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(54) **TWEETER**

(57) A high-tone loudspeaker according to the invention includes a semi-dome type metal diaphragm obtained by integrally forming a dome portion, a cone portion, and an edge portion. In this diaphragm, a ratio of a difference between a bottom inclination angle of the dome portion and a bottom inclination angle of the cone portion to a larger bottom inclination angle between the bottom inclination angle of the dome portion and the bottom inclination angle of the cone portion is set at 15% or less, and a ratio of a difference between a surface area of the dome portion and a surface area of the cone portion to a larger area between the surface area of the dome portion and the surface area of the cone portion is set at 15% or less. A voice coil fitting portion is provided on a lower side of a bottom of the dome portion.

FIG 1A

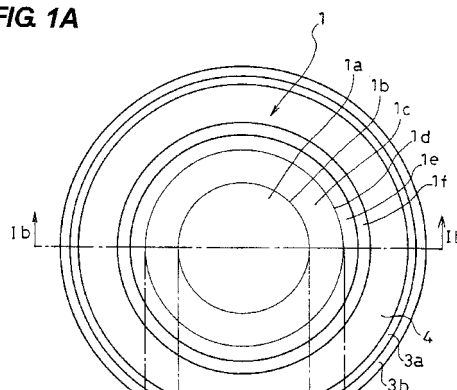
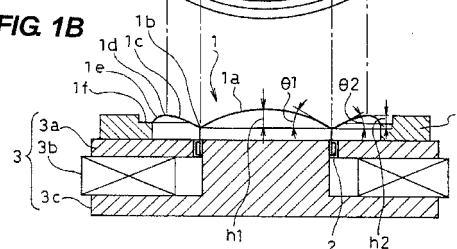


FIG 1B



EP 1 694 092 A1

Description

Technical Field

5 **[0001]** The present invention relates to a high-tone loudspeaker (also called a tweeter) for reproducing sound in an ultra-high-frequency range covering 100 kHz.

Background Art

10 **[0002]** In recent years, in order to cope with a sound source having high quality and a super-wide band as in a DVD audio player, a super audio CD (SACD) player, and the like, a high-tone loudspeaker which can reproduce sound in an ultra-high-frequency range covering 100 kHz is required in not only an independent speaker system of a component stereo set but also a low-cost compact stereo set.

15 **[0003]** In order to reproduce sound in an ultra-high-frequency range covering 100 kHz, a method for adding an ultra-high-tone loudspeaker (also called a super tweeter) covering an ultra-high frequency range extending from 10 kHz or 20 kHz to 100 kHz is known. However, in this method, since the cost increases by the ultra-high-tone loudspeaker to be added, the method has been unable to be applied to the compact stereo set. In order to reproduce sound in an ultra-high-frequency range without increasing cost, it is desirable to use a high-tone loudspeaker having a reproducing band extending from several kHz to about 100 kHz.

20 **[0004]** There are two types of diaphragm for a high-tone loudspeaker, which are a cone type and a dome type. A diaphragm of a semi-cone type obtained by combining a cone type diaphragm and a dome type diaphragm has been employed. As conventional arts of a high-tone loudspeaker which reproduces sound in an ultra-high-frequency range, loudspeakers described in Japanese Patent Laid-open Publication No.S57-23392, Japanese Patent Laid-open Publication No.S63-38398, Japanese Patent Laid-open Publication No.H05-236591 and Japanese Utility Model Laid-open Publication No.H02-118393 are known. All the loudspeakers described in Japanese Patent Laid-open Publication No.S57-23392, Japanese Patent Laid-open Publication No.S63-38398, Japanese Patent Laid-open Publication No.H05-236591 and Japanese Utility Model Laid-open Publication No.H02-118393 use semi-dome type diaphragms. A loudspeaker having a semi-dome type diaphragm is called a semi-dome type loudspeaker.

30 **[0005]** Hereinafter, a semi-dome type high-tone loudspeaker will be described with reference to FIG. 12, and a dome type high-tone loudspeaker will be described below with reference to FIG. 13.

35 **[0006]** FIG. 12 is a sectional diagram of a typical semi-dome type high-tone loudspeaker (hereinafter a "high-tone loudspeaker" will be simply referred to as a "loudspeaker") according to a first conventional art. In this figure, a semi-dome type diaphragm 31 includes a dome portion 31a and a cone portion 31c surrounding the dome portion 31a. A periphery of the cone portion 31c is fixed to a frame 34 through an edge portion 31e. The dome portion 31a, the cone portion 31c and the edge portion 31e are formed by integrally molding a resin film. A voice coil 32 is fixed to a boundary portion 31b between the dome portion 31a and the cone portion 31c. The frame 34 is fixed to a magnetic field portion 33 having an annular magnet 35.

40 **[0007]** A material of the diaphragm 31 is, for example, polyethylene naphthalete (PEN) and the diaphragm 31 has a thickness of 0.075 mm. The diameter of the voice coil 32 is about 16 mm, and the outer diameter of the edge portion 31e is about 25 mm.

45 **[0008]** FIG. 13 is a sectional diagram of a dome type loudspeaker according to a second conventional art. The loudspeaker has a nominal diameter of 25 mm. An edge portion 41e is formed to the periphery of a dome type diaphragm 41, and a periphery of the edge portion 41e is fixed to a frame 44. A voice coil 42 is fixed to the peripheral portion of the diaphragm 41. The frame 44 is fixed to a magnetic field portion 43 having an annular magnet 45. The diaphragm 41 is formed by a titanium foil having a thickness of 0.025 mm and has a diameter of about 25 mm.

50 **[0009]** FIG. 14 shows sound-pressure frequency characteristics of the loudspeaker according to the first and second conventional arts. A solid-line curve a indicates the characteristic of the loudspeaker of the first conventional art shown in FIG. 12, and a dotted-line curve b indicates the characteristic of the loudspeaker of the second conventional art shown in FIG. 13. As is apparent from FIG. 14, the semi-dome type loudspeaker of the first conventional art indicated by the curve a can reproduce a frequency higher than a frequency which can be reproduced by the dome type loudspeaker of the second conventional art indicated by the curve b. The difference described above occurs for the reason described on pages 158 and 213 of "Speaker System upper-half volume" by Yamamoto Takeo. According to the document, a high-range reproducing limit frequency (first-order high-range resonant frequency) increases in proportion to a decrease in weight of a voice coil, an increase in inclination of a bottom of the diaphragm, and an increase in total height of the diaphragm. The high-range reproducing limit frequency increases in proportion to an increase in Young's modulus of the material of the diaphragm.

55 **[0010]** In semi-dome type and dome type loudspeakers having equal diameters, the diameter of the voice coil of the semi-dome type loudspeaker can be made smaller than the diameter of the voice coil of the dome type loudspeaker

because of the structure of the semi-dome type loudspeaker. As a result, the weight of the voice coil of the semi-dome type loudspeaker is considerably smaller than the weight of the voice coil of the dome type loudspeaker (first condition). In general, the weight of a voice coil is in approximately proportion to square of the diameter of the voice coil.

[0011] The semi-dome type diaphragm can be increased in height by using a resin film having good moldability (second condition). According to the first and second conditions, in a loudspeaker having a semi-dome type diaphragm, despite the fact that the diaphragm is formed of a resin having Young's modulus smaller than that of a metal, a high-range reproducing limit frequency higher than that of a loudspeaker having a metal dome type diaphragm can be achieved.

[0012] When the semi-dome type loudspeaker shown in FIG. 12 and the dome type loudspeaker shown in FIG. 13 which have equal diameters are compared with each other, the diameter of the voice coil 32 of the semi-dome type loudspeaker is smaller than that of the voice coil 42 of the dome type loudspeaker. For this reason, the magnetic field portion 33 of the semi-dome type loudspeaker is smaller than the magnetic field portion 43 of the dome type loudspeaker, therefore, the cost is reduced. For this reason, in recent years, semi-dome type loudspeakers are popularly used.

Disclosure of Invention

Problems to be solved by the Invention

[0013] The semi-dome type diaphragm according to the first conventional art has a complex shape. For this reason, it is not easy to form a metal plate such as a titanium foil into an accurate semi-dome type of shape. The metal plate is often wrinkled or torn in press forming, and the cost increases because a high yield cannot be achieved. For example, when a total height h of the diaphragm 31 shown in FIG. 12 is made extremely small, above-mentioned wrinkling or tearing can be prevented. However, when the total height h is decreased, even though a metal having a high Young's modulus is used, the high-range reproducing limit frequency cannot be increased as described above. Therefore, in a conventional art, a semi-dome type diaphragm has been generally made by using a resin film having good moldability. Since resin has a Young's modulus lower than that of metal, a high-frequency reproducing frequency band of a loudspeaker using a resin semi-dome type diaphragm is limited to be extended. As indicated by a curve a in FIG. 14, an upper limit of the reproducing frequency is 50 kHz, and sound in an ultra-high range up to 100 kHz has been unable to be reproduced.

[0014] Therefore, in order to further extend the high-frequency reproducing frequency band of a semi-dome type loudspeaker up to about 100 kHz, a diaphragm must be made of a metal having a high Young's modulus.

[0015] Another problem in a metal diaphragm is that a sound pressure frequency characteristic has a large peak or dip. The large peak or dip occurs because the internal loss of a metal foil used as a material of a metal diaphragm is smaller than the internal loss of a resin film. Vibration of the diaphragm made of a metal foil causing a small internal loss has a large number of resonance modes, and a large number of peaks and dips having high levels are generated in the sound-pressure frequency characteristic. Such peaks and dips adversely affect sound quality.

[0016] As described above, there have been too many problems to be practically applied in the current state of making a loudspeaker for reproducing sound in an ultra-high range by using a semi-dome type diaphragm

[0017] It is an object of the present invention to provide an inexpensive high-tone loudspeaker having an excellent sound-pressure frequency characteristic in an high range and an ultra-high range.

Means for Solving the Problems

[0018] A high-tone loudspeaker according to the present invention includes a semi-dome type diaphragm in which a dome portion, a cone portion arranged around the dome portion, and an edge portion arranged around the cone portion are constructed by integrally forming a metal thin plate. A voice coil is connected to a boundary portion between the dome portion and the cone portion. On the boundary between the dome portion and the cone portion, an angle between a tangent of a surface of the dome portion and a reference surface perpendicular to the central axis of the voice coil is defined as a "bottom inclination angle of a dome portion", and an angle between a tangent of the surface of the cone portion and the reference surface is defined as a "bottom inclination angle of the cone portion". In such a case, a ratio of a difference between the bottom inclination angle of the dome portion and the bottom inclination angle of the cone portion to a larger angle between the bottom inclination angle of the dome portion and the bottom inclination angle of the cone portion is set at 15% or less. Further, a ratio of a difference between a surface area of the dome portion and a surface area of the cone portion to a larger area between the surface area of the dome portion and the surface area of the cone portion is set at 15% or less.

[0019] According to the present invention, the ratio of the difference between the bottom inclination angle of the dome portion of the diaphragm and the bottom inclination angle of the cone portion to the larger angle between the bottom inclination angle of the dome portion and the bottom inclination angle of the cone portion is set at 15% or less. In this manner, when a plate-shaped material of a diaphragm is pressured between a pair of dies which press-form the dia-

phragm, a tensile force acting on the material on the dome portion side is almost equal to a tensile force acting on the material on the cone portion side. For this reason, the material does not move while scraping against the die at a part of the die where the material pressures a boundary between the dome portion and the cone portion, and the material is not wrinkled or torn near the boundary between the dome portion and the cone portion. The ratio of the difference between the surface area of the dome portion and the surface area of the cone portion to the larger area between the surface area of the dome portion and the surface area of the cone portion is set at 15% or less, so that a sum of stretching lengths of the material which stretches to form the cone portion is almost equal to a sum of stretching lengths of the material which stretches to form the dome portion in the press work. For this reason, the whole material almost uniformly stretches. The difference between the bottom inclination angle of the dome portion and the bottom inclination angle of the cone portion is set at 15% or less as described above, the respective stiffnesses of the bottoms of the dome portion and the cone portion are almost equal to each other. As a result, a drive force of the voice coil is uniformly transmitted to the dome portion and the cone portion. Therefore, a resonant mode of only one of the dome portion and the cone portion does not strongly appear, and a sound-pressure frequency characteristic is not considerably disturbed.

Effect of the Invention

[0020] According to the present invention, a metal semi-dome type diaphragm is used as a diaphragm of a high-tone loudspeaker, and a ratio of a difference between a bottom inclination angle of a dome portion of the diaphragm and a bottom inclination angle of a cone portion to a larger angle between the bottom inclination angle of the dome portion and the bottom inclination angle of the cone portion is set at 15% or less. Further, a ratio of the difference between a surface area of the dome portion and a surface area of the cone portion to a larger area between the surface area of the dome portion and the surface area of the cone portion is set at 15% or less. With the above configuration, a metal thin plate made to be the diaphragm can be avoided from being wrinkled or torn in forming of the metal thin plate. Also, according to the present, since a metal having a high 'Young' modulus is used as the material of the diaphragm, a high-range reproducing limit frequency can be increased.

[0021] Further, according to the present, since a drive force of the voice coil is uniformly transmitted to the dome portion and the cone portion of the diaphragm with the above configuration, a resonant mode does not strongly appear at only one of the dome portion and the cone portion. Therefore, peaks and dips in a sound-pressure frequency characteristic decrease, and an excellent sound-pressure frequency characteristic can be obtained.

Brief Description of Drawings

[0022]

FIG. 1A is a plan view of a high-tone loudspeaker according to a first embodiment of the present invention, and FIG. 1B is a sectional view taking along a line Ib-Ib in FIG. 1A.

FIG. 2 is a sectional view of a pair of metal dies during press forming of a diaphragm used in the high-tone loudspeaker according to the first embodiment of the present invention.

FIG. 3 is a sectional view of a pair of metal dies during press forming of a diaphragm produced in an experimental phase on the way to the completion of the present invention by the present inventor.

FIG. 4 is a sectional view of a pair of metal dies during press forming of another diaphragm produced in the experimental phase on the way to the completion of the present invention by the present inventor.

FIG. 5 is graph of a sound-pressure frequency characteristic of a high-tone loudspeaker according to the first embodiment of the present invention.

FIG. 6 is a graph of a sound-pressure frequency characteristic of a high-tone loudspeaker using a diaphragm in an experimental phase on the way to the completion of the present invention.

FIG. 7 is a graph of a sound-pressure frequency characteristic of a high-tone loudspeaker using another diaphragm in the experimental phase on the way to the completion of the present invention.

FIG. 8 is a partial sectional view of a diaphragm of a high-tone loudspeaker according to a second embodiment of the present invention.

FIG. 9 is a partial sectional view of a diaphragm of a high-tone loudspeaker according to a third embodiment of the present invention.

FIG. 10 is a graph of a sound-pressure frequency characteristic of the high-tone loudspeaker according to the second embodiment of the present invention.

FIG. 11 is a graph of a sound-pressure frequency characteristic of a high-tone loudspeaker using still another diaphragm in the experimental phase on the way to the completion of the present invention.

FIG. 12 is a sectional view of a conventional high-tone loudspeaker.

FIG. 13 is a sectional view of another conventional high-tone loudspeaker.

FIG. 14 is a graph of a sound-pressure frequency characteristic of a conventional high-tone loudspeaker.

Explanation of Reference Symbols

[0023]

- 1, 11, 21 Diaphragm
- 1a, 11a, 16a, 17a, 21a Dome portion
- 1b, 11b, 21b First boundary portion
- 1c, 11c, 16c, 17c, 21c Cone portion
- 1d, 11d, 16d, 17d, 21d Second boundary portion
- 1e, 11e, 16e, 17e, 21e Edge portion
- 1f, 11f, 21f Fixing portion
- 11g, 21g Voice coil fitting portion
- 2, 12, 22 Voice coil
- 3 Magnetic field portion
- 3a Magnetic field plate
- 3b Magnet
- 3c Yoke
- 4 Frame
- 5 Material
- 6 Lower die
- 6a, 7a Dome-shaped projecting portion
- 6b, 7b First boundary recessed portion
- 7 Upper die
- 6d, 7d Second boundary projecting portion
- 7f Projecting flat portion

Best Mode for Carrying Out the Invention

[0024] Preferred embodiments of a high-tone loudspeaker according to the present invention will be described below.

[0025] A high-tone loudspeaker according to the present invention includes a metal semi-dome type diaphragm described below. This diaphragm has a cone portion formed around a dome portion. A ratio of a difference between a bottom inclination angle of the dome portion and the bottom inclination angle of the cone portion to a larger angle between the bottom inclination angle of the dome portion and the bottom inclination angle of the cone portion is set at 15% or less. A ratio of a difference between a surface area of the dome portion and a surface area of a cone portion to a larger area between the surface area of the dome portion and the surface area of the cone portion is set at 15% or less. With this configuration, when press forming is performed by using a metal foil serving as a material of the metal diaphragm, the metal foil does not slidably move at a boundary portion between the dome portion and the cone portion in the dies of a pressing machine. Then, in the dies during press forming, the respective parts of the metal foil of the dome portion and the cone portion uniformly stretch, and the respective total spreading lengths are almost equal. Therefore, even though the total height of the diaphragm is large, the metal foil is not wrinkled or torn in the press forming, and a metal semi-dome type diaphragm having a desired shape can be obtained. Since the semi-dome type diaphragm can be formed by a metal material having a high Young's modulus, a high-range reproducing limit frequency increases to make it possible to reproduce sound in an ultra-high range.

[0026] The ratio of the difference between the respective surface areas of the dome portion and the cone portion to the larger area between the surface area of the dome portion and the surface area of the cone portion is set at 15% or less to evenly stretch the metal foil of the dome portion and the cone portion. As a result, stiffnesses of the respective bottoms near the boundary between the dome portion and the cone portion are almost equal to each other. For this reason, a drive force of a voice coil is uniformly transmitted to the dome portion and the cone portion of the diaphragm. In this manner, a strong resonant mode does not appear at only one of the dome portion and the cone portion, and an excellent sound-pressure frequency characteristic having a small number of peaks and dips in the sound-pressure frequency characteristic can be obtained.

[0027] According to another embodiment of the present invention, a cylindrical voice coil fitting portion surrounding the dome portion is provided at a lower portion of the bottom of the dome portion. A ratio of a difference between a total surface area of the voice coil fitting portion and the dome portion and a surface area of the cone portion to a larger surface area between the total surface area and the surface area of the cone portion is set at 15% or less. A ratio of a height of the voice coil fitting portion to a voice coil diameter is set at 5% or less. With this configuration, in addition to

the above effect, the diaphragm and the voice coil are easily adhesively connected to each other, and mass productivity of high-tone loudspeakers can be improved.

[0028] According to still another embodiment of the present invention, a cylindrical voice coil fitting portion surrounding a cone portion is provided at a lower portion of the bottom of the cone portion. A ratio of a total surface area of the voice coil fitting portion and the cone portion and a surface area of a dome portion to a larger surface area between the total surface area and the surface area of the dome portion is set at 15% or less. Furthermore, a ratio of a height of the voice coil fitting portion to a voice coil diameter is set at 5% or less. With this configuration, in addition to the above effect, the diaphragm and the voice coil can be easily adhesively connected to each other, and mass productivity of high-tone loudspeakers can be improved.

[0029] Preferred embodiments of a high-tone loudspeaker according to the present invention will be described below with reference to FIGS. 1A to 7.

First Embodiment

[0030] A loudspeaker according to the first embodiment of the present invention will be described below with reference to FIGS. 1A to 7.

[0031] FIG. 1A is a plan view of a high-tone loudspeaker having a semi-dome type diaphragm according to the first embodiment, and FIG. 1B is a sectional view taking along a line Ib-Ib in FIG. 1A. The high-tone loudspeaker (to be simply referred to as a "loudspeaker" hereinafter) has a nominal diameter of 25 mm.

[0032] In FIGS. 1A and 1B, a diaphragm 1 has a circular dome portion 1a, a cone portion 1c formed around the dome portion 1a, an edge portion 1e formed around the cone portion 1c, and a fixing portion 1f formed around the edge portion 1e. The dome portion 1a, the cone portion 1c, the edge portion 1e, and the fixing portion 1f are constructed by integrally forming a metal thin film (metal foil). A voice coil 2 is fixed to a first boundary portion 1b between the dome portion 1a and the cone portion 1c. The diaphragm 1 is fixed to a frame 4 of a magnetic field portion 3 at the fixing portion 1f. The magnetic field portion 3 has a known configuration, and an annular magnet 3b is arranged between a magnetic field plate 3a and a yoke 3c. The cone portion 1c is formed between the first boundary portion 1b and a second boundary portion 1d which is a top of the cone portion 1c. The edge portion 1e extending from the second boundary portion 1d to the fixing portion 1f has a smoothly descending inclination.

[0033] A specification of the diaphragm 1 according to the first embodiment is as follows. A material of the diaphragm 1 is a titanium foil having a thickness of 0.025 mm. A diameter of the dome portion 1a is 16.5 mm, and a diameter of the voice coil 2 is also 16.5 mm. A diameter of the second boundary portion 1d is 23 mm, and an outer diameter of the edge portion 1e is 25 mm. A bottom inclination angle θ_1 of the dome portion 1a is 28° , a bottom inclination angle θ_2 of the cone portion 1c is 30° , and the difference therebetween is 2° . A ratio of 2° to 30° is about 6.7%.

[0034] A total height h_1 of the dome portion 1a is 2.1 mm, and a curvature radius of the dome portion 1a is 17.5 mm. A total height h_2 of the cone portion 1c is 1.5 mm which is smaller than the total height h_1 of the dome portion 1a. A surface area of the dome portion 1a is 2.27 cm^2 , and a surface area of the cone portion 1c is 2.33 cm^2 . Both of these surface areas are set to be almost equal.

[0035] The above-described specification is obtained as a result of a large number of sample experiments performed by the inventor to confirm that the titanium-foil diaphragm 1 is not torn or wrinkled in forming. According to the specification, the semi-dome type diaphragm 1 according to the present invention can be relatively easily obtained.

[0036] FIG. 5 is a diagram of a sound-pressure frequency characteristic of a loudspeaker using the diaphragm 1 according to the first embodiment. As shown in FIG. 5, a reproducing lower-limit frequency is about 1.5 kHz. Although a maximum reproducing frequency is measured up to only 100 kHz, the maximum producing frequency is estimated to be over 100 kHz. In comparison to the high-range characteristic of the conventional loudspeaker shown in FIG. 14, it is understood that the loudspeaker using the diaphragm 1 according to the first embodiment has an excellent ultra-high range reproducing capability without large peaks or dips.

[0037] With reference to FIGS. 2, 3, 4, 6, and 7, a reason why the diaphragm 1 of the first embodiment can be obtained and a process of obtaining the specification of the diaphragm 1 will be described in detail below.

[0038] FIG. 2 is a sectional view of a pair of dies 15 for press work to form the diaphragm 1 according to the first embodiment, and FIGS. 3 and 4 are sectional views of two examples of dies 16 and 17 among a large number of dies used by the present inventor in experiments, respectively. In FIGS. 2 to 4, for descriptive convenience and for making the figures easy to understand, sections are not hatched. In FIGS. 2 to 4, each of the press dies 15 to 17 has a lower die 6 and an upper die 7. The dies 15 to 17 are fixed to a pressing machine (not shown), and they pressure a metal foil (titanium foil or the like) serving as a material 5 sandwiched between the lower dies 6 and the upper dies 7. In this manner, products having shapes depending on the shapes of the dies are obtained.

[0039] In the respective dies 15 to 17, a projecting portion and a recessed portion (will be described below) are formed on a surface of each die. In the lower die 6, a dome-shaped projecting portion 6a is formed at a central part, and a first boundary recessed portion 6b is formed around the dome-shaped projecting portion 6a. A second boundary projecting

portion 6d is formed around the first boundary recessed portion 6b. In the upper die 7, a dome-shaped recessed portion 7a is formed at a central part, and a first boundary projecting portion 7b is formed around the dome-shaped recessed portion 7a. A second boundary recessed portion 7d is formed around the first boundary projecting portion 7b. On an outermost periphery of the upper die 7, a projecting flat portion 7f having a flat surface at its top is formed.

[0040] In the pair of dies 15 in FIG. 2, the first boundary recessed portion 6b of the lower die 6 and a first boundary projecting portion 7b of the upper die are set such that the bottom inclination angle θ_1 of the dome portion 1a of the completed diaphragm 1 and the bottom inclination angle θ_2 of the cone portion 1c are almost equal to each other. By making the angles θ_1 and θ_2 almost equal to each other, tensile forces acting on the material 5 at the dome portion 1a side and the cone portion 1c side are almost equal to each other when the planar material 5 is sandwiched and pressured between the lower die 6 and the upper die 7 in the pair of dies 15. For this reason, the material 5 does not slidably move at positions of the first boundary recessed portion 6b and the first boundary projecting portion 7b. The "slidable moving" means that the material 5 moves while scraping against the surface of the die. Occurrence of wrinkles or tears in the pressing step is mostly caused when the material 5 slidably moves in the dies 15. For this reason, as described above, when the material 5 does not slidably move, wrinkles or tears do not occur.

[0041] In the diaphragm 1 according to the first embodiment, the surface area of the dome portion 1a and the surface area of the cone portion 1c are made almost equal to each other. For this reason, in the pressing step, a sum of spreading amount of the material 5 to form the dome portion 1a and a sum of spreading amount of the material 5 to form the cone portion 1c are made to almost equal to each other. Since the entire material 5 almost uniformly spreads, good formability can be achieved. Due to the good formability, the forming step needs not to be divided into a large number of stages (several stages). The material 5 can be sufficiently formed even in two stages. The number of stages is decreased to reduce the cost of the dies and forming time, and a reduction in cost of the diaphragm 1 can be achieved.

[0042] Forming by using a pair of dies 16 will be described in detail below with reference to FIG. 3. The pair of dies 16 is formed such that the bottom inclination angle θ_1 of a dome portion 16a of the diaphragm formed by the dies 16 is 46° , the bottom inclination angle θ_2 of a cone portion 16c is 29° , and the angle θ_1 is larger than the angle θ_2 by about 17° . When the angle θ_1 is larger than the angle θ_2 , in a process in which the lower die 6 and the upper die 7 are closed to pressure the material 5, a tensile force acting on the material 5 to form the dome portion 16a is larger than a tensile force acting on the material 5 to form the cone portion 16c. For this reason, the material 5 slidably moves toward the dome portion 16a between the first boundary recessed portion 6b and the first boundary projecting portion 7b. As a result, the dome portion 16a of the formed diaphragm is wrinkled. When an amount of slidable moving is large, the material is torn at the boundary portion between dome portion 16a and the cone portion 16c.

[0043] Forming by using a pair of dies 17 will be described below with reference to FIG. 4. The pair of dies 17 is formed such that the bottom inclination angle θ_1 of a dome portion 17a of the diaphragm formed by the dies 17 is 24° , the bottom inclination angle θ_2 of a cone portion 17c is 42° , and the angle θ_1 is smaller than the angle θ_2 by about 18° . When the angle θ_1 is smaller than the angle θ_2 , in a process in which the lower die 6 and the upper die 7 are closed to pressure the material 5, a tensile force acting on the material of the cone portion 17c is larger than a tensile force acting on the material of the dome portion 17a. For this reason, the material 5 slidably moves toward the cone portion 17c between the first boundary recessed portion 6b and the first boundary projecting portion 7b. As a result, the cone portion 17c of the formed diaphragm is wrinkled. When an amount of slidable moving is large, the material 5 is torn at the boundary portion between dome portion 17a and the cone portion 17c.

[0044] In the dies 16 and 17, in the process of closing the lower die 6 and the upper die 7, when the first boundary recessed portion 6b and the first boundary projecting portion 7b pressure the material 5, a frictional force acts between the first boundary recessed portion 6b and the material 5 as well as between the first boundary projecting portion 7b and the material 5. For this reason, when the difference between the angle θ_1 and the angle θ_2 is small to some extent, for example, even if the tensile forces acting on the material 5 at the dome portion 16a and the cone portion 16c are different from each other, the material 5 does not slidably move. According to various experiments by the inventor, when a ratio of the difference between the angle θ_1 and the angle θ_2 to a larger angle between the angle θ_1 and the angle θ_2 is 10% or less, it is found out that the material 5 does not slidably move at all. Furthermore, when the ratio is about 15% or less, it is found out that the material 5 rarely slidably moves. Therefore, according to the present embodiment, when the ratio of the difference between the bottom inclination angle θ_1 of the dome portion 16a and the bottom inclination angle θ_2 of the cone portion 16c to the larger angle between the bottom inclination angle θ_1 of the dome portion 16a and the bottom inclination angle θ_2 of the cone portion 16c is 15% or less, the material 5 has no risk of being wrinkled or torn in press forming, and the diaphragm 1 can be manufactured at a high yield.

[0045] In the pair of dies 17 shown in FIG. 4, curvature radiuses of the dome-shaped projecting portion 6a of the lower die 6 and the dome-shaped recessed portion 7a of the upper die 7 are larger than curvature radiuses of the dome-shaped projecting portion 6a and the dome-shaped recessed portion 7a of the pair of dies 15 according to the first embodiment shown in FIG. 2. For this reason, a total height of the dome portion 17a of the formed diaphragm is smaller than a total height of the dome portion 1a of the diaphragm 1 formed by the pair of dies 15 according to the embodiment. Since the curvature radiuses of the dome-shaped projecting portion 6a and the dome-shaped recessed portion 7a in

the mold 17 are large, in the process of closing the lower die 6 and the upper die 7, the first boundary projecting portion 7b is brought into contact with the planar material 5, and then the dome-shaped projecting portion 6a is brought into contact with the material 5 after the lower die 6 and the upper die 7 are further closed. For this reason, even if the angle $\theta 1$ and the angle $\theta 2$ are made almost equal to each other, it is found out that the material 5 slightly slidably moves at the first boundary projecting portion 7b. With the slidable moving, the dome portion 17a may be wrinkled. For this reason, it is found out that the total height of the dome portion is desirably high to some extent. According to the experiments by the inventor, it is desirable that a total height (h1) of the dome portion is approximately 0.8 or more times of a total height (h2) of the cone portion.

[0046] As shown in FIGS. 2 and 3, when the total height (h1) of the dome portion is considerably larger than the total height (h2) of the cone position, as well as when the angle $\theta 1$ and the angle $\theta 2$ are almost equal to each other, in the process of closing the lower die 6 and the upper die 7, before the second boundary projecting portion 6d is brought into contact with the material 5, the first boundary projecting portion 7b is brought into contact with the material 5. For this reason, stretching amount of the materials at the dome portion 16a side and at the cone portion 16c side are not uniform, and the dome portion 16a tends to be wrinkled. In order to prevent this, it is found out that the total height of the dome portion 16a is desirably approximately twice or less of the total height of the cone portion 16c.

[0047] A sound-pressure frequency characteristic of a loudspeaker using the diaphragm formed by using the pair of dies 16 shown in FIG. 3 is shown in FIG. 6. The loudspeaker has the following specification. A nominal diameter is 25 mm, and the diameter of a voice coil is 16.5 mm which is almost equal to the diameter of the dome portion 16a. Although the bottom inclination angle $\theta 1$ of the dome portion 16a and the bottom inclination angle $\theta 2$ of the cone portion 16c are almost equal to each other, a surface area of the cone portion 16c is smaller than a surface area of the dome portion 16a.

[0048] The surface area of the dome portion 16a is 2.3 cm², and the total height of the dome portion 16a is 2.3 mm. The curvature radius of the dome portion 16a is 16 mm. The surface area of the cone portion 16c is 1.7 cm², and the total height of the cone portion 16c is 1.3 mm. The surface area of the dome portion 16a is approximately 1.35 times of the surface area of the cone portion 16c. Both of the bottom inclination angle $\theta 1$ of the dome portion 16a and the bottom inclination angle $\theta 2$ of the cone portion 16c are 31°. A diameter of the boundary portion between the cone portion 16c and an edge portion 16e is 21.5 mm, and the outer diameter of the edge portion 16e is 23.5 mm.

[0049] A solid-line curve a in FIG. 6 indicates a sound-pressure frequency characteristic of the loudspeaker using a diaphragm in which, although the bottom inclination angle $\theta 1$ of the dome portion 16a is equal to the bottom inclination angle $\theta 2$ of the cone portion 16c, the surface area of the cone portion 16c is larger than the surface area of the dome portion 16a. The surface area of the dome portion 16a of the loudspeaker is 2.26 cm², a total height of the dome portion 16a is 2.0 mm, and the curvature radius of the dome portion 16a is 18 mm. The surface area of the cone portion 16c is 3.2 cm², and the total height of the cone portion 16c is 1.3 mm. The surface area of the cone portion 16c is approximately 1.42 times of the surface area of the dome portion 16a. The bottom inclination angle $\theta 1$ of the dome portion 16a is 27.3°, and the bottom inclination angle $\theta 2$ of the cone portion 16c is 30°. A diameter of a second boundary portion 16d between the cone portion 16c and the edge portion 16e is 25 mm, and an outer diameter of the edge portion 16e is 27 mm.

[0050] When the surface area of the dome portion 16a is considerably larger than the surface area of the cone portion 16c, a weight of the dome portion 16a is considerably larger than a weight of the cone portion 16c. Thus a drive force of the voice coil 2 is largely distributed to the dome portion 16a having the larger weight. Since a radiation area of the dome portion 16a is larger than a radiation area of the cone portion 16c, a resonant mode of the dome portion 16a strongly appears in the sound-pressure frequency characteristic. As indicated by the solid-line curve a in FIG. 6, a large resonant peak appears, and a large dip appears at a frequency lower than the resonant peak.

[0051] When the surface area of the cone portion 16c is larger than the surface area of the dome portion 16a, the weight of the cone portion 16c is larger than that of the dome portion 16a. For this reason, a drive force of the voice coil 2 is largely distributed to the cone portion 16c. Since the radiation area of the cone portion 16c is larger than the radiation area of the dome portion 16a, a resonant mode of the cone portion 16c strongly appears in the sound-pressure frequency characteristic. As indicated by a dotted-line curve b in FIG. 6, the frequency of a resonant peak of the curve b is lower than the frequency of the resonant peak of the curve a, and a large dip appears at a frequency higher than that of the resonant peak.

[0052] When a difference between the bottom inclination angle $\theta 1$ of the dome portion 16a and the bottom inclination angle $\theta 2$ of the cone portion 16c is large, a difference between the stiffness of the bottoms of the dome portion 16a and the cone portion 16c is large. Thereby, disturbance of the sound-pressure frequency characteristic tends to be further remarkable.

[0053] In the loudspeaker according to the first embodiment, the bottom inclination angle $\theta 1$ of the dome portion 1a and the bottom inclination angle $\theta 2$ of the cone portion 1c are made almost equal to each other, and the surface area of the dome portion 1a and the surface area of the cone portion 1c are made almost equal to each other. In this manner, the weights of the dome portion 1a and the cone portion 1c are almost equal to each other, and the stiffnesses of the bottoms of the dome portion 1a and the cone portion 1c are almost equal to each other. As a result, the drive force of the voice coil 2 is uniformly transmitted to the dome portion 1a and the cone portion 1c of the diaphragm 1. Therefore,

a resonant mode of only one of the dome portion 1a and the cone portion 1c does not strongly appear and a sound-pressure frequency characteristic is not largely disturbed, an excellent sound-pressure frequency characteristic as shown in FIG. 5 is obtained.

[0054] The diaphragm 1 of the loudspeaker according to the first embodiment has a shallower shape having a curvature radius larger than and a height h_1 smaller than those of a diaphragm of a general loudspeaker commercially available. When the shape of the diaphragm 1 is rather shallow, the resonant modes of the dome portion 1a and the cone portion 1c are not completely independent of each other. When viewed from the voice coil 2 serving as a drive portion, the resonant mode of the dome portion 1a and the resonant mode of the cone portion 1c tend to be inverted from each other. For this reason, when the surface areas and the weights of the dome portion 1a and the cone portion 1c are almost equal to each other, the respective resonant peaks and the dips of the dome portion 1a and the cone portion 1c are canceled out, so that a sound-pressure frequency characteristic tends to be smooth.

[0055] According to an experiment performed by the inventor, when a ratio of the difference between the surface area of the dome portion 1a and the surface area of the cone portion 1c or the difference between the respective weights of the dome portion 1a and the cone portion 1c to a larger surface area or a larger weight is set within about 15%, it is found out that generation of a large peak or a large dip can be avoided. This will be described below in detail with reference to FIG. 7.

[0056] FIG. 7 shows a sound-pressure frequency characteristic of a loudspeaker in an experimental phase by the present inventor.

[0057] In FIG. 7, a bold-solid-line curve a indicates a sound-pressure frequency characteristic of the loudspeaker according to the first embodiment. A thin-solid-line curve b indicates a sound-pressure frequency characteristics of the loudspeaker using the diaphragm 1 according to the first embodiment in which the bottom inclination angle θ_1 of the dome portion are set at 29° and the bottom inclination angle θ_2 of the cone portion 1c are set at 29.5° . The surface area of the dome portion 1a is set at 2.2 cm^2 , and the surface area of the cone portion 1c is set at 1.92 cm^2 . That is, the curve b indicates a sound-pressure frequency characteristic of a loudspeaker using the diaphragm in which the surface area of the dome portion 1a is approximately 1.15 times of the surface area of the cone portion 1c.

[0058] A dotted-line curve c indicates a sound-pressure frequency characteristic of a loudspeaker using the diaphragm 1 according to the first embodiment in which the surface area of the dome portion 1a is set at 2.2 cm^2 , the surface area of the cone portion 1c is set at 2.52 cm^2 , and the surface area of the cone portion 1c is larger than the surface area of the dome portion 1a by about 15%.

[0059] When the curve c in FIG. 7 is compared with the curve b in FIG. 6, it is found out that a large peak at about 20 kHz is considerably reduced. When the curve c in FIG. 7 is compared with the most preferable curve a in FIG. 7, it is found out that a peak changes within 3 dB. When the curve b in FIG. 7 is compared with the curve a in FIG. 6, it is found out that large dips at about 25 kHz are considerably reduced. When the curve b in FIG. 7 is compared with the curve a in FIG. 7, it is found out that a dip falls within about 3 dB. That is, if a ratio of the difference between the surface area of the dome portion 1a and the surface area of the cone portion 1c to a larger surface area is set within about 15%, generation of a large peak or a large dip can be prevented.

[0060] The thicknesses of the dome portion 1a and the cone portion 1c of the diaphragm 1 are constant, the weights of the dome portion 1a and the cone portion 1c are in proportion to the surface areas of the dome portion 1a and the cone portion 1c. When the thickness of the diaphragm 1 is not uniform, the respective surface areas may be designed such that a ratio of the difference between the weights of the dome portion 1a and the cone portion 1c to a larger one of the weights falls within about 15%.

[0061] As described above, according to the first embodiment, an inexpensive loudspeaker which can reproduce sound in an ultra-high range and has an excellent sound-pressure frequency characteristic can be realized.

[0062] In the loudspeaker according to the first embodiment, a titanium foil is used as the material of the semi-dome type diaphragm. However, a thin film (foil) made of beryllium, aluminum, duralumin which is an aluminum alloy, a magnesium alloy, copper, brass, or the like may be used.

[0063] In the first embodiment, although the shape of the dome portion of the diaphragm is spherical, even though the shape is an aspherical shape such as a concave ellipsoidal bomb-shell-like surface, the effect of the present invention can be obtained.

Second Embodiment

[0064] A loudspeaker according to a second embodiment of the present invention will be described below with reference to FIG. 8. FIG. 8 is a sectional view of the right half of a diaphragm 11 of the loudspeaker according to the second embodiment. The left half (not shown) is symmetrical about a center line C.

[0065] In FIG. 8, the semi-dome type diaphragm 11 has a circular dome portion 11a, a cylindrical voice coil fitting portion 11g formed around the circular dome portion 11a, and a cone portion 11c formed around the voice coil fitting portion 11g. The cone portion 11c is connected to an edge portion 11e through a second boundary portion 11d which

is the top of the cone portion 11c. A fixing portion 11f is formed around the edge portion 11e, The dome portion 11a, the voice coil fitting portion 11g, the cone portion 11c, the edge portion 11e, and the fixing portion 11f are constructed by integrally forming a titanium foil. A height of the voice coil fitting portion 11g is 0.4 mm. A tip portion 11i of the voice coil fitting portion 11g has a curvature (R) having a radius of about 0.2 mm to prevent the tip portion 11i from being torn in a press forming process. An inner periphery 11h of the voice coil fitting portion 11g is tapered such that the diameter of the inner periphery 11h gradually decreases from the proximal-end portion 11i to the circular dome portion 11a. With the tapered shape, a material can be prevented from being torn in press molding and it becomes easy to perform an operation of inserting a winding frame (bobbin) 12a of a voice coil 12 into the inner periphery 11h of the voice coil fitting portion 11g in assembling.

[0066] A nominal diameter of the loudspeaker according to the second embodiment is 25 mm. A material of the diaphragm 11 is a titanium foil having a thickness of 0.025 mm. An outer diameter (diameter of a first boundary portion 11b) of the dome portion 11a is 17 mm, and a diameter of the second boundary portion 11d between the cone portion 11c and the edge portion 11e is 24 mm. An outer diameter of the edge portion 11e is 26 mm. A bottom inclination angle θ_1 of the dome portion 11a of the diaphragm 11 is 28° , a bottom inclination angle θ_2 of the cone portion 11c is 30° , and both the angles are almost equal to each other. A diameter of a bottom of the dome portion 11a is 16.6 mm. A total height h_1 of the dome portion 11a is 2.1 mm, and a curvature radius of the dome portion 11a is 17.6 mm. A total height h_2 of the cone portion 11c is 1.5 mm.

[0067] A diameter of the winding frame 12a of the voice coil 12 is 16.5 mm, and the upper winding frame 12a is inserted into the inner periphery 11h of the voice coil fitting portion 11g. After the insertion, an adhesive agent is applied to the first boundary portion 11b and the inner periphery 11h to have the winding frame 12a fixed to the diaphragm 11. By applying an adhesive agent also to the first boundary portion 11b, a high-range sound-pressure frequency characteristic is not deteriorated by a reduction of the stiffness of a portion on which the curved surface of the first boundary portion 11b is formed. In the diaphragm 11 in the loudspeaker according to the second embodiment, a surface area of the voice coil fitting portion 11g is 0.27 cm^2 , a surface area of the dome portion 11a is 2.31 cm^2 , and a surface area of the cone portion 11c is 2.45 cm^2 . A total surface area of the voice coil fitting portion 11g and the dome portion 11a is 2.58 cm^2 which is almost equal to the surface area of the cone portion 11c.

[0068] In the diaphragm 11 according to the second embodiment, the voice coil fitting portion 11g is formed around the dome portion 11a to make it easy to perform the fixing operation of the voice coil 12. However, since the height (0.4 mm) of the voice coil fitting portion 11g is made considerably smaller than a diameter (16.5 mm) of the voice coil 12, an influence of the voice coil fitting portion 11g on formability in forming of the diaphragm 11 can be made vanishingly small. In order to keep the formability of the diaphragm 11 preferable, a height h_3 of the voice coil fitting portion 11g must be 5% or less of the diameter of the dome portion 11a. When the height h_3 is larger than 5%, the material tends to be torn near the voice coil fitting portion 11g.

[0069] As described above, according to the second embodiment, as same as in the diaphragm 1 according to the first embodiment, the semi-dome type diaphragm 11 can be easily formed without being wrinkled or torn in press forming using a titanium foil as a material.

[0070] In the diaphragm 11 according to the second embodiment, the voice coil fitting portion 11g is formed around the dome portion 11a to obtain the following advantages. More specifically, when the winding frame 12a of the voice coil 12 is fixed to the diaphragm 11, the winding frame 12a is reliably held by inserting the winding frame 12a into the voice coil fitting portion 11g. Therefore, an assembling operation is considerably easily performed, and excellent mass productivity can be achieved without any trouble such as displacement in assembling. Since a jig or the like in assembling is unnecessary, production costs can be reduced. A region having a height of 0.4 mm on the voice coil fitting portion 11g adheres to the winding frame 12a. Therefore, high adhesive strength can be obtained to make it possible to improve the reliability of the loudspeaker.

[0071] A sound-pressure frequency characteristic of the loudspeaker according to the second embodiment is shown in FIG. 10. When FIG. 10 is compared with FIG. 5 showing the sound-pressure frequency characteristic of the loudspeaker according to the first embodiment, the sound-pressure frequency characteristic shown in FIG. 10 has peaks and dips which are slightly larger in number than those in the sound-pressure frequency characteristic shown in FIG. 5. However, it is found out that the high-range reproducing limit frequency of the sound-pressure frequency characteristic exceeds 100 kHz and that an excellent sound-pressure frequency characteristic can be obtained.

[0072] The inventor has performed various experiments to realize a diaphragm 11 on which the voice coil fitting portion 11g of the loudspeaker according to the second embodiment is formed, optimum specifications of the dome portion 11a, the cone portion 11b, and the voice coil fitting portion 11g have been obtained. The process of obtaining the optimum specifications will be described below in detail.

[0073] In FIG. 8, a surface area of the dome portion 11a is represented by S_a , a surface area of the cone portion 11c is represented by S_c , and a surface area of the voice coil fitting portion 11g is represented by S_g . The inventor manufactured loudspeakers having three types of experimental diaphragms 11 in which the relationships among the areas S_a , S_c , and S_g are expressed by the following expressions (1), (2), and (3) to examine sound-pressure frequency

characteristics of the loudspeakers.

$$S_a + S_g < S_c \quad (1)$$

$$S_a + S_g > S_c \quad (S_a \cong S_c) \quad (2)$$

$$S_a + S_g \cong S_c \quad (3)$$

[0074] All the diaphragms 11 are made of a titanium foil having a thickness of 0.025 mm. The dimensions of the dome portion 11a and the voice coil fitting portion are equal to those of the second embodiment. A bottom inclination angle of the dome portion 11a is 28°, and a bottom inclination angle of the cone portion is 30°, so that both the angles are almost equal to each other.

[0075] FIG. 11 shows sound-pressure frequency characteristics of the loudspeakers using the three types of experimental diaphragms. A dotted-line curve a indicates a sound-pressure frequency characteristic of the loudspeaker using the diaphragm 11 having the relationship expressed by expression (1). The area S_g is 0.27 cm², the area S_a is 2.31 cm², the area S_c is 3.2 cm², and a sum of areas ($S_a + S_g$) is 2.58 cm². The area S_c is larger than the sum of areas ($S_a + S_g$) by about 24%. In the loudspeaker using the diaphragm, a peak appears at about 20 kHz as indicated by the curve a in FIG. 11, and the sound-pressure frequency characteristic in FIG. 11 is inferior to that in FIG. 5.

[0076] A thin-solid-line curve b in FIG. 11 is obtained when the areas S_a and S_c are made equal to each other and have the relationship given by expression (2). The area S_a is 2.31 cm², the area S_c is 2.2 cm², and a sum of the areas S_a and S_g , i.e. ($S_a + S_g$), is 2.58 cm². The area S_c is smaller than the sum of areas ($S_a + S_g$) by about 15%. In this example, although a small dip appears at about 25 kHz, no large peak is seen at about 20 kHz. The sound-pressure frequency characteristic in FIG. 11 is slightly equal to the sound-pressure frequency characteristic of the second embodiment shown in FIG. 5 and falls within the allowable range but not optimum.

[0077] A bold-solid-line curve c in FIG. 11 is obtained in a case of the diaphragm 11, having a relationship given by expression (3), according to the second embodiment. An excellent sound-pressure characteristic is obtained. Since the voice coil fitting portion 11g and the winding frame 12a of the voice coil 12 are fixed to each other by an adhesive agent, the voice coil fitting portion 11g operates together with the voice coil 12. From this point of view, the inventor had understood that the surface area of the voice coil fitting portion 11g did not need to be added to the surface area of the dome portion 11a at first. However, as results of the various experiments, since a titanium foil serving as the material of the diaphragm 11 has a Young's modulus considerably higher than the adhesive agent, it is found out that the voice coil fitting portion 11g does not operate as a part of the voice coil 12 but operates as a part of the dome portion 11a. With respect to this point, when a total surface area obtained by adding the surface area of the voice coil fitting portion 11g to the surface area of the dome portion 11a is set to be almost equal to the surface area of the cone portion 11c, it is found out that an optimum result can be obtained. When a ratio of a difference between the total surface area of the surface area of the dome portion 11a and the surface area of the voice coil fitting portion 11g and the surface area of the cone portion 11c to a larger surface area between the total surface area and the surface area of the cone portion 11c falls within about 15%, as shown in FIG. 11, a sound-pressure frequency characteristic having peaks and dips which are relatively small in number can be obtained.

[0078] In the diaphragm 11 according to the second embodiment shown in FIG. 8, the first boundary portion 11b is positioned between the dome portion 11a and the voice coil fitting portion 11g. However, the first boundary portion 11b may have a curved surface such that the dome portion 11a and the voice coil fitting portion 11g are connected to each other by a curved surface. When the first boundary portion 11b is made to have a curved surface, the curvature radius is preferably large with respect to the formability of the diaphragm 11. However, when the curvature radius is large, in the step of fixing the voice coil 12 to the voice coil fitting portion 11g, positioning accuracy of the voice coil 12 may be deteriorated. A jig for accurate positioning may be required, or operation time may become longer, so that productivity may be deteriorated. Therefore, the curvature radius is preferably set at about 0.2 mm or less.

Third Embodiment

[0079] A loudspeaker according to the third embodiment of the present invention will be described below with reference to FIG. 9. FIG. 9 is a sectional view of the right half of a diaphragm 21 of a loudspeaker (nominal diameter of 25 mm)

according to the third embodiment. Since the left half is symmetrical about a center line C, the left half is omitted in FIG. 9. The diaphragm 21 according to the third embodiment is of a semi-dome type, and has a dome portion 21a, a cone portion 21c, an edge portion 21e, and a fixing portion 21f. At a first boundary portion 21b between the dome portion 21a and the cone portion 21c, a voice coil fitting portion 21g is arranged on the lower side of the bottom of the cone portion 21c.

[0080] Specification of the diaphragm 21 is as follows. A material of the diaphragm 21 is a titanium foil having a thickness of 0.025 mm. A diameter of the first boundary portion 21b is 16.2 mm, and a diameter of the voice coil 22 is 16.5 mm. A diameter of a second boundary portion 21d between the cone portion 21c and the edge portion 21e is 22.5 mm. An outer diameter of the edge portion 21e is 24.5 mm.

[0081] A bottom inclination angle θ_1 of the dome portion 21a is 28.5° , and a bottom inclination angle θ_2 of the cone portion 21c is 27° , so that the angles are made almost equal to each other. A surface area of the dome portion 21a is 2.2 cm^2 , a surface area of the voice coil fitting portion 21g is 0.27 cm^2 , and a surface area of the cone portion 21c is 2.05 cm^2 . A total surface area of the cone portion 21c and the voice coil fitting portion 21g is 2.32 cm^2 .

[0082] According to the third embodiment, the total surface area of the cone portion 21c and the voice coil fitting portion 21g is made almost equal to the surface area of the dome portion 21a. A total height h_1 of the dome portion 21a is 2.05 mm, and a curvature radius of the dome portion 21a is 17 mm. A total height h_2 of the cone portion 21c is 1.35 mm. An outer peripheral portion 21i of the dome portion 21a at the first boundary portion 21b has a curved surface (R) having a curvature radius of about 0.2 mm. A height h_3 of the voice coil fitting portion 21g is 0.4 mm. The height h_3 of the voice coil fitting portion is preferably 5% or less of the diameter of the voice coil fitting portion with respect to formability of a diaphragm. A diameter of the bottom of the cone portion 21c is 16.4 mm. The voice coil fitting portion 21g is tapered such that the diameter gradually decreases from the lower side to the upper side in FIG. 9. The voice coil 22 is fixed to the diaphragm 21 such that the outer peripheral surface of the voice coil fitting portion 21g is fitted in a winding frame 22a of the voice coil 22a to adhere to the winding frame 22a. An adhesive agent is filled between the outer peripheral surface of the voice coil fitting portion 21g and the outer peripheral surface of the winding frame 22a.

[0083] According the third embodiment, the diaphragm 21 has the above specification, so that a titanium-foil material is prevented from being wrinkled or torn when the material is pressed to form the diaphragm 21. The sound-pressure frequency characteristic of the loudspeaker according to the third embodiment is almost equal to the sound-pressure frequency characteristic according to the second embodiment shown in FIG. 10. As a result, an excellent sound-pressure frequency characteristic can be obtained. When a ratio of a difference between a total surface area of the surface area of the cone portion 21c and the surface area of the voice coil fitting portion 21g and the surface area of the dome portion 21a to a larger surface area between the total surface area and the surface area of the dome portion 21a is about 15%, a sound-pressure frequency characteristic being free from large peaks or large dips can be obtained.

[0084] Since the diaphragm 21 according to the third embodiment has the voice coil fitting portion 21g, the step of fixing the voice coil 22 to the diaphragm 21 is easy. The curvature radius of the outer peripheral portion 21i of the dome portion 21a is preferably large with respect to formability. However, when the curvature radius is increased, a gap is formed between the inner peripheral surface of the winding frame 22a and the outer peripheral surface of the voice coil fitting portion 21g when the voice coil 22 is fixed. When the adhesive agent fails to be filled in the gap without any space, a high-range sound-pressure frequency characteristic may be deteriorated. For this reason, it must be careful to in the assembling process. When the adhesion is perfectly performed, the winding frame 22a is perfectly fixed to the diaphragm 21 without any problem.

Industrial Applicability

[0085] The present invention can be used in a high-tone loudspeaker which reproduces sound in a ultra-high range.

Claims

1. A high-tone loudspeaker comprising:

a semi-dome type diaphragm in which a dome portion, a cone portion arranged around the dome portion, and an edge portion arranged around the cone portion are constructed by integrally forming a metal thin plate; a voice coil connected to a boundary portion between the dome portion and the cone portion; and a magnetic field portion which gives an electromagnetic drive force to the voice coil depending on a current flowing in the voice coil, wherein

at a boundary between the dome portion and the cone portion, a ratio of a difference between a bottom inclination angle of the dome portion and a bottom inclination angle of the cone portion to a larger bottom inclination angle between the bottom inclination angle of the dome portion and the bottom inclination angle of the cone portion is set at not more than 15%, and a ratio of a difference between a surface area of the dome portion and a surface

area of the cone portion to a larger area between the surface area of the dome portion and the surface area of the cone portion is set at not more than 15%.

2. The high-tone loudspeaker according to claim 1, wherein the bottom inclination angle of the dome portion and the bottom inclination angle of the cone portion are made almost equal to each other.
3. The high-tone loudspeaker according to claim 1, wherein the surface area of the dome portion and the surface area of the cone portion are made almost equal to each other.
4. The high-tone loudspeaker according to claim 1, wherein at a boundary between the dome portion and the cone portion, the diaphragm has a voice coil fitting portion formed in a cylindrical shape having the same central axis as that of the voice coil.
5. The high-tone loudspeaker according to claim 3, wherein a ratio of a height of the voice coil fitting portion to a diameter of the voice coil fitting portion is not more than 5%.
6. The high-tone loudspeaker according to claim 4, wherein the voice coil fitting portion is formed from an outer periphery of the dome portion in an opposite direction of a projecting direction of the dome portion.
7. The high-tone loudspeaker according to claim 4, wherein the voice coil fitting portion is formed from an outer periphery of the cone portion in an opposite direction of a projecting direction of the cone portion.
8. The high-tone loudspeaker according to claim 6, wherein a ratio of a difference between a total surface area of the surface area of the dome portion and the surface area of the voice coil fitting portion and the surface area of the cone portion to a larger surface area between the total surface area and the surface area of the cone portion is set at not more than 15%.
9. The high-tone loudspeaker according to claim 7, wherein a ratio of a difference between a total surface area of the surface area of the cone portion and the surface area of the voice coil fitting portion and the surface area of the dome portion to a larger surface area between the total surface area and the surface area of the dome portion is set at not more than 15%.

FIG 1A

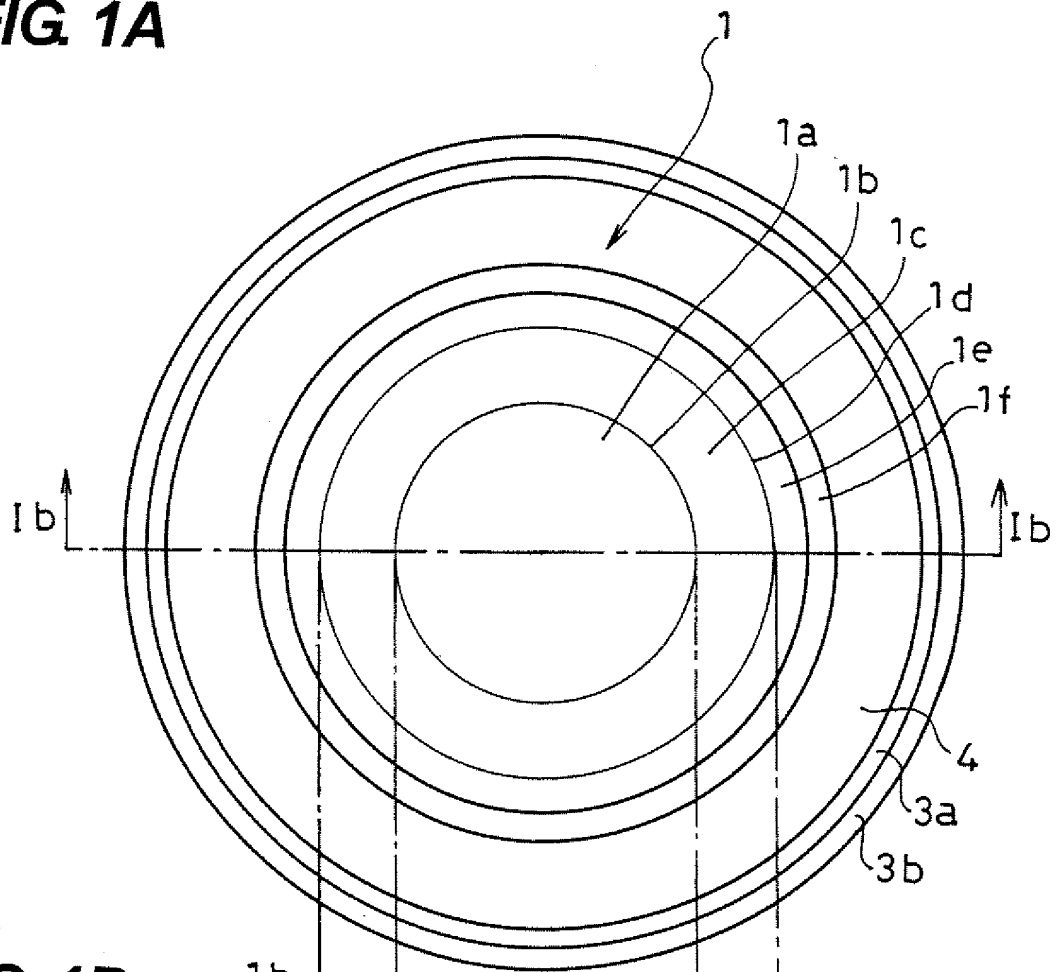


FIG 1B

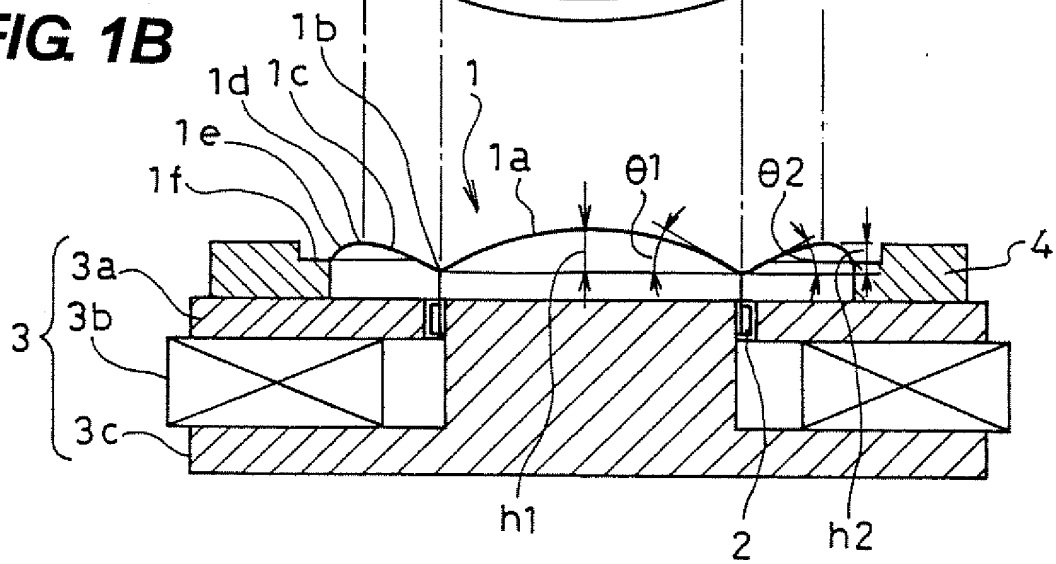


FIG 2

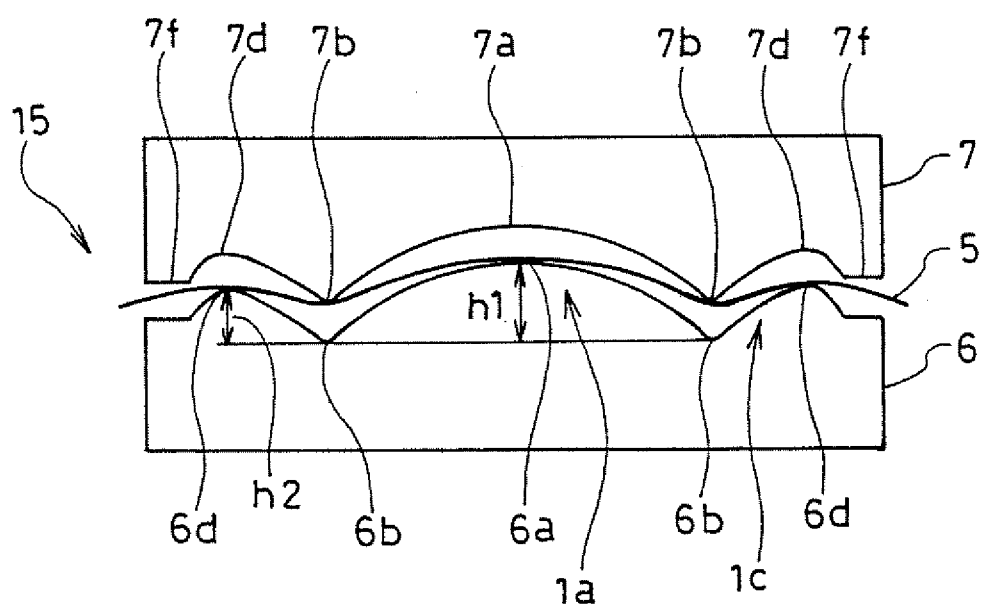


FIG. 3

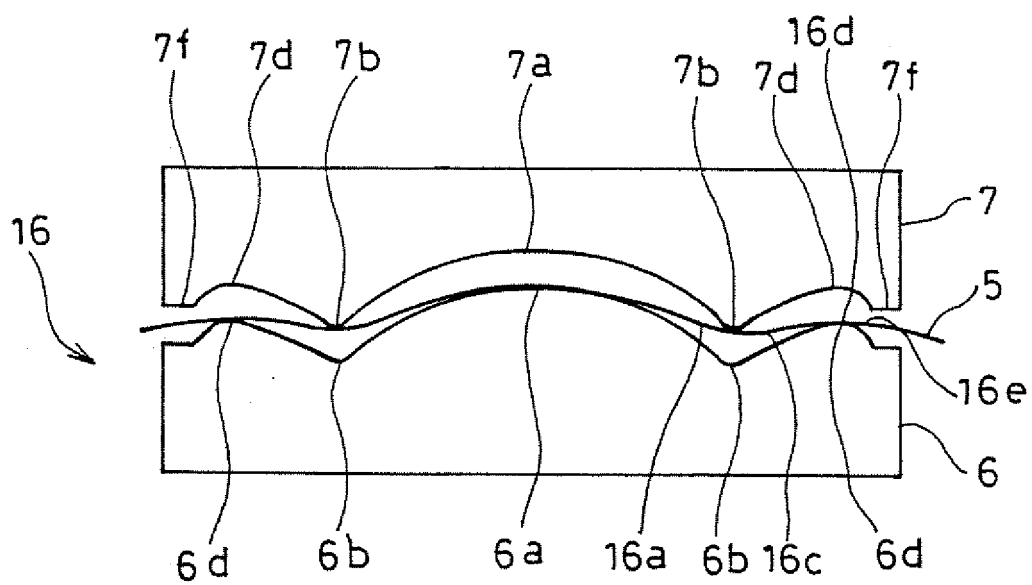
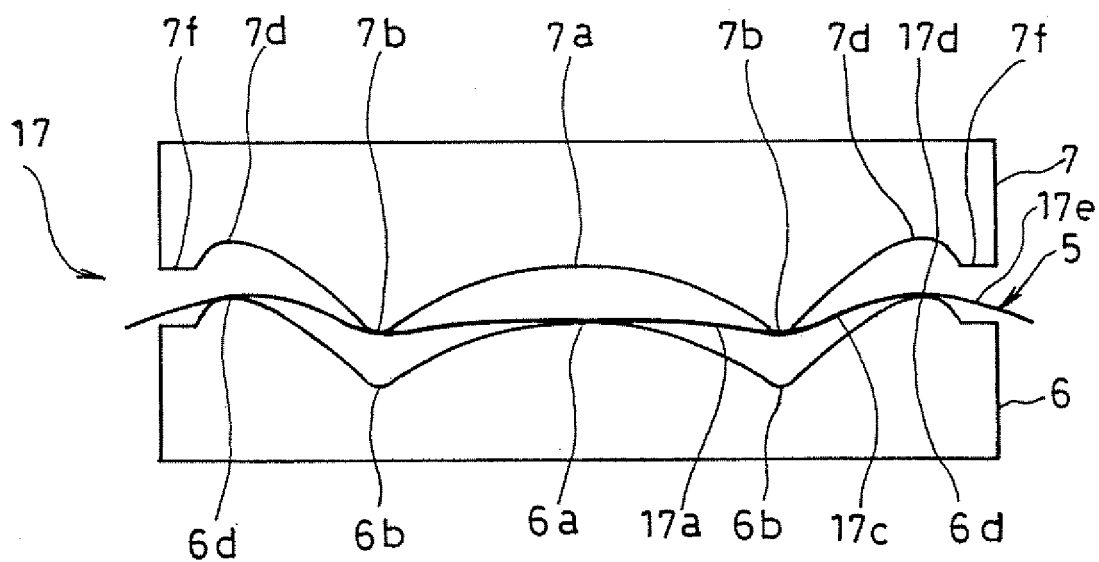
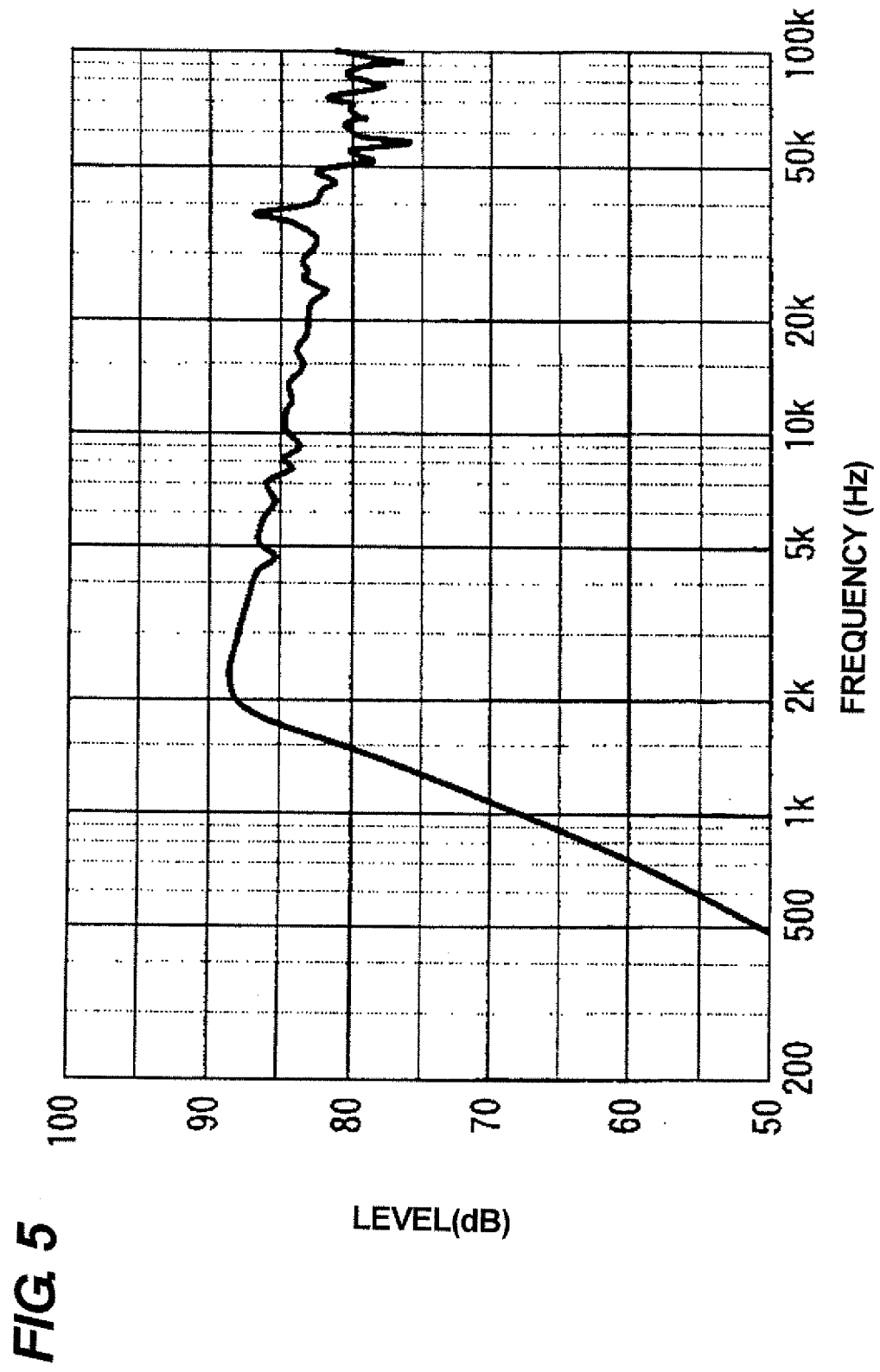


FIG. 4





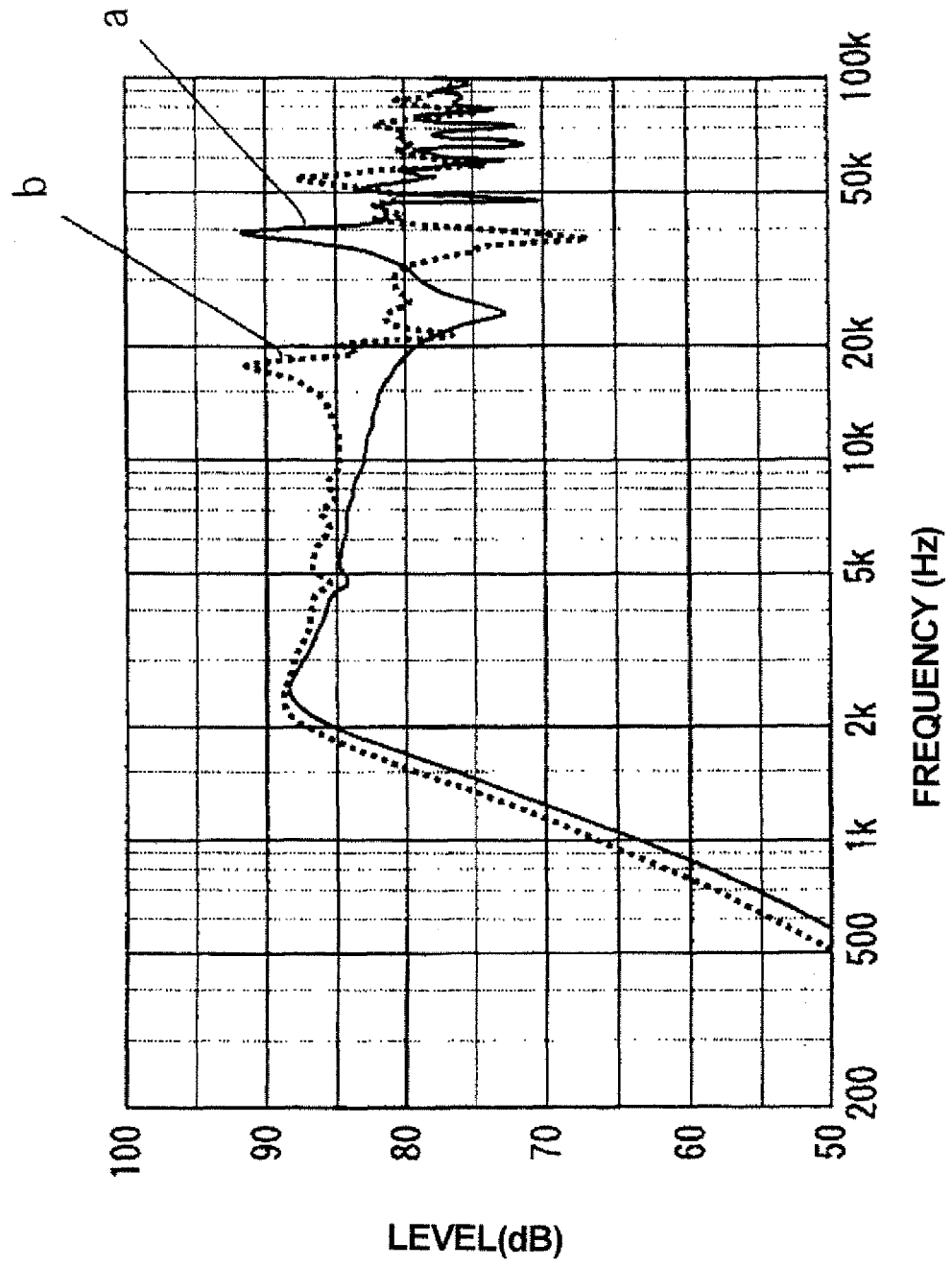


FIG. 6

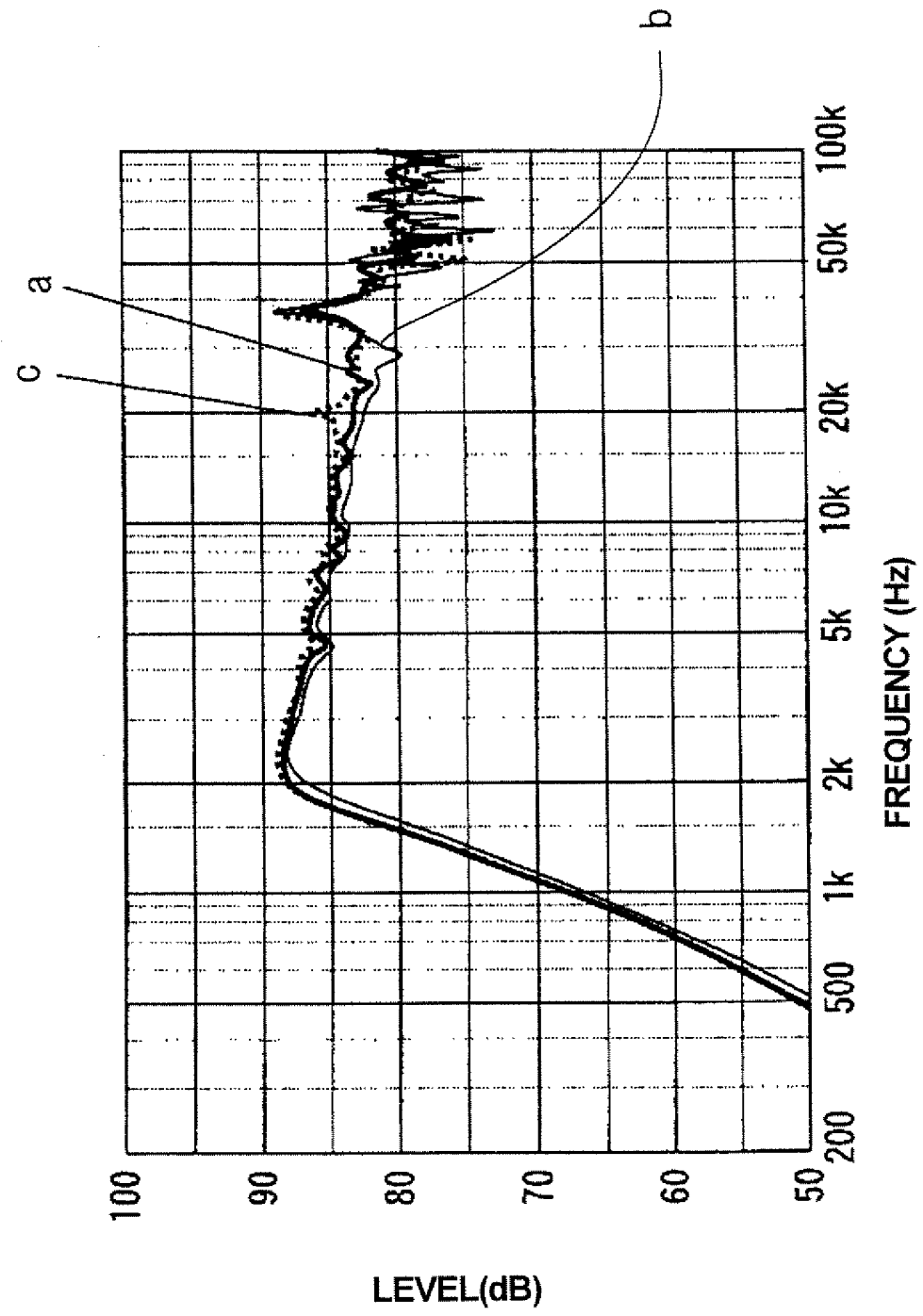


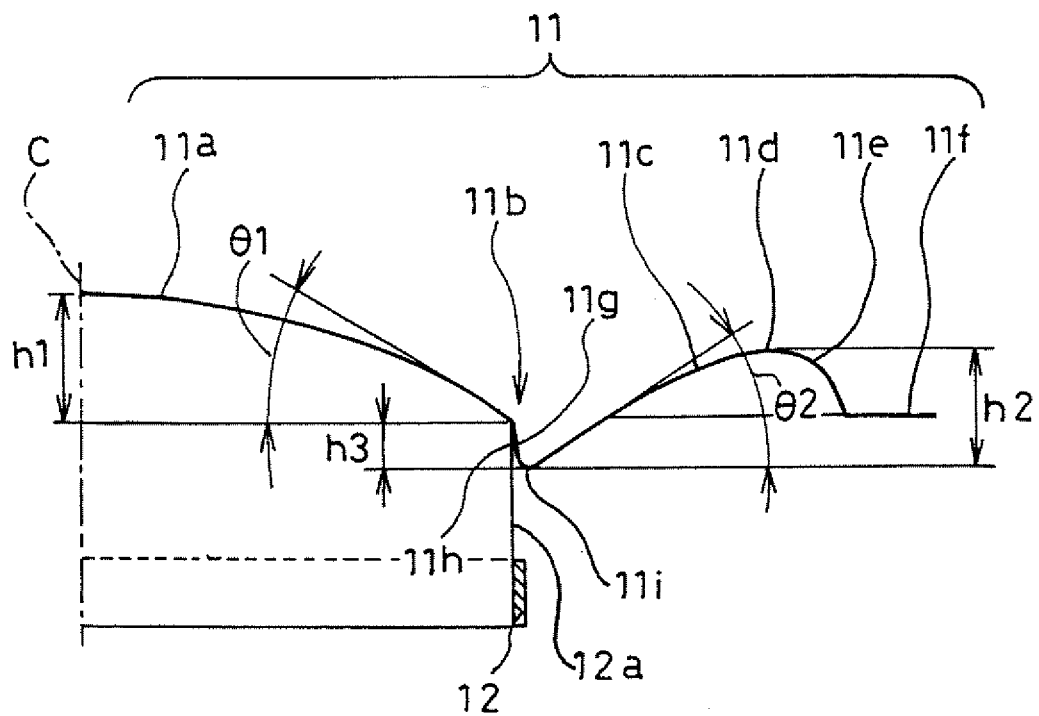
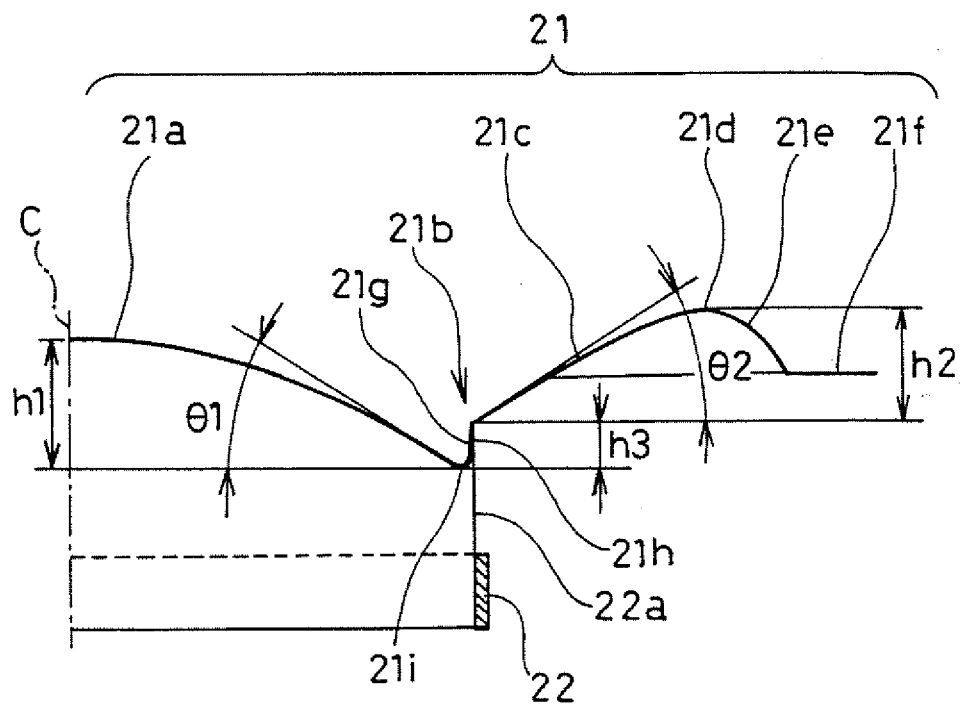
FIG. 8

FIG. 9



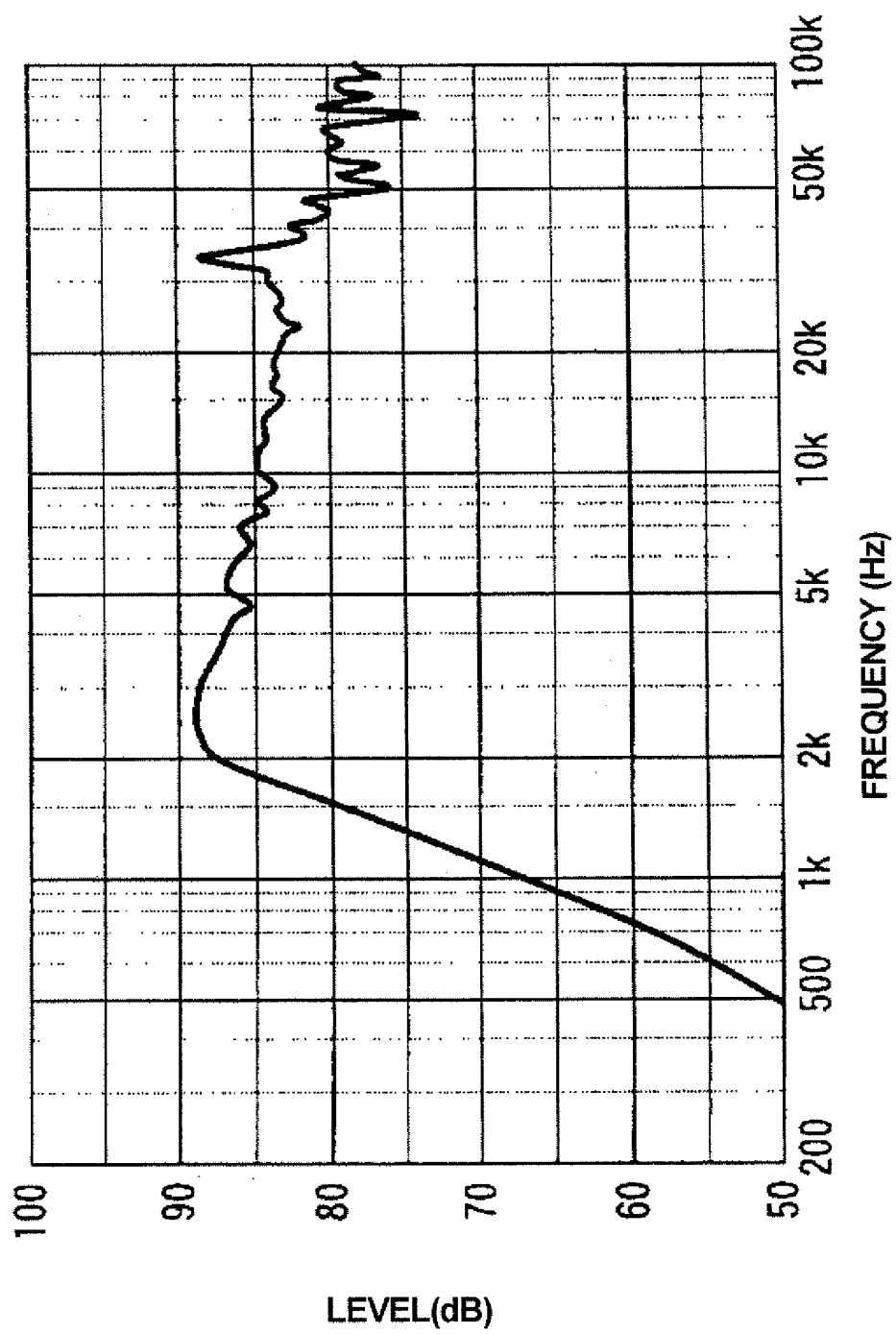


FIG. 10

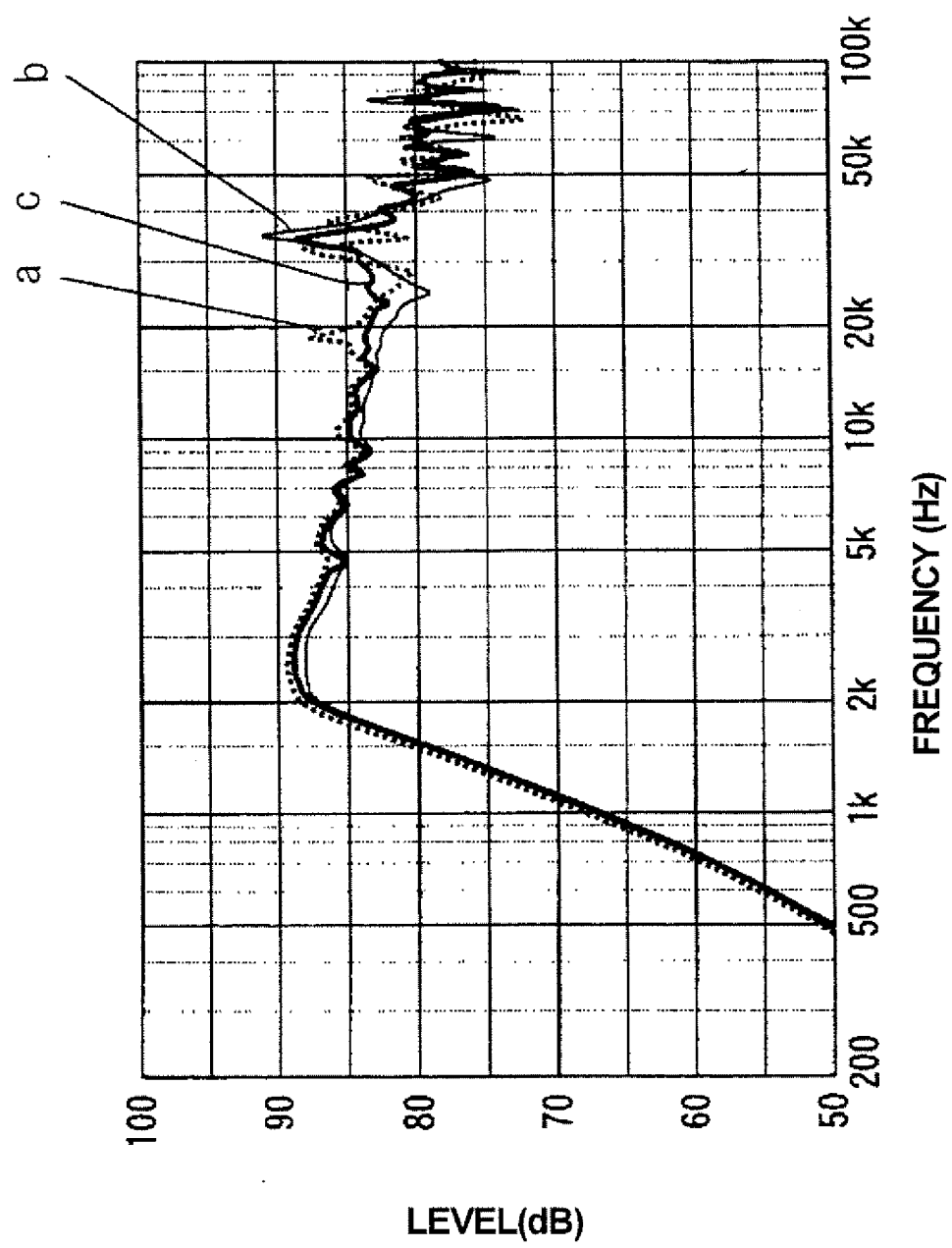
**FIG. 11**

FIG. 12

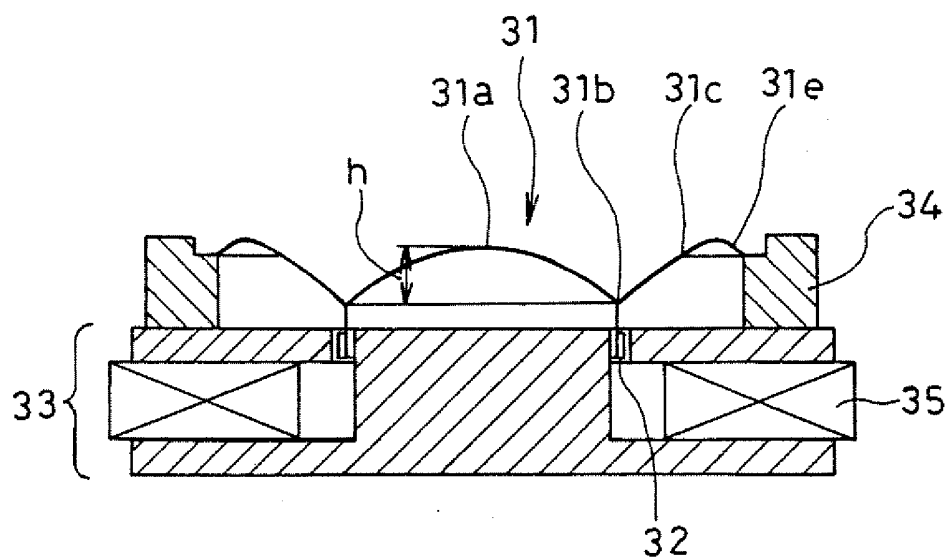
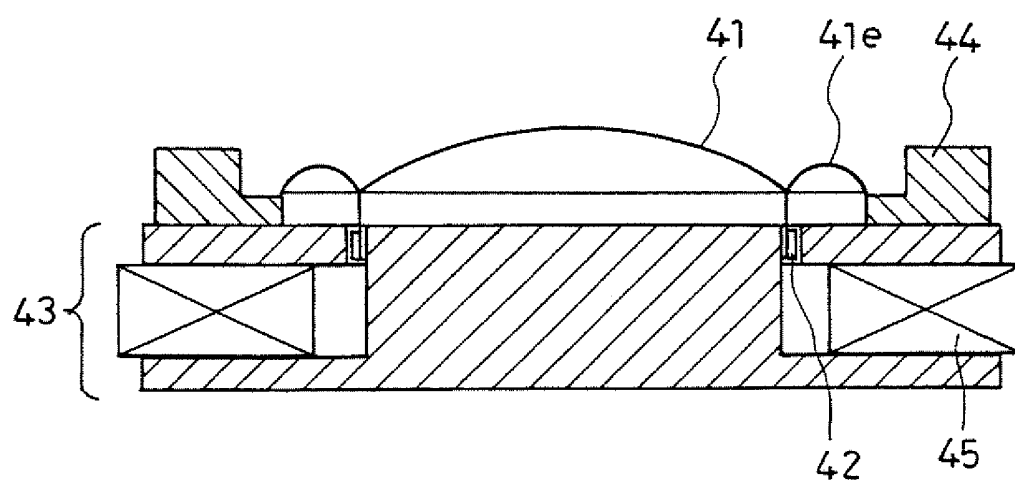
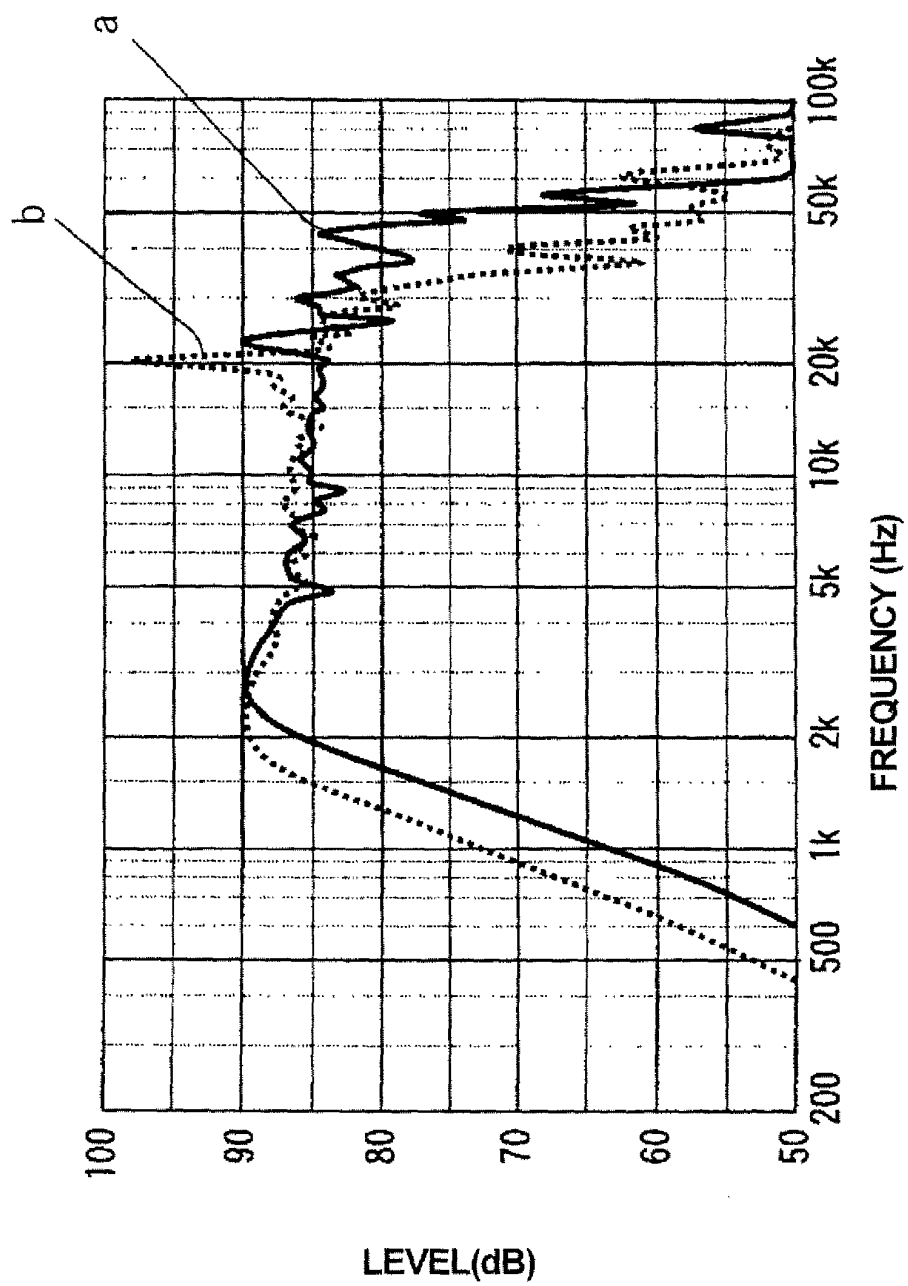


FIG. 13





INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/016771

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl ⁷ H04R7/02, 7/12		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) Int.Cl ⁷ H04R7/02, 7/12		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Toroku Jitsuyo Shinan Koho 1994-2005 Kokai Jitsuyo Shinan Koho 1971-2005 Jitsuyo Shinan Toroku Koho 1996-2005		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2003-299191 A (Matsushita Electric Industrial Co., Ltd.), 17 October, 2003 (17.10.03), Full text; all drawings (Family: none)	1-9
A	JP 2003-199193 A (Pioneer Electronic Corp., Tohoku Pioneer Corp.), 11 July, 2003 (11.07.03), Full text; all drawings (Family: none)	1-9
A	JP 2002-125290 A (Sony Corp.), 26 April, 2002 (26.04.02), Full text; all drawings (Family: none)	1-9
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
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Date of the actual completion of the international search 12 January, 2005 (12.01.05)		Date of mailing of the international search report 25 January, 2005 (25.01.05)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/016771

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 8-79884 A (Pioneer Electronic Corp.), 22 March, 1996 (22.03.96), Full text; all drawings & US 5719946 A	1-9

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