer.

* * * * *

专利名称(译)	超声波换能器		
公开(公告)号	US10672972	公开(公告)日	2020-06-02
申请号	US15/551304	申请日	2016-01-18
[标]申请(专利权)人(译)	株式会社日立制作所		
申请(专利权)人(译)	HITACHI，LTD.		
当前申请(专利权)人(译)	HITACHI，LTD.		
[标]发明人	MOTOKI KAZUYA KOBAYASHI KAZUHIRO WATANABE TORU		
发明人	MOTOKI, KAZUYA KOBAYASHI, KAZUHIRO WATANABE, TORU		
IPC分类号	H01L41/113 H01L41/09 G01S7/521 A61B8/14 H04R17/10 H04R17/00		
CPC分类号	G01S7/521 H04R17/10 H01L41/09 H04R17/00 A61B8/14 H01L41/113		
代理机构(译)	贝克博茨L.L.P.		
优先权	2015038544 2015-02-27 JP		
其他公开文献	US20180040805A1		
外部链接	Espacenet		

摘要(译)

在压电元件24和电路板16之间设置有共振层30和声音分离层34，所述压电元件彼此相邻，所述压电元件具有用于驱动所述压电元件的电子电路。 压电元件。 谐振层30的声阻抗高于压电元件24的声阻抗，而声分离层34的声阻抗低于电路板的声阻抗（16）。 超声波在声阻抗差大的共振层30与声音分离层34的界面处反射，并向电路板16传播。 ）减少。