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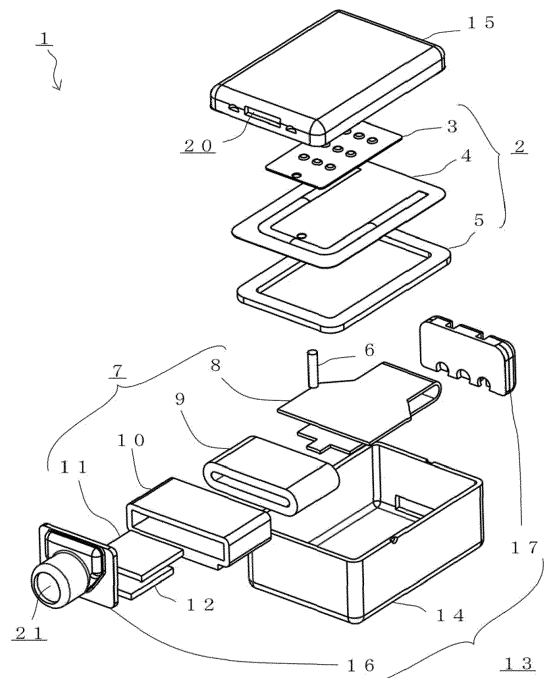
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(54) **ELECTROACOUSTIC DIAPHRAGM AND ELECTROACOUSTIC TRANSDUCER USING SAME**

(57) There are provided an electroacoustic diaphragm and an electroacoustic transducer suitable for a balanced armature electroacoustic transducer employing an electromagnetic drive method. The electroacoustic diaphragm includes a substantially flat plate-shaped diaphragm portion and a drive rod connection portion formed at an end portion of the diaphragm portion and connected to a drive rod. The diaphragm portion includes multiple dimples formed in such a manner that a base material forming the diaphragm portion is deformed in a thickness direction thereof such that one side of the base material is recessed and protrudes to the other side, and a flat portion formed among the multiple dimples such that the base material is not deformed in the thickness direction.

Fig. 2



Description

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

[0001] The present invention relates to an electroacoustic diaphragm of an electroacoustic transducer used for earphones attached to user's ears to reproduce audio, and specifically relates to an electroacoustic diaphragm suitable for a balanced armature electroacoustic transducer.

2. DESCRIPTION OF THE RELATED ART

[0002] A compact lightweight electroacoustic transducer used for earphones attached to user's ears to reproduce audio has been demanded, and a balanced armature electroacoustic transducer as an electromagnetic type electroacoustic transducer has been sometimes used. The electromagnetic type electroacoustic transducer is configured such that an electroacoustic diaphragm connected to a vibratable armature through a drive rod vibrates to convert an electric signal into a sound wave.

[0003] In the balanced armature electroacoustic transducer, the electroacoustic diaphragm vibrates in a compact case. For this reason, a standing wave is easily generated in a sound path, and great pressure is applied to the diaphragm. Strength is demanded for the diaphragm, and therefore, a metal-based material such as aluminum, titanium, or stainless steel is often used. For holding the strength of the diaphragm, ribs are sometimes provided.

[0004] For example, JP-A-2012-004850 discloses an electroacoustic transduction device including a diaphragm unit. The diaphragm unit includes: a drive unit having a pair of magnets arranged facing each other, a yoke attached to the pair of magnets, a coil to which a drive current is supplied, and an armature with a vibration portion vibrating upon supply of the drive current to the coil and arranged between the magnets in a pair through the coil; a holding frame with an opening; a resin film bonded to the holding frame to cover the opening of the holding frame; a diaphragm held in the holding frame with the diaphragm being bonded to the resin film; and a beam portion formed integrally with the diaphragm and having a tip end portion coupled to the vibration portion of the armature to transmit vibration of the vibration portion to the diaphragm.

[0005] Paragraph 0089 of JP-A-2012-004850 discloses as follows: the diaphragm 22 is made of a thin metal material such as aluminum or stainless steel, and is formed in such a rectangular shape that an outer shape thereof is slightly smaller than an inner shape of the holding frame 20; and reinforcement ribs 22a positioned apart from each other in a right-to-left direction are provided to extend in a front-to-back direction at the diaphragm 22, and are formed in an upwardly-protruding shape. As de-

scribed above, when the ribs are provided at the diaphragm in the balanced armature electroacoustic transducer, these ribs are provided only on an upper side to avoid contact with the drive unit. For this reason, there is a problem that sufficient strength cannot be obtained.

[0006] Moreover, in manufacturing of the balanced armature electroacoustic transducer, variation in sound pressure sensitivity is great, leading to a quality control problem. A main cause for such a situation is that the relative position of the diaphragm in a sound path is not stabilized in a case of the balanced armature electroacoustic transducer. That is, when the diaphragm approaches the case forming the sound path to decrease a relative distance, a reproduced sound pressure level might be extremely increased, and for this reason, falls outside an acceptable range in quality control. With the upwardly-protruding ribs at the diaphragm, a similar problem is easily caused.

20 SUMMARY OF THE INVENTION

[0007] The present invention has been made to solve the above-described problem of the typical technique. An object of the present invention is to provide an electroacoustic diaphragm of an electroacoustic transducer used for earphones attached to user's ears to reproduce audio, and specifically provides an electroacoustic diaphragm suitable for a balanced armature electroacoustic transducer employing an electromagnetic drive method.

[0008] The electroacoustic diaphragm of the present invention includes a substantially flat plate-shaped diaphragm portion and a drive rod connection portion formed at an end portion of the diaphragm portion and connected to a drive rod. The diaphragm portion includes multiple dimples formed in such a manner that a base material forming the diaphragm portion is deformed in a thickness direction thereof such that one side of the base material is recessed and protrudes to the other side, and a flat portion formed among the multiple dimples such that the base material is not deformed in the thickness direction.

[0009] Preferably, in the electroacoustic diaphragm of the present invention, the outer shape of a recessed or raised portion defining each dimple is a circular shape or a polygonal shape with substantially equal width and length dimensions.

[0010] Preferably, in the electroacoustic diaphragm of the present invention, the recessed or raised portions defining the multiple dimples are arranged in line in any of longitudinal, transverse, and diagonal directions.

[0011] Preferably, in the electroacoustic diaphragm of the present invention, all of the raised portions defining the multiple dimples are formed on the one side of the base material forming the diaphragm portion.

[0012] Preferably, in the electroacoustic diaphragm of the present invention, the base material forming the diaphragm portion contains at least magnesium or magnesium alloy, and a magnesium hydroxide layer is formed on a surface of the base material.

[0013] The electroacoustic transducer of the present invention includes the above-described electroacoustic diaphragm, a diaphragm frame portion supporting the periphery of the electroacoustic diaphragm, a drive rod portion connected to the drive rod connection portion of the electroacoustic diaphragm, a magnetic drive portion including an armature portion configured to vibrate the drive rod portion, and a case portion housing the magnetic drive portion and the diaphragm frame portion and forming a sound path for guiding a sound wave emitted from the electroacoustic diaphragm to the opposite side of the drive rod portion and the magnetic drive portion.

[0014] The electroacoustic transducer of the present invention is an electroacoustic transducer including an electroacoustic diaphragm configured such that all of raised portions defining multiple dimples are formed on one side of a base material forming a diaphragm portion. The raised portions of the multiple dimples are arranged on a sound path side as the one side of the base material.

[0015] Hereinafter, advantageous effects of the present invention will be described.

[0016] The electroacoustic diaphragm of the present invention is the electroacoustic diaphragm including the substantially flat plate-shaped diaphragm portion and the drive rod connection portion formed at the end portion of the diaphragm portion and connected to the drive rod. Thus, the balanced armature electroacoustic transducer employing the electromagnetic drive method can be configured with the diaphragm frame portion supporting the periphery of the electroacoustic diaphragm, the drive rod portion connected to the drive rod connection portion of the electroacoustic diaphragm, the magnetic drive portion including the armature portion configured to vibrate the drive rod portion, and the case portion housing the magnetic drive portion and the diaphragm frame portion and forming the sound path for guiding the sound wave emitted from the electroacoustic diaphragm to the opposite side of the drive rod portion and the magnetic drive portion.

[0017] In the electroacoustic diaphragm, the diaphragm portion includes the multiple dimples formed in such a manner that the base material forming the diaphragm portion is deformed in the thickness direction such that the one side of the base material is recessed and protrudes to the other side, and the flat portion formed among the multiple dimples such that the base material is not deformed in the thickness direction. The recessed or raised portions defining the multiple dimples are arranged in line in any of the longitudinal, transverse, and diagonal directions. Each dimple is defined by the recessed or raised portion deformed by bending of the base material of the diaphragm portion, and can enhance strength of the diaphragm portion as compared to the case of providing no dimples.

[0018] Thus, even for the electroacoustic diaphragm suitable for the balanced armature electroacoustic transducer including the substantially flat plate-shaped diaphragm portion, sufficient strength can be obtained. Preferably,

the base material forming the diaphragm portion contains the magnesium or the magnesium alloy, and the magnesium hydroxide layer is formed on the surface of the base material. With this configuration, a sound pressure level can be increased with broader reproduced sound pressure frequency properties.

[0019] In the balanced armature electroacoustic transducer, the quality control problem such as a substantial increase in the reproduced sound pressure level is easily caused in a case where the relative position of the diaphragm in the sound path is not stabilized. In the case of the typical diaphragm configured such that the continuously-raised or -recessed ribs are provided at the diaphragm, such a problem becomes more prominent. With the continuous ribs at the diaphragm, the ribs approach an upper surface of the case forming the sound path to expand an area with a short relative distance, and for this reason, the diaphragm is substantially close to the upper surface of the case forming the sound path. However, with the electroacoustic diaphragm including, as in the present invention, the multiple dimples and the flat portion formed among the multiple dimples such that the base material is not deformed in the thickness direction, variation in the reproduced sound pressure level can be reduced, and a yield ratio in manufacturing can be improved.

[0020] The outer shape of the recessed or raised portion defining each dimple of the diaphragm portion of the electroacoustic diaphragm is the circular shape or the polygonal shape with the substantially equal width and length dimensions. As a result, the flat portion where the base material is not deformed in the thickness direction is formed among the multiple dimples. That is, the multiple dimples allow the relatively-broad flat portion of the diaphragm portion without formation of a portion greatly protruding from the flat portion to the one side or the other side, such as the continuously-raised or -recessed rib. Thus, even in a case where the diaphragm portion has sufficient strength, the volume of the sound path in the balanced armature electroacoustic transducer can be increased without a decrease in an average relative distance between the diaphragm and the upper surface of the case forming the sound path.

[0021] Specifically, in the electroacoustic diaphragm, all of the raised portions defining the multiple dimples are preferably formed on the one side of the base material forming the diaphragm portion. In this case, the electroacoustic transducer can be configured such that the raised portions of the multiple dimples are arranged on the sound path side as the one side of the base material. The relative distance between the diaphragm and the upper surface of the case forming the sound path can be increased, and a defect such as noise due to contact between the diaphragm and the magnetic drive portion can be prevented.

[0022] In the electroacoustic diaphragm of the present invention, the diaphragm portion has sufficient strength. In the case of using the balanced armature electroacous-

tic transducer in which the relative position of the diaphragm in the sound path is less stabilized, variation in the reproduced sound pressure level can be reduced, and the yield ratio in manufacturing can be improved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

Figs. 1A and 1B are a sectional view and a perspective view of a specific structure of an electroacoustic transducer of an embodiment of the present invention;

Fig. 2 is a development view of the specific structure of the electroacoustic transducer of the embodiment of the present invention;

Figs. 3A and 3B are perspective views of a specific structure of an electroacoustic diaphragm of the embodiment of the present invention;

Figs. 4A to 4D are perspective views of specific structures of electroacoustic diaphragms of comparative examples;

Fig. 5 shows graphs of sound pressure frequency properties of the electroacoustic transducer of the present invention and an electroacoustic transducer of a comparative example;

Fig. 6 shows graphs of a change in the sound pressure frequency properties due to a change in the relative position of the diaphragm of the electroacoustic transducer of the embodiment of the present invention in a sound path;

Fig. 7 shows graphs of a change in sound pressure frequency properties of an electroacoustic transducer of another embodiment of the present invention;

Fig. 8 shows graphs of a change in the sound pressure frequency properties due to a change in the relative position of the diaphragm of the electroacoustic transducer of the comparative example in a sound path;

Fig. 9 shows graphs of a change in the sound pressure frequency properties due to a change in the relative position of the diaphragm of the electroacoustic transducer of the comparative example in the sound path; and

Fig. 10 shows graphs of a change in the sound pressure frequency properties due to a change in the relative position of the diaphragm of the electroacoustic transducer of the comparative example in the sound path.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] Hereinafter, an electroacoustic diaphragm and an electroacoustic transducer according to preferred embodiments of the present invention will be described, but the present invention is not limited to these embodiments.

[0025] Figs. 1A, 1B, and 2 are views of a specific struc-

ture of an electroacoustic transducer 1 according to one embodiment of the present invention. Fig. 1B is a perspective view of the electroacoustic transducer 1, and Fig. 1A is a sectional view along an A-A line of Fig. 1B.

Moreover, Fig. 2 is a development view for describing the configuration of the electroacoustic transducer 1. Specifically, the electroacoustic transducer 1 is a balanced armature electroacoustic transducer, the balanced armature electroacoustic transducer being an extremely-small substantially parallelepiped rectangular structure with an entire length, which includes a protruding portion, of about 7.35 mm, an entire width of about 3.45 mm, and an entire height of about 3.00 mm. Thus, the electroacoustic transducer 1 is an electroacoustic transducer suitable for earphones attached to user's ears to reproduce audio, specifically canal earphones etc.

[0026] The electroacoustic transducer 1 includes a diaphragm 3 in a case 13 forming a housing of the electroacoustic transducer 1. The electroacoustic transducer 1 is configured to perform electroacoustic conversion of an audio signal supplied to a terminal 17 to vibrate the diaphragm 3, thereby reproducing audio from an output hole 21. A diaphragm unit 2 including the diaphragm 3, a drive rod 6 connected to the diaphragm unit 2, and a magnetic drive portion 7 including an armature 8 configured to vibrate the drive rod 6 are housed in the case 13.

[0027] The case 13 includes a substantially parallelepiped rectangular lower case body 14, an upper case body 15 covering an upper surface of the lower case body 14, a nozzle portion 16 defining the output hole 21, and the terminal 17 to which the audio signal is input. The lower case body 14, the upper case body 15, and the nozzle portion 16 are made of a metal material such as non-magnetic aluminum. The inside of the case 13 is, with respect to the diaphragm unit 2, separated into a space 18 where the magnetic drive portion 7 is housed and a sound path 19 for guiding a sound wave emitted from the diaphragm 3. The sound path 19 communicates, through a sound hole 20 provided at the upper case body 15, with the output hole 21 defined by the nozzle portion 16.

[0028] The diaphragm unit 2 includes the substantially flat plate-shaped diaphragm 3, an edge 4 flexibly supporting the periphery of the diaphragm 3, and a diaphragm frame 5 fixing the periphery of the edge 4 to the case 13. As will be described later, the diaphragm 3 has a substantially flat plate-shaped diaphragm portion 30 and a drive rod connection portion 31 formed at an end portion of the diaphragm portion 30 and connected to the drive rod 6. Moreover, multiple dimples 32 are formed at the diaphragm 3. The periphery of the diaphragm 3 is supported by the flexible edge 4, and therefore, the diaphragm 3 vibrates in accordance with vibration of the drive rod 6. The edge 4 is formed of a film material having a thickness of about 15 μm and using urethane-based elastomer as a material. The diaphragm frame 5 is made of a material similar to that of the case 13. The diaphragm frame 5 fixes an outer peripheral side of the flexible edge

4, and is fixed to a predetermined inner peripheral side position of the lower case body 14.

[0029] The drive rod 6 is, at one end side thereof, connected to the diaphragm 3 of the diaphragm unit 2, and is, at the other end side thereof, connected to the armature 8 of the magnetic drive portion 7. The drive rod 6 is a rod-shaped member having a diameter of about 0.05 mm and using stainless steel as a material. The one end side of the drive rod 6 is fitted in the drive rod connection portion 31 as a hole formed at the end portion of the diaphragm portion 30. The other end side of the drive rod 6 is coupled to a vibratable end portion of the armature 8. The armature 8 is a member formed in such a manner that a plate material of permalloy as ferromagnetic metal is formed into a predetermined shape and the resultant is bent in a substantially U-shape or a substantially E-shape.

[0030] The magnetic drive portion 7 including the armature 8 further includes an annular coil 9 as a winding to which the audio signal is supplied from the terminal 17, an annular yoke 10 attached adjacent to the coil 9 and made of magnetic metal, and magnets 11, 12 attached to the inside of the yoke 10. The yoke 10 and the magnetized magnets 11, 12 generate a direct-current magnetic field in a magnetic gap formed among these components. An end side of the armature 8 to which the drive rod 6 is coupled is, through the inside of the annular coil 9 and the annular yoke 10, arranged in the magnetic gap in a vibratable state. On the other hand, the opposite end side of the armature 8 to which the drive rod 6 is not coupled is fixed to an upper end surface of the yoke 10.

[0031] In the electromagnetic type electroacoustic transducer 1, the magnetic field generated in the magnetic gap where the armature 8 as a magnetic body is arranged is changed, and a change in attraction of the magnetic field is utilized. That is, the armature 8 needs to be arranged in the vibratable state at a predetermined position in the magnetic gap with balance between elastic force of the bent armature 8 and the attraction of the direct-current magnetic field formed by the magnets 11, 12. When the audio signal is supplied to the coil 9, an alternate-current magnetic field according to a signal current is generated, and the armature 8 as the magnetic metal is magnetized. One end side of the armature 8 is arranged in the vibratable state in the magnetic gap where the direct-current magnetic field is generated, and therefore, drive force acts to perform push-pull operation according to a magnetization change. As a result, the armature 8 vibrates to move the drive rod 6 in an upper-to-lower direction as viewed in the A-A sectional view of Fig. 1A.

[0032] Thus, in the electroacoustic transducer 1, the diaphragm 3 of the diaphragm unit 2 connected to the drive rod 6 vibrates in the upper-to-lower direction as viewed in the A-A sectional view of Fig. 1A, thereby generating the sound wave in the sound path 19. As illustrated in the sectional view of Fig. 1A, the sound path 19 is a space defined on an upper side (an F-side) with re-

spect to a predetermined position Z0 of the diaphragm unit 2 in the case 13, and communicates with the output hole 21 as a sound wave outlet. The sound path 19 is an extremely-small space, and a greater distance between the diaphragm 3 of the diaphragm unit 2 and an inner surface of the upper case body 15 results in a greater volume of the sound path 19.

[0033] On the other hand, the space 18 where the drive rod 6 and the magnetic drive portion 7 are housed is, as illustrated in the sectional view of Fig. 1A, necessary on a lower side of the diaphragm unit 2 in the case 13. The magnetic drive portion 7 and the armature 8 need to be sufficiently separated toward a lower side (a B-side) with respect to the position Z0 of the diaphragm unit 2 such that no noise is generated due to contact even when the diaphragm 3 of the diaphragm unit 2 vibrates with a great amplitude. If the space 18 is expanded, the sound path 19 on the opposite side with respect to the diaphragm unit 2 is narrowed, and therefore, the space 18 and the sound path 19 are in an opposing relationship.

[0034] In a typical balanced armature electroacoustic transducer, a quality control program such as a significant increase in a reproduced sound pressure level is easily caused in a case where the position Z0 of the diaphragm 3 of the diaphragm unit 2 is not stabilized at a manufacturing step. That is, when the stationary position of the diaphragm 3 in the extremely-narrow sound path 19 is slightly moved to the upper side (the F-side) or the lower side (the B-side) from Z0 as the predetermined position, the volume of the sound path 19 changes, and as a result, a problem leading to variation in the reproduced sound pressure level is caused. When the diaphragm 3 approaches the inner surface of the upper case body 15 forming the sound path 19 to decrease a relative distance, the reproduced sound pressure level might be extremely increased.

[0035] Figs. 3A and 3B are perspective views of a specific structure of the diaphragm 3 of the present embodiment. In the electroacoustic transducer 1 of the present embodiment, the diaphragm 3 of the diaphragm unit 2 illustrated in Figs. 1A, 1B, and 2 is formed as a diaphragm 3a or a diaphragm 3b provided with the multiple dimples 32 as illustrated in the figures and as described later. In this manner, the problem caused in the typical balanced armature electroacoustic transducer is solved. Hereinafter, the electroacoustic transducer 1 using the diaphragm 3a illustrated in Fig. 3A or the diaphragm 3b illustrated in Fig. 3B will be described as a specific example of the diaphragm 3 illustrated in Figs. 1A, 1B, and 2.

[0036] In the diaphragm 3a, 3b of the present embodiment, the diaphragm portion 30 is formed of a base material containing magnesium or magnesium alloy. The diaphragm 3a, 3b of the present embodiment is an extremely-small lightweight diaphragm. The size of the diaphragm 3a, 3b is about 3.96 mm in a longitudinal direction and about 2.20 mm in a transverse direction, and the thickness of the base material is about 0.045 mm. A magnesium hydroxide layer is formed on a surface of the

base material containing the magnesium alloy in the diaphragm 3a, 3b. Thus, as compared to the case of forming no magnesium hydroxide layer, surface hardness is improved, and stiffness is enhanced. Consequently, sufficient strength can be obtained.

[0037] The diaphragms 3a, 3b are common with each other on the following points: the diaphragm 3a, 3b has the substantially flat plate-shaped diaphragm portion 30 and the drive rod connection portion 31 formed at the end portion of the diaphragm portion 30 and connected to the drive rod 6; the multiple dimples 32 (or 33) are formed at the diaphragm 3a, 3b; and a flat portion 34 where the base material does not deform in a thickness direction thereof is formed among the multiple dimples 32. Differences between the diaphragms 3a, 3b are the number of multiple dimples 32 (or 33) and the direction and arrangement of the dimples 32 (or 33). The outer shape of a recessed or raised portion defining the dimple of the present embodiment is a circular shape, and the diameter of the outer shape is about 0.30 mm. Moreover, a distance from the flat portion 34 to a protruding tip end, i.e., the height of the recessed or raised portion defining the dimple, is about 0.05 mm.

[0038] In the diaphragm 3a, the total of 25 dimples 32, 33 in five lines and five columns are provided at the substantially flat plate-shaped diaphragm portion 30. The dimples 32 are dimples raised toward the upper side (the F-side). Conversely, the dimples 33 are dimples raised toward the lower side (the B-side). The dimple described herein is a portion formed in such a manner that the base material forming the diaphragm portion 30 is deformed in the thickness direction thereof such that one side of the base material is recessed and the other side of the base material protrudes. Thus, as viewed from the upper side (the F-side) toward which the dimples 32 protrude in a raised shape, the dimples 33 are portions formed in a recessed shape and protruding toward the other side. In the diaphragm 3a, the raised dimples 32 and the recessed dimples 33 are alternately arranged in the longitudinal or transverse direction. As a result, the raised dimples 32 or the recessed dimples 33 are sequentially provided in a diagonal direction. As will be described later, the diaphragm 3a, the flat portion 34 where the base material does not deform in the thickness direction thereof is broadly formed among the multiple dimples.

[0039] Next, in the diaphragm 3b, the total of nine dimples 32 in three lines and three columns are provided at the substantially flat plate-shaped diaphragm portion 30. The dimples 32 are dimples raised toward the upper side (the F-side). As viewed from the upper side (the F-side), only the dimples 32 protruding in a raised shape are arranged in the diaphragm 3b. That is, all of the raised portions defining the dimples 32 are formed on one side of the base material forming the diaphragm portion 30. Moreover, in the diaphragm 3b, the flat portion 34 where the base material does not deform in the thickness direction thereof is more broadly formed among the multiple dimples 32.

[0040] The dimples 32, 33 enhance stiffness of the substantially flat plate-shaped diaphragm portion 30 in the diaphragm 3a, 3b, and as a result, stiffness of the diaphragm 3a, 3b can be enhanced. The outer shape of the recessed or raised portion defining the dimple in the present embodiment is the circular shape with a diameter of about 0.30 mm, but is not limited to the circular shape. Such an outer shape may be an oval or track shape or a polygonal shape with substantially equal width and length dimensions. Alternatively, the outer shape may be a regular polygonal shape (e.g., a regular triangular shape, a regular quadrangular shape, a regular pentagonal shape, a regular hexagonal shape, a regular octagonal shape, and a regular dodecagonal shape). The diaphragm 3a, 3b of the present embodiment includes the dimples 32 and/or the dimples 33 for enhancing the stiffness of the substantially flat plate-shaped diaphragm portion 30. Thus, the flat portion 34 in the diaphragm portion 30 is formed relatively broad without formation of a portion greatly protruding from the flat portion 34 to the one side or the other side. Consequently, the stiffness is enhanced as compared to the case of a typical diaphragm 300 configured such that continuously-protruding ribs are formed as described later, and the problem leading to variation in the reproduced sound pressure level can be avoided.

[0041] Figs. 4A to 4D are perspective views of a specific structure of the diaphragm 300 of a comparative example. Specifically, Figs. 4A to 4D each illustrate diaphragms 300a to 300d of comparative examples common with the diaphragms 3a, 3b of the present embodiment on such a point that the diaphragm portion 30 is formed of the base material containing the magnesium or the magnesium alloy. For example, the diaphragm 300a of Fig. 4A is different from the embodiment and other comparative examples in that the substantially flat plate-shaped diaphragm portion 30 does not include the structure for enhancing the stiffness, such as the dimples or the ribs. Thus, the diaphragm 300a of the comparative example is, needless to say, not provided with the portion greatly protruding from the flat portion 34 of the diaphragm portion 30 to the one side or the other side.

[0042] Next, the diaphragms 300b to 300d of the comparative examples are different from the diaphragms 3a, 3b of the embodiment in that the stiffness enhancing structure provided at the diaphragm portion 30 is not the multiple dimples but the ribs with a greater length than a width. Fig. 4B is the perspective view of the diaphragm 300b configured such that three ribs 35 elongated in the longitudinal direction are provided at the substantially flat plate-shaped diaphragm portion 30. All of the three ribs 35 of the diaphragm 300b are ribs protruding in a raised shape as viewed from the upper side (the F-side). A distance from the flat portion 34 to a protruding tip end, i.e., the height of the rib 35, is about 0.08 mm.

[0043] Thus, in the diaphragm 300b of the comparative example, the ribs 35 greatly protruding to the upper side from the flat portion 34 are formed, and therefore, the flat

portion 34 in the diaphragm portion 30 is relatively narrow. Moreover, in the diaphragm 300b, the ribs 35 are closer to the inner surface of the upper case body 15 forming the sound path 19, and therefore, a relative distance between the diaphragm 300b and the inner surface of the upper case body 15 is substantially smaller than that in the case of the embodiment.

[0044] Next, Fig. 4C is the perspective view of the diaphragm 300c configured such that three ribs 36 elongated in the longitudinal direction are provided at the substantially flat plate-shaped diaphragm portion 30. All of the three ribs 36 of the diaphragm 300c are ribs formed in a recessed shape as viewed from the upper side (the F-side) and protruding in a raised shape as viewed from the lower side (the B-side). The height of the rib 36 is the same as that of the above-described rib 35. Thus, the ribs 36 greatly protruding to the lower side from the flat portion 34 are formed at the diaphragm 300c of the comparative example, and therefore, the flat portion 34 in the diaphragm portion 30 is relatively narrow. Moreover, in the diaphragm 300c, the ribs 36 are further from the inner surface of the upper case body 15 forming the sound path 19, and therefore, a relative distance between the diaphragm 300c and the inner surface of the upper case body 15 is substantially larger than that in the case of the embodiment.

[0045] Further, Fig. 4D is the perspective view of the diaphragm 300d configured such that three ribs 35, 36, 35 elongated in the longitudinal direction are provided at the substantially flat plate-shaped diaphragm portion 30. The two ribs 35 of the diaphragm 300d are ribs protruding in the raised shape as viewed from the upper side (the F-side), and the rib 36 is a rib formed in the recessed shape as viewed from the upper side (the F-side) and protruding in the raised shape as viewed from the lower side (the B-side). Thus, the ribs 35 greatly protruding to the upper side from the flat portion 34 and the rib 36 greatly protruding to the lower side from the flat portion 34 are formed at the diaphragm 300d of the comparative example, and therefore, the flat portion 34 in the diaphragm portion 30 is relatively narrow. Moreover, in the diaphragm 300d, the ribs 35 are closer to the inner surface of the upper case body 15 forming the sound path 19, and on the other hand, the rib 36 is further from such an inner surface.

[0046] Fig. 5 shows graphs of sound pressure frequency properties of the electroacoustic transducer 1 of the present embodiment and a (not-shown) electroacoustic transducer of a comparative example. Specifically, the electroacoustic transducer 1 is that including the diaphragm 3a of the above-described embodiment, and is indicated by a thick solid line of the graph. On the other hand, the electroacoustic transducer of the comparative example is that including the diaphragm 300a or the diaphragm 300b of the above-described comparative examples instead of the diaphragm 3a of the embodiment. The case of the diaphragm 300a of the comparative example is indicated by a thin dashed line, and the case of

the diaphragm 300b of the comparative example is indicated by a thin chain line. Note that the graphs of Fig. 5 show, common to the cases of the embodiment and the comparative examples, a case where a tube (an inner diameter of about 1.4 mm $\times$ a length of about 10 mm) is attached to the nozzle portion 16 defining the output hole 21, assuming an embodiment of earphones.

[0047] Thus, the graphs of Fig. 5 show a diaphragm stiffness improvement effect exerted by the multiple dimples 32, 33 of the diaphragm 3a of the above-described embodiment. In the case of the diaphragm 3a including the multiple dimples 32, 33, there is an advantage that the reproduced sound pressure level is increased as compared to the case of the diaphragm 300a not having the stiffness enhancing structure such as the ribs at the substantially flat plate-shaped diaphragm portion 30 in a frequency band of equal to or lower than about 3 kHz. Moreover, a peak frequency in a secondary resonance mode is about 6 kHz in the case of the diaphragm 300a of the comparative example, and is about 8 kHz in the case of the diaphragm 300b of the comparative example. On the other hand, such a peak frequency increases to about 10 kHz in the diaphragm 3a of the embodiment. This shows that the stiffness of the diaphragm portion 30 is highest in the case of the diaphragm 3a of the embodiment, and shows that a frequency band reproducible by the electroacoustic transducer 1 including the diaphragm 3a is extended to a higher frequency band than that of the case of the comparative examples.

[0048] Next, Fig. 6 shows graphs of an exhibited change in the sound pressure frequency properties in a case where the relative position of the diaphragm 3a of the electroacoustic transducer 1 of the embodiment has changed in the sound path 19. Specifically, the electroacoustic transducer 1 is common on such a point that the electroacoustic transducer 1 includes the diaphragm 3a of the above-described embodiment. A graph indicated by a thick solid line shows F:0.26/B:0.60 in the case of the diaphragm 3a at the standard position Z0, and shows a case where a distance from the diaphragm 3a to the upper case body 15 forming the sound path 19 is about 0.26 mm. On the other hand, a graph indicated by a thin dashed line shows F:0.10/B:0.76 in the case of the diaphragm 3a at a position slightly on the upper side with respect to the standard position Z0, and shows a case where the distance from the diaphragm 3a to the upper case body 15 forming the sound path 19 is shortened by a difference of about 0.16 mm. Similarly, a graph indicated by a thin chain line shows F:0.43/B:0.43 in the case of the diaphragm 3a at a position slightly on the lower side with respect to the standard position Z0, and shows a case where the distance from the diaphragm 3a to the upper case body 15 forming the sound path 19 is increased by a difference of about 0.17 mm.

[0049] That is, the graphs of Fig. 6 show a range where variation in the reproduced sound pressure level might be caused in a case where the stationary position of the diaphragm 3a in the extremely-narrow sound path 19 has

moved to the upper side (the F-side) or the lower side (the B-side) from Z0 as the predetermined position. The case of the thin dashed line shows that the sound pressure level might increase by about 10 dB in a frequency band of equal to or lower than about 8 kHz as a main audio reproduction band when the diaphragm 3a is attached to a position slightly on the upper side (the F-side) from Z0 as the predetermined position. On the other hand, the case of the thin chain line shows that the sound pressure level might decrease by about 5 dB when the diaphragm 3a is attached to a position slightly on the lower side (the B-side) from Z0 as the predetermined position. Preferably, regardless of the stationary position of the diaphragm 3a, no change is, with less variation in the reproduced sound pressure level, made from the thick solid line indicating the case of the diaphragm 3a at Z0 as the predetermined position.

[0050] Next, Fig. 7 shows, as in the case of Fig. 6, an exhibited change in the sound pressure frequency properties in a case where the relative position of the diaphragm 3b of the electroacoustic transducer 1 of the present embodiment in the sound path 19 has changed. As in the case of the diaphragm 3a of the above-described embodiment, a graph indicated by a thick solid line shows F:0.26/B:0.60 in the case of the diaphragm 3b at the standard position Z0, a graph indicated by a thin dashed line shows F:0.10/B:0.76 in the case of the diaphragm 3b at a position slightly on the upper side with respect to the standard position Z0, and a graph indicated by a thin chain line shows F:0.43/B:0.43 in the case of the diaphragm 3b at a position slightly on the lower side with respect to the standard position Z0.

[0051] The graphs of Fig. 7 similarly show a range where variation in the reproduced sound pressure level might be caused in a case where the stationary position of the diaphragm 3b of the embodiment in the extremely-narrow sound path 19 has moved to the upper side (the F-side) or the lower side (the B-side) from Z0 as the predetermined position. However, a difference between the graph indicated by the thin dashed line and the graph indicated by the thin chain line is not different much from that in the case of Fig. 6 in a frequency band of equal to or lower than about 8 kHz as the main audio reproduction band. As will be described later, in the case of the diaphragm 3a or the diaphragm 3b of the embodiment, variation in the reproduced sound pressure level is relatively small even when the diaphragm shifts from the predetermined position.

[0052] Next, Fig. 8 shows, as in the case of Fig. 6 or 7, an exhibited change in the sound pressure frequency properties in a case where the relative position of the diaphragm 300b of the electroacoustic transducer of the comparative example in the sound path 19 has changed. A graph indicated by a thick solid line shows F:0.26/B:0.60 in the case of the diaphragm 300b at the standard position Z0, a graph indicated by a thin dashed line shows F:0.10/B:0.76 in the case of the diaphragm 300b at a position slightly on the upper side with respect

to the standard position Z0, and a graph indicated by a thin chain line shows F:0.43/B:0.43 in the case of the diaphragm 300b at a position slightly on the lower side with respect to the standard position Z0.

[0053] The graphs of Fig. 8 show that the range of variation in the reproduced sound pressure level might be increased as compared to the case of the diaphragm 3a or the diaphragm 3b of the embodiment as illustrated in Fig. 6 or 7 in a case where the stationary position of the diaphragm 300b in the extremely-narrow sound path 19 has moved to the upper side (the F-side) or the lower side (the B-side) from Z0 as the predetermined position. The graphs of Fig. 8 show that a difference between the graph indicated by the thin dashed line and the graph indicated by the thin chain line is greater than that in the case of Fig. 6 or 7 in a frequency band of equal to or lower than about 8 kHz as the main audio reproduction band. Thus, there is a probability that variation in the reproduced sound pressure level is greater than that in the case of the embodiment.

[0054] Next, Fig. 9 shows, as in the cases of Figs. 6 to 8, an exhibited change in the sound pressure frequency properties in a case where the relative position of the diaphragm 300c of the electroacoustic transducer of the comparative example in the sound path 19 has changed. A graph indicated by a thick solid line shows F:0.26/B:0.60 in the case of the diaphragm 300c at the standard position Z0, a graph indicated by a thin dashed line shows F:0.10/B:0.76 in the case of the diaphragm 300c at a position slightly on the upper side with respect to the standard position Z0, and a graph indicated by a thin chain line shows F:0.43/B:0.43 in the case of the diaphragm 300c at a position slightly on the lower side with respect to the standard position Z0.

[0055] The graphs of Fig. 9 show that the range of variation in the reproduced sound pressure level might be increased as compared to the case of the diaphragm 3a or the diaphragm 3b of the embodiment as illustrated in Fig. 6 or 7 in a case where the stationary position of the diaphragm 300c in the extremely-narrow sound path 19 has moved to the upper side (the F-side) or the lower side (the B-side) from Z0 as the predetermined position. The graphs of Fig. 9 show that there is, in a frequency band of equal to or lower than about 8 kHz as the main audio reproduction band, almost no difference between the graph indicated by the thick solid line and the graph indicated by the thin chain line and there is even a frequency band where such a relationship is inverted. This shows the probability of reaching the lower limit in an acceptable range in quality control even when the diaphragm 300c is arranged at Z0 as the predetermined position, and a problem that improvement of a yield ratio in manufacturing cannot be expected might be caused.

[0056] Next, Fig. 10 shows, as in the cases of Figs. 6 to 9, an exhibited change in the sound pressure frequency properties in a case where the relative position of the diaphragm 300d of the electroacoustic transducer of the comparative example in the sound path 19 has changed.

A graph indicated by a thick solid line shows F:0.26/B:0.60 in the case of the diaphragm 300d at the standard position Z0, a graph indicated by a thin dashed line shows F:0.10/B:0.76 in the case of the diaphragm 300d at a position slightly on the upper side with respect to the standard position Z0, and a graph indicated by a thin chain line shows F:0.43/B:0.43 in the case of the diaphragm 300d at a position slightly on the lower side with respect to the standard position Z0.

[0057] The graphs of Fig. 10 show that the range of variation in the reproduced sound pressure level might be significantly increased as compared to the case of the diaphragm 3a or the diaphragm 3b of the embodiment as illustrated in Fig. 6 or 7 in a case where the stationary position of the diaphragm 300d in the extremely-narrow sound path 19 has moved to the upper side (the F-side) or the lower side (the B-side) from Z0 as the predetermined position. The graphs of Fig. 10 show that a difference between the graph indicated by the thin dashed line and the graph indicated by the thin chain line is greater than those in the case of other embodiments and other comparative examples in a frequency band of equal to or lower than about 8 kHz as the main audio reproduction band. Thus, variation in the reproduced sound pressure level is greater, and therefore, a problem that improvement of the yield ratio in manufacturing cannot be expected might be caused.

[0058] Note that the graphs of Figs. 6 to 10 show, common to the cases of the embodiment and the comparative examples, a case where the tube attached to the nozzle portion 16 defining the output hole 21 in the case of the graphs of Fig. 5 is not attached.

[0059] Study has been conducted based on comparison among the graphs of Figs. 6 to 10. In the case of the embodiment of Figs. 6 and 7, the diaphragm 3a, 3b of the embodiment includes the multiple dimples 32 (or 33) formed in such a manner that the base material forming the diaphragm portion 30 is deformed in the thickness direction such that the one side of the base material is recessed and protrudes to the other side, and the flat portion 34 formed among the multiple dimples such that the base material is not deformed in the thickness direction. On the other hand, in the case of the comparative examples of Figs. 8 to 10, the diaphragm 300b, 300c, 300d of the comparative example includes, at the diaphragm portion 30, the continuously-raised or -recessed ribs 35, 36. This is because of the following reason: in a case where the stationary position of the diaphragm 3b in the extremely-narrow sound path 19 has moved to the upper side (the F-side) or the lower side (the B-side) from Z0 as the predetermined position, when the continuous ribs 35, 36 are provided at the diaphragm portion 30, a change in the volume of the sound path 19 is relatively greater than that in the case of providing the dimples 32, 33, and as a result, the range of variation in the reproduced sound pressure level is increased.

[0060] Thus, at the electroacoustic diaphragm 3 suitable for the balanced armature electroacoustic transduc-

er 1 including the substantially flat plate-shaped diaphragm portion 30, the multiple dimples 32, 33 formed in such a manner that the base material forming the diaphragm portion 30 is deformed in the thickness direction such that the one side of the base material is recessed and protrudes to the other side are more preferably provided than the continuous ribs 35, 36. The flat portion 34 where the base material is not deformed in the thickness direction can be provided broadly among the multiple dimples. Thus, even in a case where the diaphragm 3 approaches the inner surface of the upper case body 15 forming the sound path 19 to decrease the relative distance, a substantial increase in the reproduced sound pressure level can be prevented. Consequently, variation in the reproduced sound pressure level of the electroacoustic transducer 1 can be reduced, leading to improvement of the yield ratio in manufacturing.

[0061] Specifically, in the case of the diaphragm 3b of the embodiment, all of the raised portions defining the total of nine dimples 32 are formed on the upper side (the F-side) as the one side of the base material forming the diaphragm portion 30. Thus, in the electroacoustic transducer 1 of the embodiment, the raised portions of the multiple dimples 32 are arranged on a sound path 19 side in the case 13. In this case, no raised portions protrude on the lower side (the B-side) of the diaphragm 3b. Thus, in the electroacoustic transducer 1 of the embodiment, a defect such as noise due to contact of the diaphragm 3b with a fixed portion of the armature 8 at an upper end surface of the magnetic drive portion 7 can be prevented. Moreover, in the case of the diaphragm 3b of the embodiment, even when the diaphragm shifts from the predetermined position, variation in the reproduced sound pressure level can be reduced, and the yield ratio in manufacturing can be improved.

[0062] Note that in the diaphragm 3a or the diaphragm 3b of the above-described embodiment, the dimples 32, 33 in five lines and five columns or three lines and three columns are provided at the substantially flat plate-shaped diaphragm portion 30. However, the number of multiple dimples, the directions of the raised and recessed portions of the multiple dimples, and arrangement of the multiple dimples are not limited to those in the case of the above-described embodiment. The multiple dimples may be two or more dimples. The multiple dimples may be arranged to form lines, or may be arranged dispersively, i.e., randomly, at the diaphragm portion 30. The multiple dimples may be formed in such a manner that the base material forming the diaphragm portion 30 is deformed in the thickness direction such that the one side of the base material is recessed and protrudes to the other side, and the outer shape of each of the recessed or raised portions may be in the circular shape or the polygonal shape with the substantially equal width and length dimensions. In this manner, the flat portion 34 where the base material is not deformed in the thickness direction may be formed among the multiple dimples. In a case where the diaphragm portion 30 has suf-

ficient strength, the multiple dimples allow the relatively-broad flat portion 34 in the diaphragm portion 30.

[0063] Moreover, the outer shape of the recessed or raised portion defining the dimple 32, 33 at the diaphragm 3a, 3b is not limited to the circular shape as in the embodiment. As described above, the dimple may be in other polygonal shapes, and may be a recessed or raised shape with substantially equal width and length dimensions such that no continuously-protruding ribs are formed. The height of each dimple may be such a dimension that the base material forming the diaphragm portion 30 is not ruptured even when deformed in the thickness direction such that the one side of the base material is recessed and protrudes to the other side.

[0064] Further, in the diaphragm 3a or the diaphragm 3b of the above-described embodiment, the diaphragm portion 30 is formed of the base material containing the magnesium or the magnesium alloy. Note that the base material of the diaphragm may be other lightweight high-stiffness metal-based materials providing strength, such as aluminum, titanium, and stainless steel. Note that in the diaphragm 3a, 3b, the magnesium hydroxide layer is formed on the surface of the base material containing the magnesium or the magnesium alloy so that the stiffness can be enhanced by further weight reduction and improvement of the surface hardness. As a result, in the electroacoustic transducer 1 including the diaphragm 3a, 3b of the embodiment, the reproduced sound pressure level can be enhanced, and the reproducible frequency band can be extended to a higher frequency band as compared to that in the case of the comparative examples. Needless to say, the thickness dimension of the base material of the diaphragm 3a, 3b, the outer diameter dimension of the base material of the diaphragm 3a, 3b, and the configurations and arrangement of the diaphragm portion 30 and the drive rod connection portion 31 are not limited to those of the above-described embodiment.

[0065] The electromagnetic type electroacoustic transducer using the electroacoustic diaphragm according to the present invention is not limited to the earphones attached to the user's ears to reproduce audio, specifically the canal earphones. The electromagnetic type electroacoustic transducer may be employed for other overhead type headphones each including housings and head bands. The electroacoustic diaphragm and the electroacoustic transducer according to the present invention are not limited to monaural reproduction, stereo reproduction, or multichannel surround reproduction for home use, but are also applicable to electroacoustic transducers used for audio reproduction of portable electronic equipment such as portable audio equipment, mobile phones, and smart phones.

Claims

1. An electroacoustic diaphragm comprising:

a substantially flat plate-shaped diaphragm portion; and

a drive rod connection portion formed at an end portion of the diaphragm portion and connected to a drive rod,

wherein the diaphragm portion includes:

multiple dimples formed in such a manner that a base material forming the diaphragm portion is deformed in a thickness direction thereof such that one side of the base material is recessed and protrudes to the other side, and

a flat portion formed among the multiple dimples such that the base material is not deformed in the thickness direction.

2. The electroacoustic diaphragm according to claim 1, wherein

an outer shape of a recessed or raised portion defining each dimple is a circular shape or a polygonal shape with substantially equal width and length dimensions.

3. The electroacoustic diaphragm according to claim 1, wherein

recessed or raised portions defining the multiple dimples are arranged in line in any of longitudinal, transverse, and diagonal directions.

4. The electroacoustic diaphragm according to claim 1, wherein

all of raised portions defining the multiple dimples are formed on the one side of the base material forming the diaphragm portion.

5. The electroacoustic diaphragm according to claim 1, wherein

the base material forming the diaphragm portion contains at least magnesium or magnesium alloy, and a magnesium hydroxide layer is formed on a surface of the base material.

6. An electroacoustic transducer comprising:

the electroacoustic diaphragm according to any one of claims 1 to 5;

a diaphragm frame portion supporting a periphery of the electroacoustic diaphragm;

a drive rod portion connected to the drive rod connection portion of the electroacoustic diaphragm;

a magnetic drive portion including an armature portion configured to vibrate the drive rod portion; and

a case portion housing the magnetic drive portion and the diaphragm frame portion and forming a sound path for guiding a sound wave emit-

ted from the electroacoustic diaphragm to an opposite side of the drive rod portion and the magnetic drive portion.

7. An electroacoustic transducer comprising: 5
- the electroacoustic diaphragm according to claim 4;
- a diaphragm frame portion supporting a periphery of the electroacoustic diaphragm; 10
- a drive rod portion connected to the drive rod connection portion of the electroacoustic diaphragm;
- a magnetic drive portion including an armature portion configured to vibrate the drive rod portion; and 15
- a case portion housing the magnetic drive portion and the diaphragm frame portion and forming a sound path for guiding a sound wave emitted from the electroacoustic diaphragm to an opposite side of the drive rod portion and the magnetic drive portion, 20
- wherein the raised portions of the multiple dimples are arranged on a sound path side as the one side of the base material. 25

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Fig. 1A

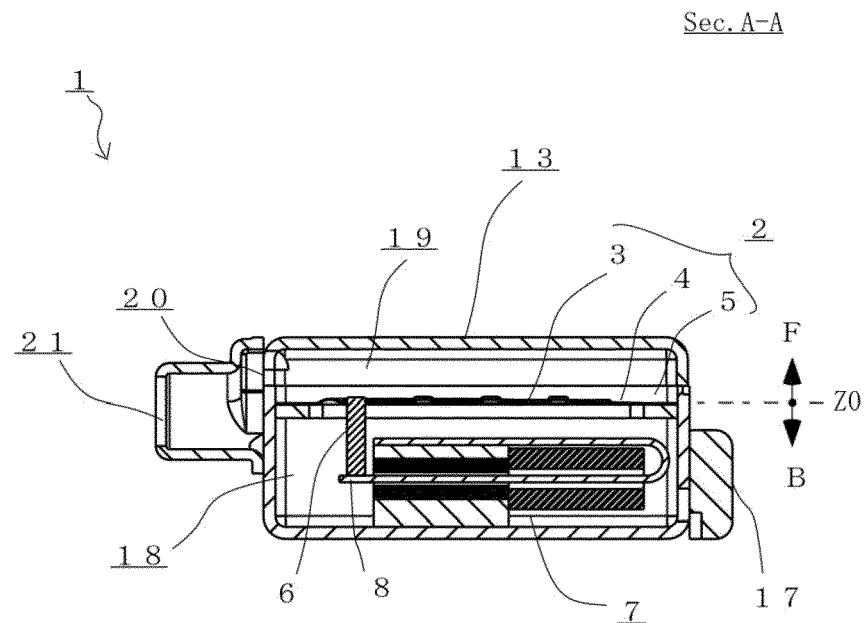


Fig. 1B

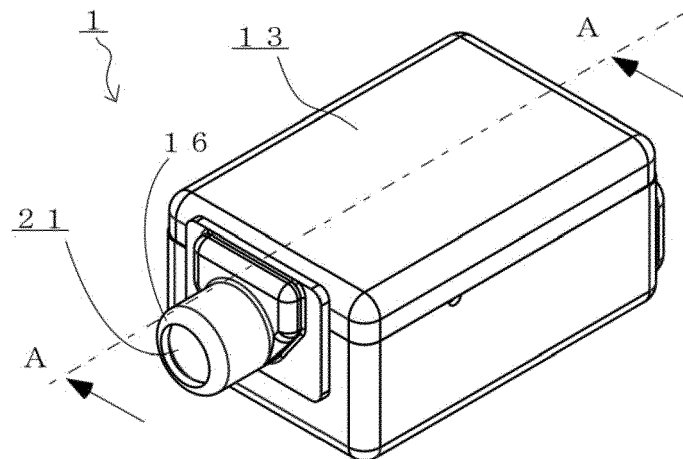


Fig. 2

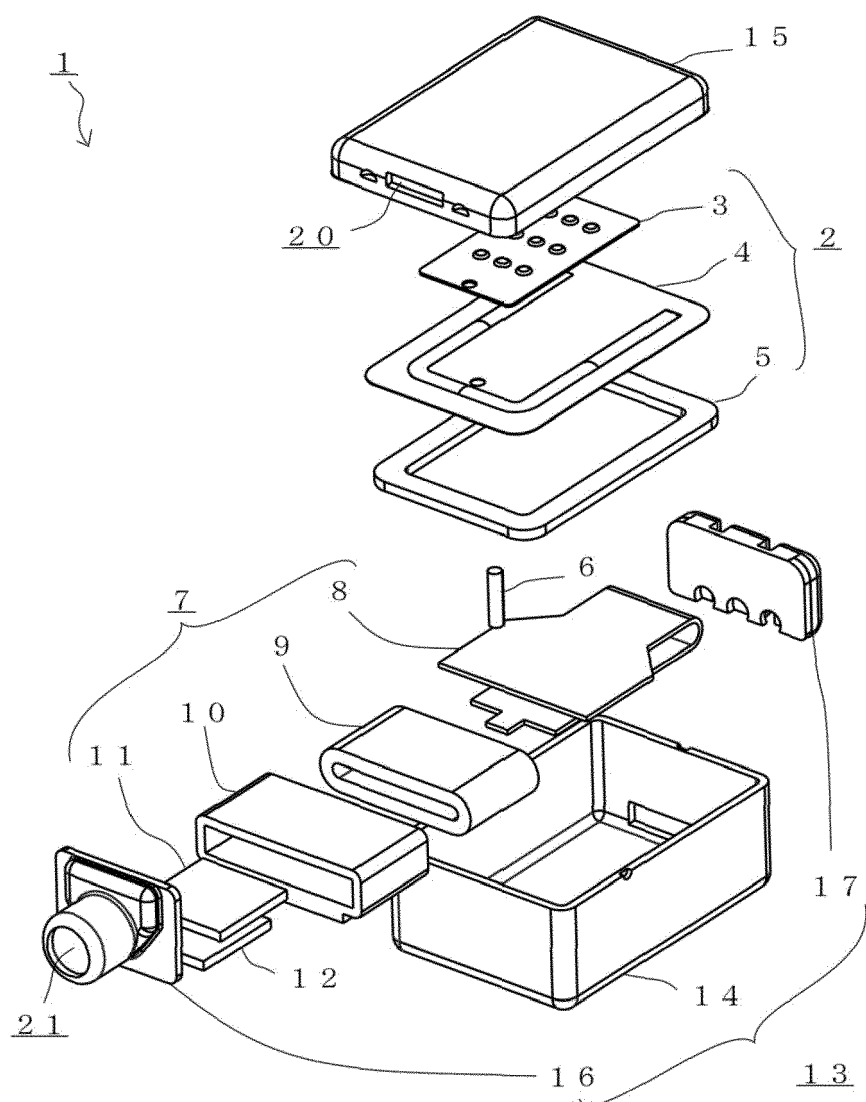


Fig. 3A

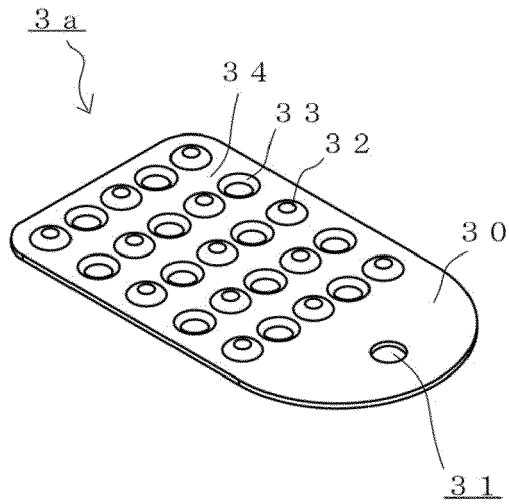


Fig. 3B

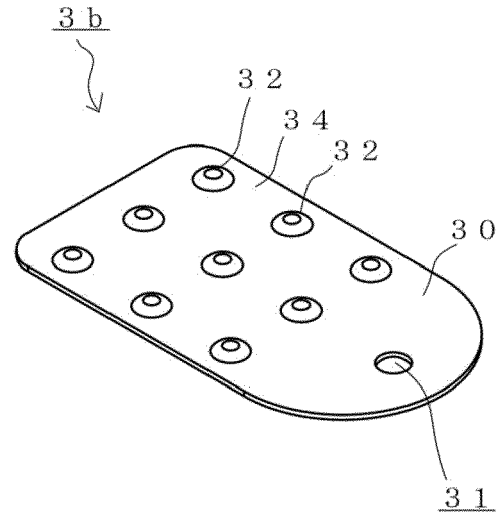


Fig. 4A

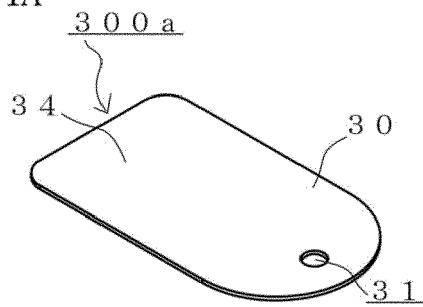


Fig. 4B

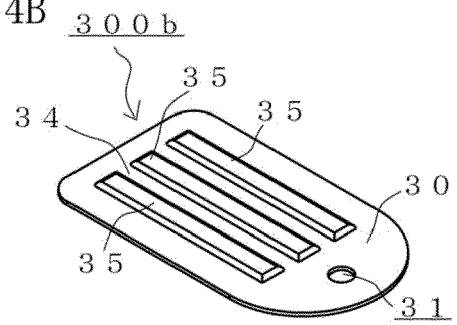


Fig. 4C

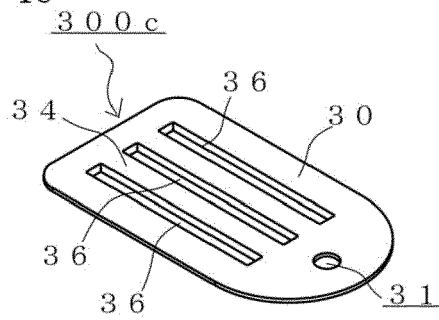


Fig. 4D

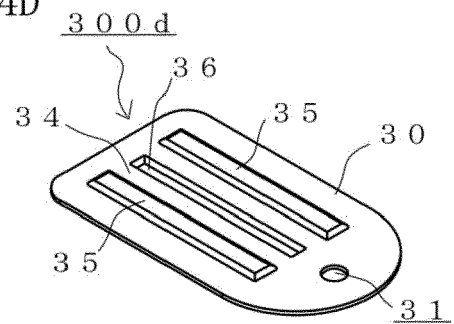


Fig. 5

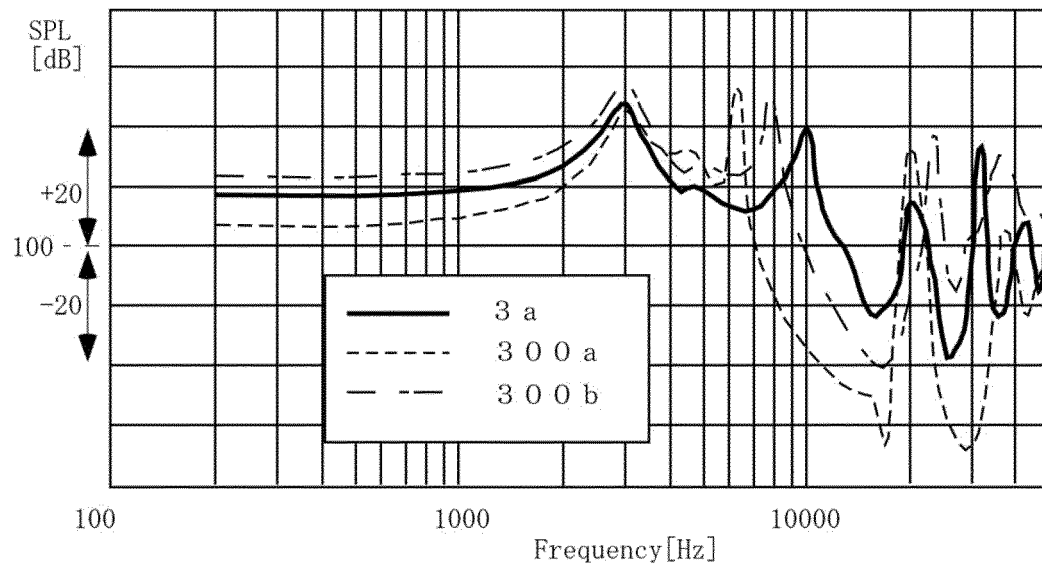


Fig. 6

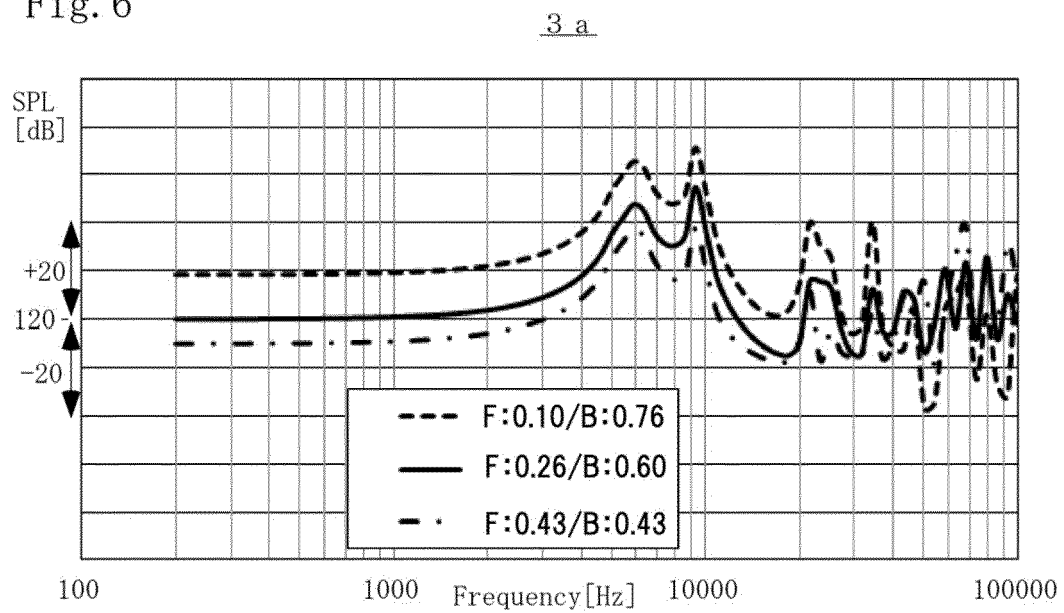


Fig. 7

3 b

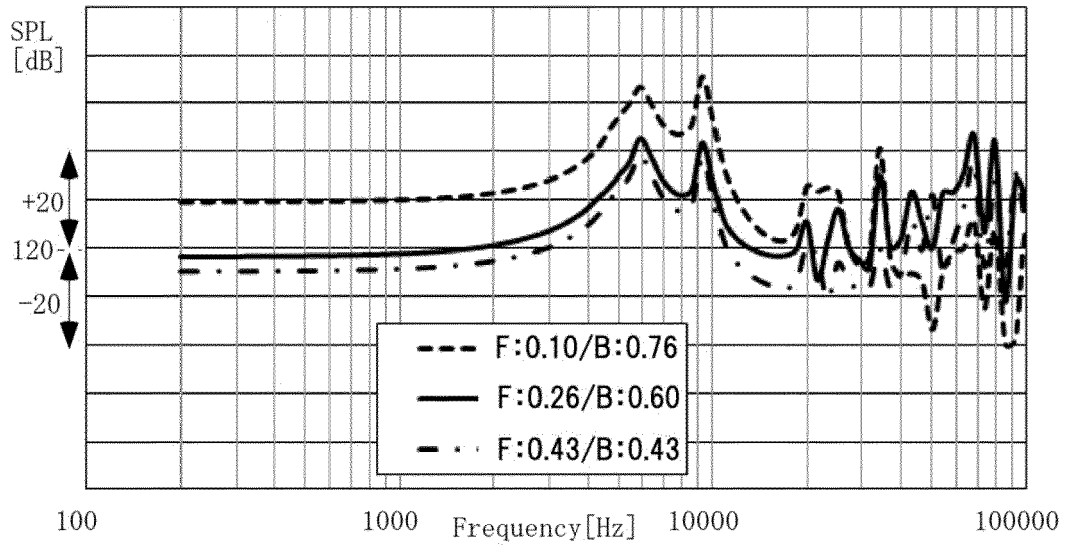


Fig. 8

3 0 0 b

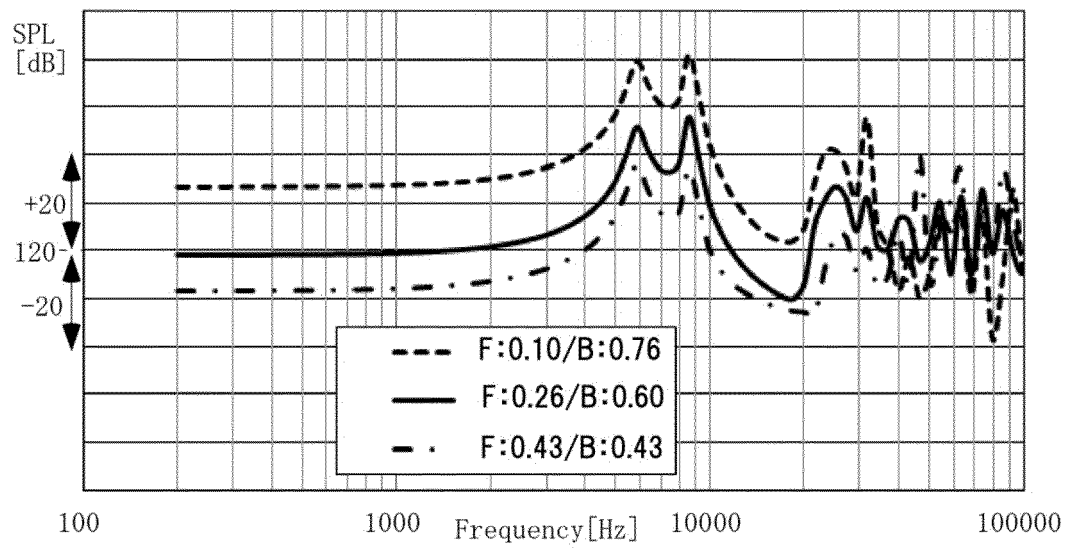


Fig. 9

3 0 0 c

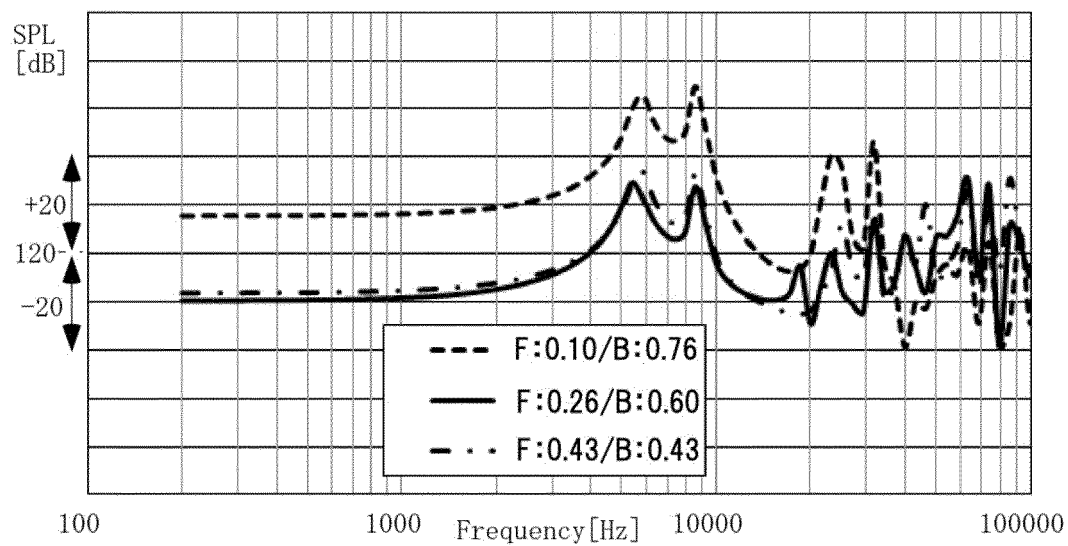
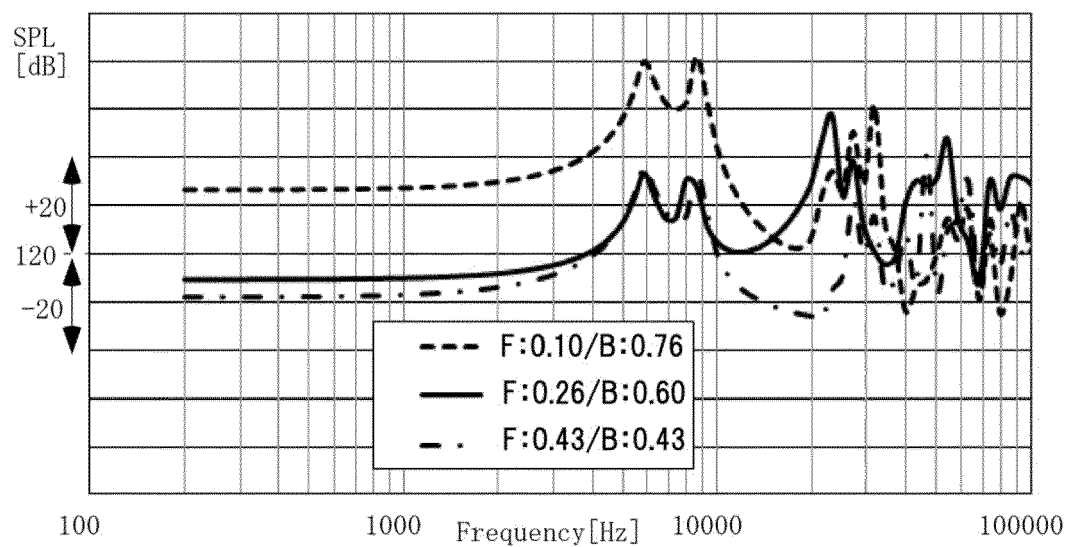


Fig. 10

3 0 0 d





EUROPEAN SEARCH REPORT

Application Number
EP 18 16 1321

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CN 104 581 550 A (HEARONIC ELECTRONICS SUZHOU CO) 29 April 2015 (2015-04-29) * abstract * * figures 1-3 *	1-7	INV. H04R11/02 ADD. H04R7/04
X	WO 2017/018074 A1 (SONY CORP [JP]) 2 February 2017 (2017-02-02) * figures 1-10 *	1-7	
			TECHNICAL FIELDS SEARCHED (IPC)
			H04R
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 25 April 2018	Examiner Moscu, Viorel
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25-04-2018

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