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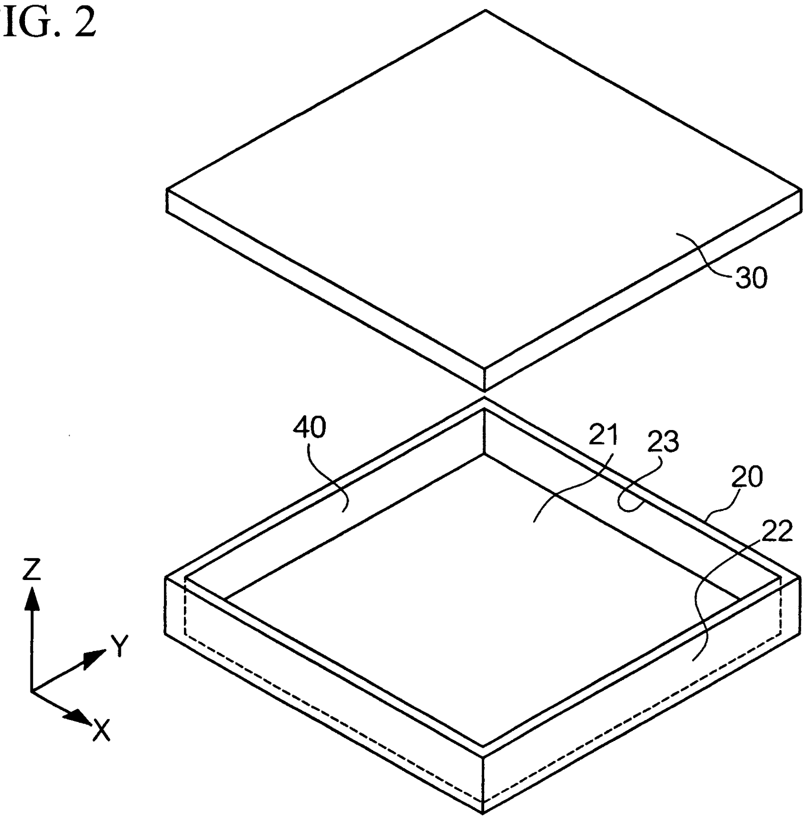
(54) Sound absorbing structure using closed-cell porous medium

(57) A sound absorbing structure (10) is constituted of a housing (20), a vibration member (30) composed of a closed-cell porous material whose airflow rate is less than 0.1 dm^3/s, and an air cavity (40) formed inside the housing in the rear side of the vibration member. Alternatively, the vibration member is formed by laminating an open-cell porous material or an air-permeable member with the closed-cell porous material. The sound absorbing structure demonstrates a high sound absorption in a low frequency range due to the closed-cell porous material.

FIG. 2



EP 2 157 567 A2

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to sound absorbing structures using closed-cell porous media. The present invention also relates to sound chambers using sound absorbing structures.

[0002] The present application claims priority on Japanese Patent Application No. 2008-211972, the content of which is incorporated herein by reference.

Description of the Related Art

[0003] In generally-known sound absorbing structures using open-cell porous media (e.g. glass wools), the sound absorption increases proportionally to the particle velocity of sound waves so that it becomes high in a high frequency range but it becomes low in a low frequency range. Generating high sound absorption in a low frequency range requires sound absorbing structures having a thickness of about λ/4 (e.g. 34 cm for 250 Hz), which are difficult to be installed in a small space.

[0004] It is possible to generate a high sound absorption in a low frequency range by use of a sound absorbing structure which absorbs sound by way of a plate or membrane vibration member and its rear air cavity, wherein a laminated board having a thickness of 4 mm is equipped with a rear air cavity having a thickness of 45 mm which is filled with glass wools therein, so that the sound absorption coefficient thereof peaks at 0.6 in a low frequency of 250 Hz, for example.
Patent Document 1: Japanese Unexamined Patent Application Publication No. 2003-316364
Patent Document 2: Japanese Unexamined Patent Application Publication No.

[0005] Patent Document 1 discloses sound absorbing media using open-cell porous materials (or cellular porous materials), which are well known in the fields of sound absorbing technology.

[0006] Patent Document 2 discloses sound absorbing media using open-cell porous materials and closed-cell porous materials with an airflow rate of 0.1 dm^3/s or more. A high airflow rate does not cause a sound pressure difference between the surface and the backside of the porous material, which in turn makes it difficult for a plate vibration member to vibrate, thus degrading a sound absorbing effect of a plate-vibration sound absorbing structure.

SUMMARY OF THE INVENTION

[0007] It is an object of the present invention to provide a sound absorbing structure using a closed-cell porous material having elasticity but not having air permeability. Specifically, the present invention aims at demonstrating a high sound absorbing effect in a low frequency range with a thin sound absorbing structure whose total thickness (i.e. the sum of the thickness of a porous material and the thickness of a rear air cavity) is about 50 mm.

[0008] A sound absorbing structure of the present invention is constituted of a vibration member composed of a closed-cell porous material, and an air cavity formed in the rear side of the vibration member.

[0009] Alternatively, the vibration member is formed by laminating an open-cell porous material with the closed-cell porous material or by laminating an air-permeable member with the closed-cell porous material.

[0010] In the above, it is preferable that an airflow rate of the closed-cell porous material be less than 0.1 dm^3/s.

[0011] A sound absorbent group is formed using a plurality of sound absorbing structures, each of which is constituted of the vibration member and the air cavity.

[0012] A sound chamber is formed using at least one sound absorbing structure including the vibration member and the air cavity.

[0013] As described above, the sound absorbing structure of the present invention is a plate/film-vibration sound absorbing structure in which the air cavity formed inside the housing is closed with the vibration member composed of the closed-cell porous material, wherein it is possible to prevent the degradation of the vibration member while securing high sound absorption characteristics, thus improving the reliability in sound absorption.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] These and other objects, aspects, and embodiments of the present invention will be described in more detail with reference to the following drawings.

[0015] Fig. 1 is a perspective view showing the constitution of a sound absorbing structure according to a preferred embodiment of the present invention.

[0016] Fig. 2 is an exploded perspective view of the sound absorbing structure which is constituted of a housing, a vibration member, and an air cavity.

[0017] Fig. 3A is a sectional view taken along line III-III in Fig. 1 showing that the housing is covered with the vibration member composed of a closed-cell porous material.

[0018] Fig. 3B is a sectional view taken along line III-III in Fig. 1 showing that the housing is covered with the vibration member composed of a closed-cell porous material and an open-cell porous material.

[0019] Fig. 3C is a sectional view taken along line III-III in Fig. 1 showing that the housing is covered with the vibration member composed of a closed-cell porous material and an air-permeable member.

[0020] Fig. 4A is a sectional view diagrammatically showing the closed-cell porous material including a plurality of closed cells.

[0021] Fig. 4B is a sectional view diagrammatically showing the open-cell porous material including a plurality of open cells.

[0022] Fig. 5 is a graph showing open-cell and closed-cell characteristic curves based on experimental results with a 10-mm-thickness air cavity formed in the rear side of the vibration member in the sound absorbing structure.

[0023] Fig. 6 is a graph showing open-cell and closed-cell characteristic curves based on experimental results with a 20-mm-thickness air cavity formed in the rear side of the vibration member in the sound absorbing structure.

[0024] Fig. 7 is a graph showing open-cell and closed-cell characteristic curves based on experimental results with a 30-mm-thickness air cavity formed in the rear side of the vibration member in the sound absorbing structure.

[0025] Fig. 8 is a graph showing open-cell and closed-cell characteristic curves based on experimental results with a 10-mm-thickness air cavity formed in the rear side of the vibration member in the sound absorbing structure.

[0026] Fig. 9 is a graph showing open-cell and closed-cell characteristic curves based on experimental results with a 20-mm-thickness air cavity formed in the rear side of the vibration member in the sound absorbing structure.

[0027] Fig. 10 is a graph showing open-cell and closed-cell characteristic curves based on experimental results with a 30-mm-thickness air cavity formed in the rear side of the vibration member in the sound absorbing structure.

[0028] Fig. 11 is a graph showing simulation results of normal incidence sound absorption coefficients on a sound absorbing structure according to a third variation of the present embodiment, wherein five characteristic curves are plotted with respect to various surface densities at the center of the vibration member.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0029] The present invention will be described in further detail by way of examples with reference to the accompanying drawings.

1. Constitution of Sound Absorbing Structure

[0030] Fig. 1 is a perspective view showing the constitution of a sound absorbing structure 10 according to a preferred embodiment of the present invention. Fig. 2 is an exploded perspective view of the sound absorbing structure 10. Figs. 3A to 3C are sectional views taken along line III-III in Fig. 1. For the sake of convenience, Figs. 1 and 2 and Figs 3A to 3C are illustrated with prescribed dimensions, which do not precisely match the actual design dimensions, in order to distinctively show the constituent elements of the sound absorbing structure 10.

[0031] The sound absorbing structure 10 is constituted of a housing 20 (serving as the base of the sound absorbing structure 10), a vibration member 30 for covering an opening 23 of the housing 20, and an air cavity 40 which is formed inside the housing 20 equipped with the vibration member 30.

[0032] The housing 20 is formed in a closed-bottom rectangular prismatic shape composed of a synthetic resin (e.g. an ABS resin), which is constituted of a base 21 and a side wall 22 as well as the opening 23. The base 21 is disposed opposite to the opening 23, while the side wall 22 is disposed to encompass the opening 23. The vibration member 30 is a squared board composed of a high polymer compound (e.g. a silicon foam, a urethane foam, a polyethylene foam, an ethylene-propylene rubber foam, etc.). The periphery of the vibration member 30 is bonded to the edge of the opening 23. Since the vibration member 30 is fixed upon the opening 23 of the housing 20, a tightly-closed air cavity 40 is formed inside the sound absorbing structure 10 (or in the rear side of the vibration member 30).

[0033] The vibration member 30 is not necessarily formed in a plate (or board) shape but is formed in a film (or membrane) shape. In short, the present embodiment requires that the vibration member 30 be formed of any type of material which is deformable upon receiving an external force and is restorable in shape due to elasticity.

[0034] In this connection, the plate shape is defined as a thin three-dimensional shape (or a rectangular parallelepiped shape) which is reduced in thickness and is enlarged in a two-dimensional area, while the film shape (or sheet shape) is further reduced in thickness compared to the plate shape and is restorable in shape due to tension.

[0035] The vibration member 30 is formed in a prescribed shape and of a prescribed material which is reduced in terms of a rigidity (i.e. a Young's modulus, a thickness, and a geometrical moment of inertia) and/or a mechanical impedance, i.e. $8x\{(\text{bending rigidity})x(\text{surface density})\}^{1/2}$, in comparison with the housing 20. That is, the vibration member 30 possesses elastic-vibration ability relative to the housing 20, so that the sound absorbing structure 10 demonstrates the sound absorbing operation by means of the vibration member 30.

[0036] The sound absorbing structure 10 having the above basic constitution is **characterized in that** the vibration member 30 is formed using a closed-cell porous material 50 shown in Fig. 3A. The airflow rate of the closed-cell porous material 50 is less than 0.1 dm^3/s, thus shutting off an airflow therethrough. As the closed-cell porous material, it is possible to use a silicon foam and an ethylene-propylene rubber foam (or EPDM, i.e. ethylene-propylene-diene-methylene rubber), for example.

[0037] Figs. 4A and 4B illustrate the cross-sectional comparison between the closed-cell porous material 50 and an open-cell porous material 60.

[0038] In the closed-cell porous material 50 shown in Fig. 4A, a plurality of closed cells 51 do not communicate with each other and overlap with each other so that they are independent of each other. The closed-cell porous material 51 having elasticity serves as an integrally vibrating board, in other words, the closed-cell porous material 51 has elasticity but does not have air permeability.

[0039] Fig. 4A diagrammatically shows that the closed cells 51 are regularly aligned, but they may be aligned in a random manner; that is, the closed-cell porous material 50 includes the closed cells 51, which do not overlap with each other, so as to prevent an airflow occurring between the surface and the backside thereof.

[0040] In the open-cell porous material 60 shown in Fig. 4B, a plurality of open cells 61 partially overlap with each other and communicate with each other; hence, the open-cell porous material 60 has a sponge-like texture dependent upon the material and the size of the cell 61. Fig. 4B diagrammatically shows that the open cells 61 are regularly aligned, but they may be aligned in a random manner; that is, the open-cell porous material 60 includes the open cells 61, which adjoin together to partially overlap with each other, so as to establish an air flow occurring between the surface and the backside thereof.

2. Operation of Sound Absorbing Structure

[0041] Generally speaking, the sound absorbing structure 10 serves as a spring-mass system composed of the mass of the vibration member 30 and the spring component of the air cavity 40.

[0042] A resonance frequency f [Hz] of the spring-mass system is given by equation (1) using an air density ρ_0 [kg/m^3], the speed of sound c_0 [m/s], a density ρ [kg/m^3], a thickness t [m] of the vibration member 30, and a thickness L [m] of the air cavity 40.

$$f = \frac{1}{2\pi}\left(\frac{\rho_0 {c_0}^2}{\rho t L}\right)^{1/2} \qquad (1)$$

[0043] When the sound absorbing structure 10 includes the vibration member 30 having elasticity subjected to elastic vibration, a bending system (representing the elastic vibration) is applied to the spring-mass system.

[0044] A resonance frequency f [Hz] of a plate/film-vibrating sound absorbing structure is given by equation (2) using a one-side length "a" [m] and another-side length "b" [m] of the rectangular shape of the vibration member 30, a Poisson ratio σ [-] of the vibration member 30, and integral numbers p, q. In the field of architectural acoustics, the calculation result of the above resonance frequency f is used for architectural acoustic designs.

$$f = \frac{1}{2\pi}\left[\frac{\rho_0 {c_0}^2}{\rho t L} + \left\{\left(\frac{p}{a}\right)^2 + \left(\frac{q}{b}\right)^2\right\}^2 \left\{\frac{\pi^4 E t^3}{12\rho t\left(1-\sigma^2\right)}\right\}\right]^{1/2} \qquad (2)$$

[0045] According to equation (2), the resonance frequency f represents the sum of the term of the spring-mass system "$\rho_0 {c_0}^2/\rho t L$" and the term of the bending system (i.e. the term directly subsequent to the term of the spring-mass system). According to equation (2), the spring-mass system of the vibration member 30 and the bending system representing the elastic vibration form important factors determining the sound absorbing condition for the sound absorbing structure 10.

[0046] In the sound absorbing structure 10 of the present embodiment, the vibration member 30 is subjected to elastic vibration dependent upon the difference between the external sound pressure applied to the exterior surface of the vibration member 30 and the internal sound pressure occurring inside the air cavity 40, in other words, the sound-pressure difference between the surface and the backside of the vibration member 30. Sound is absorbed in such a way that energy of sound waves reaching the sound absorbing structure 10 is consumed by way of the vibration of the vibration member 30. The vibration member 30 absorbs sound in a certain frequency range whose center frequency corresponds to the resonance frequency f according to equation (2).

3. Sound Absorbing Effect

[0047] The sound absorbing effect of the sound absorbing structure 10 will be described with reference to Figs. 5 to 7. Figs. 5 to 7 are graphs of characteristic curves representing results of experiments in which sounds having various frequencies are applied to sound absorbing structures (i.e. experimental subjects) so as to measure normal incidence sound absorbing coefficients.

[0048] Specifically, Figs. 5 to 7 show experimental results with respect to two types of sound absorbing structures, one of which includes an open-cell type vibration member composed of a 10-mm-thickness open-cell urethane foam and the other of which includes a closed-cell type vibration member composed of a 10-mm-thickness closed-cell silicon foam. That is, an open-cell characteristic curve A represents the sound absorption characteristic regarding the open-cell type vibration member, while a closed-cell characteristic curve B represents the sound absorption characteristic regarding the closed-cell type vibration member.

[0049] In addition, Figs. 5 to 7 differ from each other in terms of the thickness of an air cavity formed in the rear side of the vibration member; that is, Fig. 5 shows the experimental result with regard to a 10-mm-thickness air cavity; Fig. 6 shows the experimental result with regard to a 20-mm-thickness air cavity; and Fig. 7 shows the experimental result with regard to a 30-mm-thickness air cavity.

[0050] The open-cell characteristic curves A of Figs. 5 to 7 show that sound absorption coefficients decrease in a low frequency range but increase in a high frequency range, while the closed-cell characteristic curves B show that sound absorption coefficients peak at maximum values in a further low frequency range. This proves that the sound absorbing structure 10 including the vibration member 30 composed of a closed-cell porous material demonstrates an adequate sound absorbing effect. In the above, the density of the closed-cell porous material is set to 250 kg/m^3, while the density of the open-cell porous material is set to 35 kg/m^3.

[0051] Figs. 8 to 10 show experimental results with respect to two types of sound absorbing structures, one of which includes an open-cell type vibration member composed of a 10-mm-thickness open-cell urethane foam and the other of which includes a closed-cell type vibration member composed of a 10-mm-thickness closed-cell EPDM, i.e. an ethylene-propylene-diene-methylene rubber. Herein, an open-cell characteristic curve A represents the sound absorption characteristic regarding the open-cell type vibration member, while a closed-cell characteristic curve B represents the sound absorption characteristic regarding the closed-cell type vibration member.

[0052] In addition, Figs. 8 to 10 differ from each other in terms of the thickness of an air cavity formed in the rear side of the vibration member; that is, Fig. 8 shows the experimental result with regard to a 10-mm-thickness air cavity; Fig. 9 shows the experimental result with regard to a 20-mm-thickness air cavity; and Fig. 10 shows the experimental result with regard to a 30-mm-thickness air cavity.

[0053] Similar to the experimental results of Figs. 5 to 7, the experimental results of Figs. 8 to 10, which are measured using the closed-cell vibration member composed of EPDM, sound absorption coefficients peak at maximum values in a low frequency range.

[0054] According to the above experimental results, the sound absorbing structure 10 including the vibration member 30 composed of the closed-cell porous material 50 is capable of absorbing sound in a low frequency range regardless of the "slim" thickness of the vibration member 30 and the air cavity 40 in total which is 50 mm or less.

[0055] Since the closed-cell porous material 50 shuts off an airflow therethrough, it is possible to prevent external air from entering into the air cavity 40 via the vibration member 30 even when the sound absorbing structure 10 is positioned in a dusty sound field or environment. That is, it is possible to prevent the air cavity 40 from being contaminated with dust or foreign matter.

[0056] Since the closed-cell porous material 50 inherently blocks air or humidity entering therein, it is possible to enhance the durability of the vibration member 30 and to thereby improve the reliability of the sound absorbing structure 10.

[0057] Since the closed-cell porous material 50 is lower in manufacturing cost than the open-cell porous material 60, it is possible to manufacture the sound absorbing structure 10 at a relatively low cost. Since it is easier to perform cutting on the closed-cell porous material 50 rather than the open-cell porous material 60, it is possible to improve the productivity. As described above, the present embodiment demonstrates various outstanding effects.

4. Variations

[0058] The present invention is not necessarily limited to the present embodiment, which can be modified in various ways.

(1) First variation

[0059] The present embodiment exemplifies the sound absorbing structure 10 including the vibration member 30 composed of the closed-cell porous material 50, which can be modified in various ways.
[0060] Fig. 3B is a sectional view of a vibration member 31 in which the open-cell porous material 60 is laminated on the surface (i.e. the sound-incidence side) of the closed-cell porous material 50. The vibration member 31 is fixed to the housing 20 in such a way that the air cavity 40 is formed in the rear side of the closed-cell porous material 50.
[0061] Fig. 3C is a sectional view of a vibration member 32 in which an air-permeable member 70 composed of a fabric material such as a mesh, cloth, and flocked fabric is laminated on the surface (i.e. the sound-incidence side) of the closed-cell porous material 50. The vibration member 32 is fixed to the housing 20 in such a way that the air cavity 40 is formed in the rear side of the closed-cell porous material 50.
[0062] It is possible to demonstrate the foregoing effect of the present embodiment by use of the vibration members 31 and 32. Due to the arrangement of the open-cell porous material 60 or the air-permeability member 70 on the surface of the closed-cell porous material 50, it is possible to demonstrate an additional effect that sound is easily absorbed by the material 60 or 70.
[0063] It is possible to further modify the vibration member 31 such that three or more layers of the open-cell porous material 60 are laminated on the closed-cell porous material 50. Alternatively, it is possible to further laminate the air-permeability member 70 on the open-cell porous material 60 above the closed-cell porous material 50. In short, the first variation requires that the vibration member be formed using the closed-cell porous material 50 so as to reliably shut off the airflow occurring between the air cavity 40 and the external air.

(2) Second variation

[0064] Although the relevancy between the resonance frequency of the spring-mass system and the resonance frequency of the bending system based on the elastic vibration of the plate is univocally defined by equation (2), the actual behavior of the sound absorbing structure has not been fully clarified, hence, the actual working model of the sound absorbing structure demonstrating a high sound absorption in a low frequency range has not been established.
[0065] For this reason, the present inventor performed various detailed experiments so as to determine inequality (3) regarding the relationship between a fundamental frequency fa of the bending system and a resonance frequency fb of the spring-mass system. By setting parameters to suit inequality (3), the present inventor actually verified an improvement of the sound absorption, since the fundamental vibration of the bending system cooperates with the spring component of the rear air cavity so that a relatively high amplitude of vibration occurs in a frequency band between the resonance frequency of the spring-mass system and the fundamental frequency of the bending system, i.e. (resonance frequency fa of bending system) < (peak sound-absorption frequency f) < (fundamental frequency fb of spring-mass system).

$$0.05 \leq fa/fb \leq 0.65 \quad (3)$$

[0066] By setting parameters to suit inequality (4), it is possible to substantially make the peak sound-absorption frequency lower than the resonance frequency of the spring-mass system. Herein, the present inventor verified that the sound absorbing structure including parameters according to inequality (4) is suitable for absorbing sound in a low frequency range which is 300 Hz or less, since the fundamental frequency of the bending system is sufficiently lowered due to a low-degree elastic vibration mode.

$$0.05 \leq fa/fb \leq 0.40 \quad (4)$$

[0067] By setting parameters to suit inequalities (3) and (4), it is possible to design the sound absorbing structure whose peak sound-absorption frequency is lowered in a low frequency range.

(3) Third variation

[0068] The present embodiment exemplifies the sound absorbing structure 10 which is constituted of the rectangular housing 20, the vibration member 30 for closing the opening 23 of the housing 20, and the air cavity 40 formed inside the housing 20. The housing 20 is not necessarily formed in a rectangular shape, which can be changed to other shapes such as a circular shape and a polygonal shape. In addition, it is possible to dispose the concentrated mass, which is an important factor for changing the vibration condition with respect to the vibration member 30, at the center of the vibration member 30.

[0069] As described above, the sound absorbing structure 10 possesses a sound absorption mechanism composed of the spring-mass system and the bending system. The present inventor performed experiments on sound absorption coefficients at resonance frequencies with various surface densities applied to the vibration member 30.

[0070] Fig. 11 show simulation results on normal incidence sound absorption coefficients with respect to the sound absorbing structure 10, in which the vibration member 30 having the length and breadth of 100 mm × 100 mm and the thickness of 0.85 mm is fixed to the housing 20 containing the air cavity 40 having the length and breadth of 100 mm × 100 mm and the thickness of 10 mm and in which the surface density is changed with respect to the center portion having the length and breadth of 20 mm × 20 mm and the thickness of 0.85 mm. The simulation is performed based on JIS A 1405-2 (titled "Acoustics - Determination of sound absorption coefficient and impedance in impedance tubes - Part 2: Transfer-function method") so as to determine a sound field of a sound chamber for arranging the sound absorbing structure 10 in accordance with the finite element method, thus calculating sound absorption characteristics by way of transfer functions.

[0071] Specifically, Fig. 11 shows five characteristic curves D1 to D5 which are plotted using the same surface density of the periphery of the vibration member 30 of 799 g/m^2 while changing the surface density of the center portion of the vibration member 30 as 399.5 g/m^2 799 g/m^2, 1199 g/m^2, 1598 g/m^2, and 2297 g/m^2 in D1, D2, D3, D4, and D5 respectively. Thus, the average density of the vibration member 30 is set to 783 g/m^2, 799 g/m^2, 815 g/m^2 831 g/m^2, and 863- g/m^2 in D1, D2, D3, D4, and D5 respectively.

[0072] The simulation results of Fig. 11 clarify that sound absorption coefficients peak in a frequency range between 300 Hz and 500 Hz and at a frequency around 700 Hz.

[0073] Sound absorption coefficients peak around 700 Hz due to the resonance of the spring-mass system composed of the mass of the vibration member 30 and the spring component of the air cavity 40. The sound absorbing structure 10 absorbs sound in such a way that the sound absorption coefficient peaks at the resonance frequency of the bending system in a low frequency range, wherein the resonance frequency of the bending system gradually decreases as the surface density of the center portion of the vibration member 30 increases.

[0074] Generally speaking, the resonance frequency of the bending system is determined by the equation of motion directing the elastic vibration of the vibration member 30 and varies in inverse proportion to the surface density of the vibration member 30. The resonance frequency is greatly affected by the density of the antinode of the characteristic vibration (at which the amplitude becomes maximum). The simulation is performed by changing the surface density of the center portion with respect to the antinode region of 1×1 characteristic mode, thus causing variations of the resonance frequency of the bending system.

[0075] The simulation result clarifies that, by increasing the surface density of the center portion to be higher than the surface density of the periphery, the prescribed frequencies causing peak sound absorption coefficients are further lowered in a low frequency range. In other words, by changing the surface density of the center portion, it is possible to partially shift prescribed frequencies causing peak sound absorption coefficients to a further low frequency range or a further high frequency range.

[0076] Since the sound absorbing structure 10 is capable of shifting the prescribed frequency causing a peak sound absorption coefficient by simply changing the surface density of the center portion of the vibration member 30, it is possible to lower the sound absorption frequency without greatly changing the overall weight of the sound absorbing structure 10 in contrast to a typical example of the sound absorbing structure whose sound absorption frequency is changed by increasing the overall weight.

[0077] In this connection, it is possible to further increase the peak sound absorption coefficient by filling other porous sound-absorbent materials (e.g. resin foams, felts, cottony fibers such as polyester wools) inside the air cavity 40 of the sound absorbing structure 10.

(4) Fourth variation

[0078] It is possible to form a sound absorbent group including a plurality of sound absorbing structures according to one of the present embodiment and variations. Alternatively, it is possible to form a sound absorbent group including a plurality of sound absorbing structures having different sound absorption characteristics or a plurality of sound absorbing structures having three or more different sound absorption characteristics.

[0079] The sound absorbing structure and the sound absorbent group are applicable to various types of sound chambers having controlled acoustic characteristics such as soundproof chambers, halls, theaters, listening rooms of audio devices, conference rooms, compartment spaces of transportation such as vehicles, and housings of speakers and musical instruments.

[0080] Lastly, the present invention is not necessarily limited to the present invention and variations, which can be further modified in a variety of ways within the scope of the invention defined by the appended claims.

Claims

1. A sound absorbing structure comprising:

a vibration member composed of a closed-cell porous material; and
an air cavity formed in a rear side of the vibration member.

2. A sound absorbing structure comprising:

a vibration member composed of a closed-cell porous material and an open-cell porous material which are laminated together; and
an air cavity formed in a rear side of the closed-cell porous material.

3. A sound absorbing structure comprising:

a vibration member composed of a closed-cell porous material and an air-permeable member which are laminated together; and
an air cavity formed in a rear side of the closed-cell porous material.

4. The sound absorbing structure according to claim 1, wherein an airflow rate of the closed-cell porous material is less than 0.1 dm^3/s.

5. The sound absorbing structure according to claim 2, wherein an airflow rate of the closed-cell porous material is less than 0.1 dm^3/s.

6. The sound absorbing structure according to claim 3, wherein an airflow rate of the closed-cell porous material is less than 0.1 dm^3/s.

7. A sound absorbent group including a plurality of sound absorbing structures, each of which is constituted of a vibration member composed of a closed-cell porous material, and an air cavity formed in a rear side of the vibration member.

8. A sound absorbent group including a plurality of sound absorbing structures, each of which is constituted of a vibration member composed of a closed-cell porous material and an open-cell porous material which are laminated together, and an air cavity formed in a rear side of the closed-cell porous material.

9. A sound absorbent group including a plurality of sound absorbing structures, each of which is constituted of a vibration member composed of a closed-cell porous material and an air-permeable member which are laminated together, and an air cavity formed in a rear side of the closed-cell porous material.

10. A sound chamber including at least one sound absorbing structure, which is constituted of a vibration member composed of a closed-cell porous material, and an air cavity formed in a rear side of the vibration member.

11. A sound chamber including at least one sound absorbing structure, which is constituted of a vibration member composed of a closed-cell porous material and an open-cell porous material which are laminated together, and an air cavity formed in a rear side of the closed-cell porous material.

12. A sound chamber including at least one sound absorbing structure, which is constituted of a vibration member composed of a closed-cell porous material and an air-permeable member which are laminated together, and an air cavity formed in a rear side of the closed-cell porous material.

FIG. 1

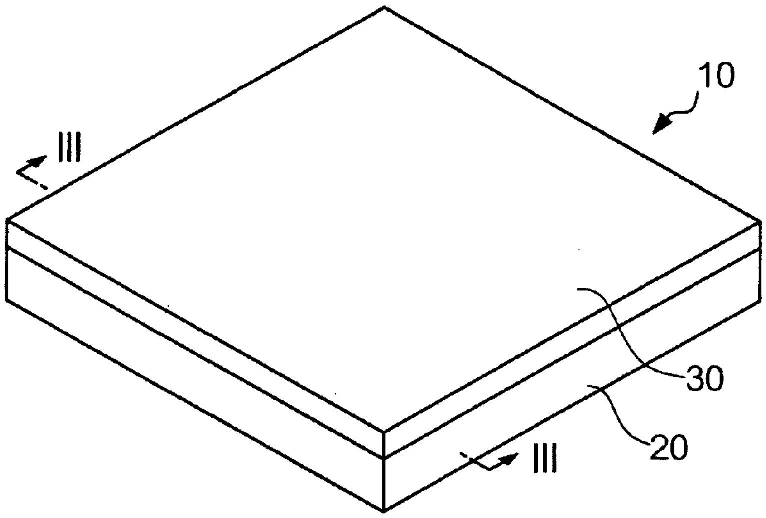


FIG. 2

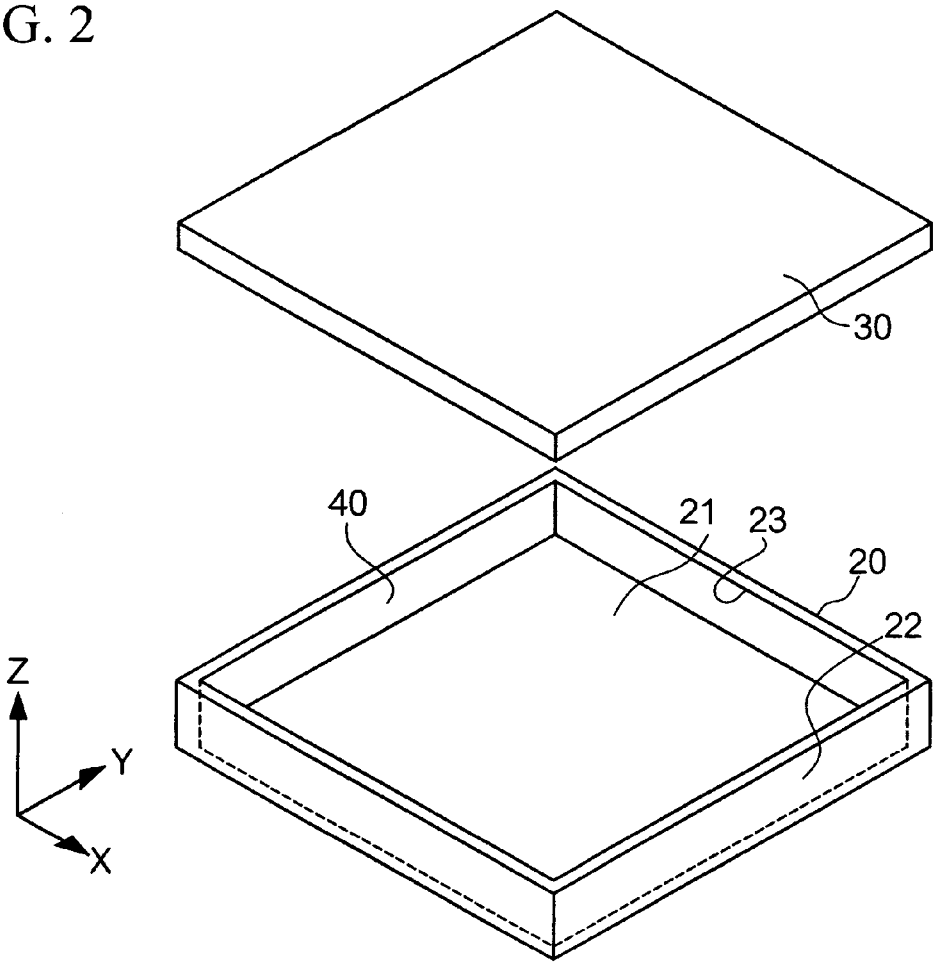


FIG. 3A

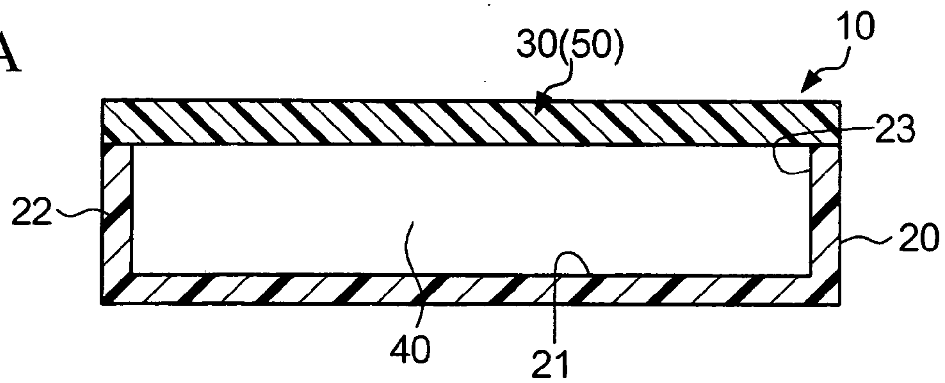


FIG. 3B

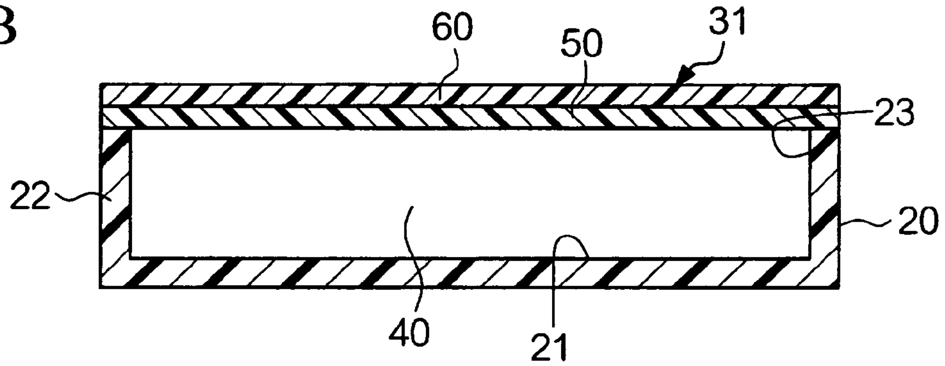


FIG. 3C

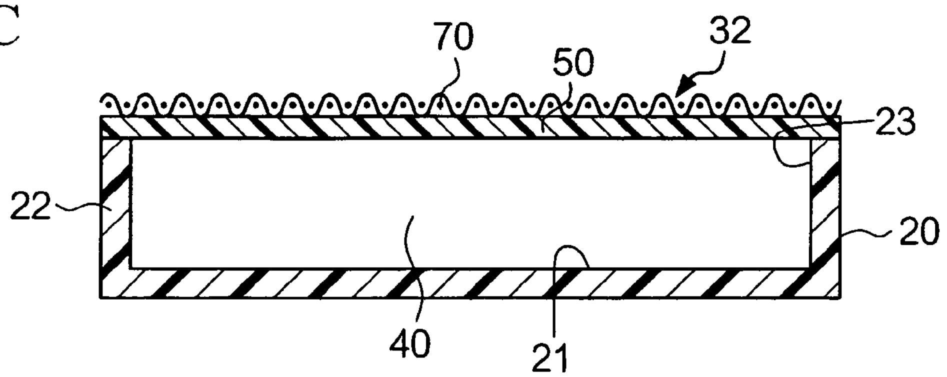


FIG. 4A

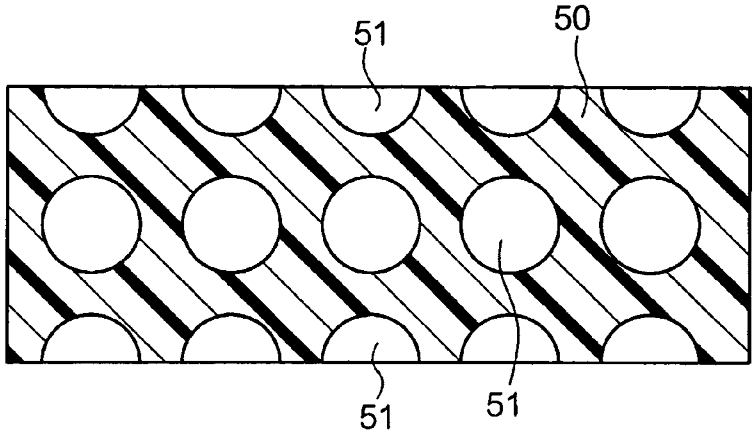


FIG. 4B

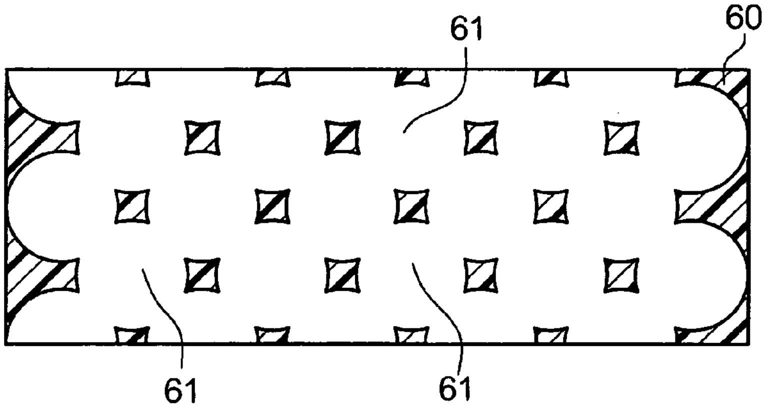


FIG. 5

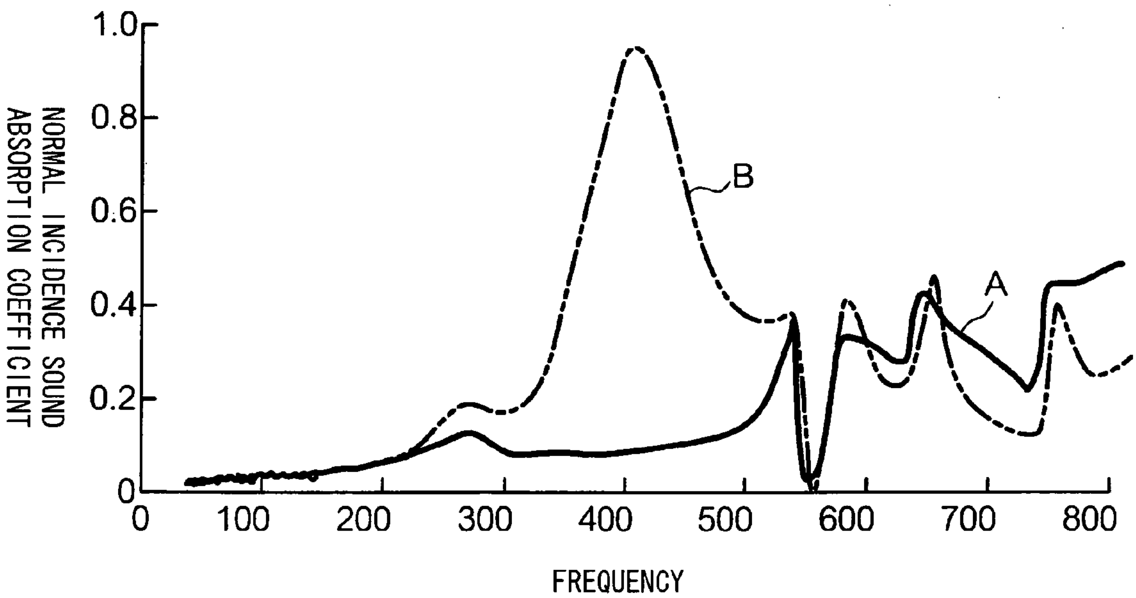
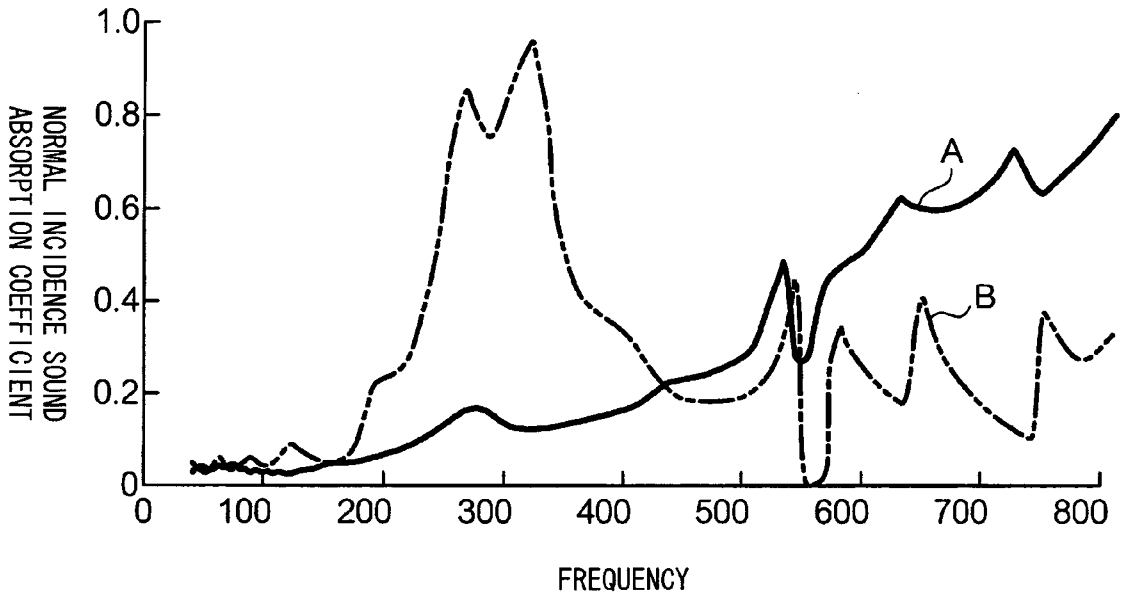


FIG. 6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0.4
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0
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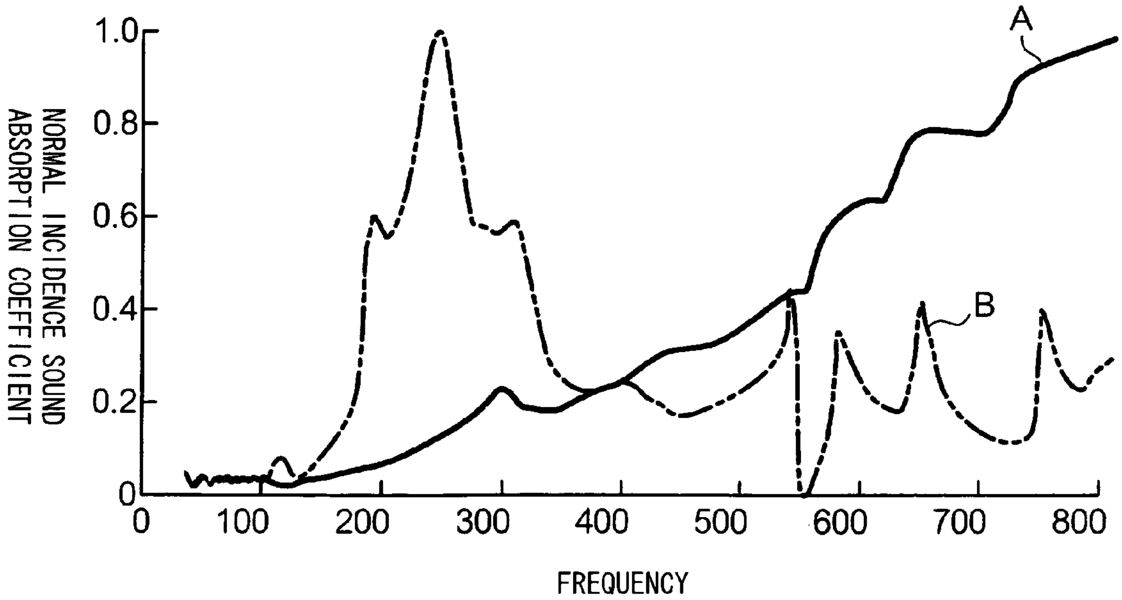
300
400
500
600
700
800
FREQUENCY
A
B

FIG. 7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700
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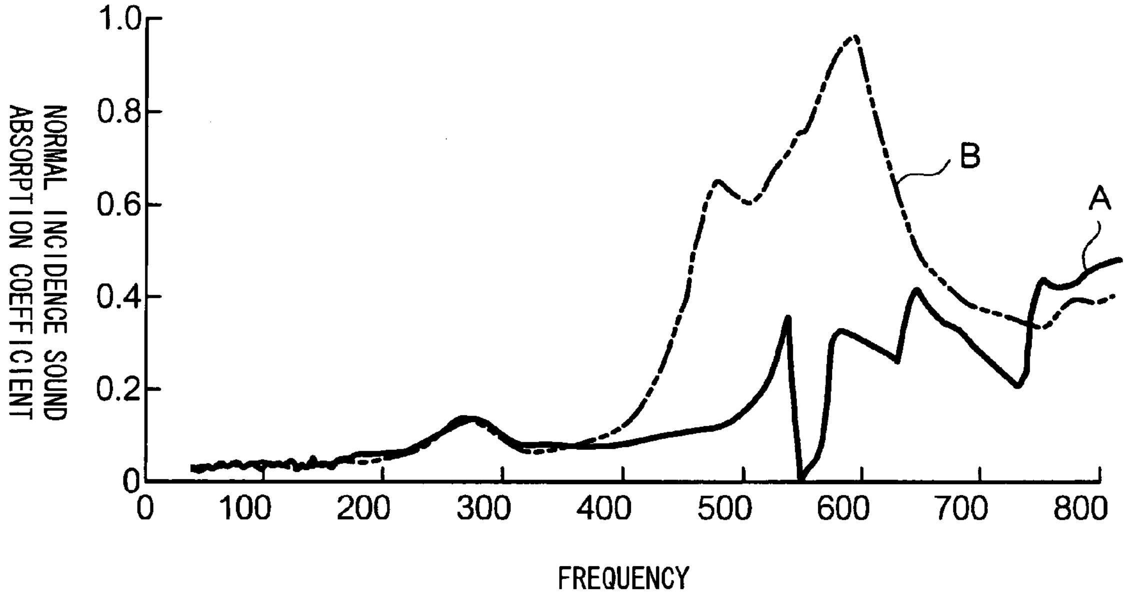
FREQUENCY
A
B

FIG. 8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FREQUENCY
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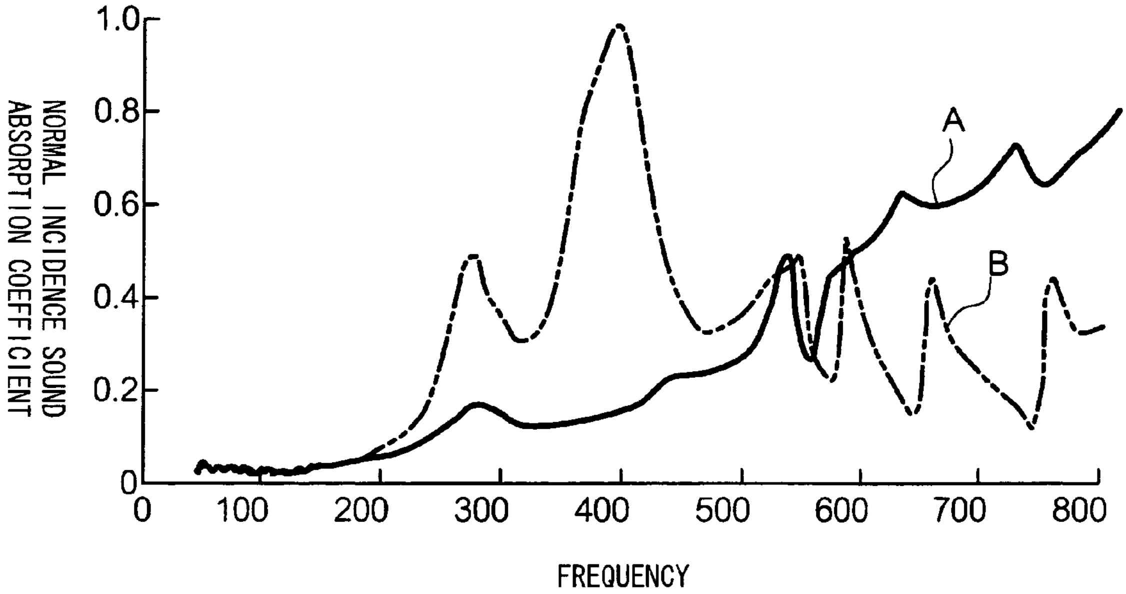
B

FIG. 9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FREQUENCY
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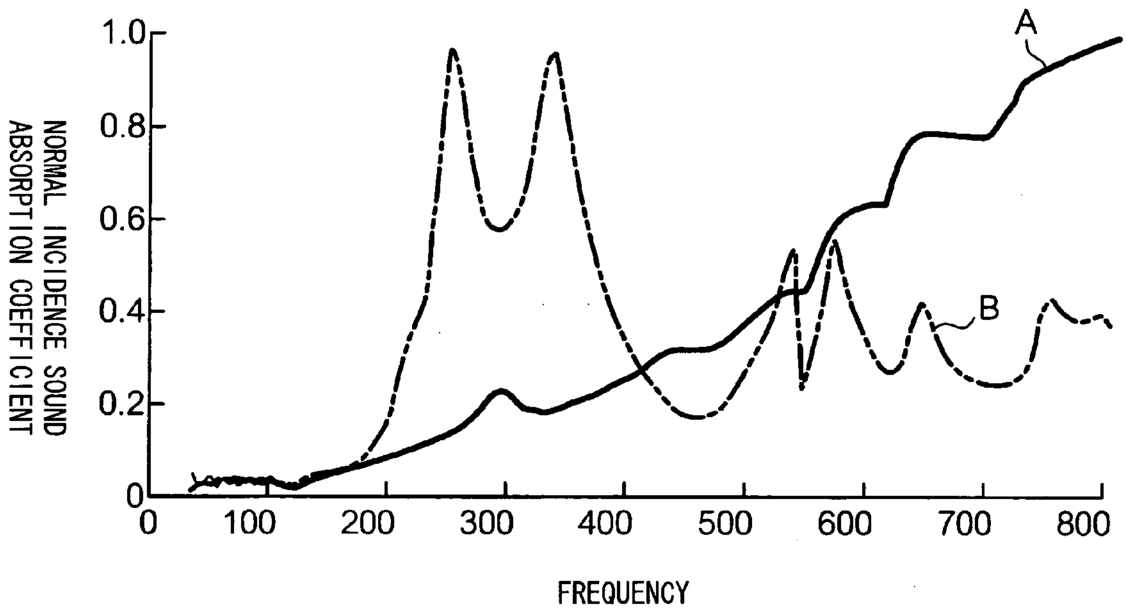
B

FIG. 10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ABSORPTION COEFFICIENT
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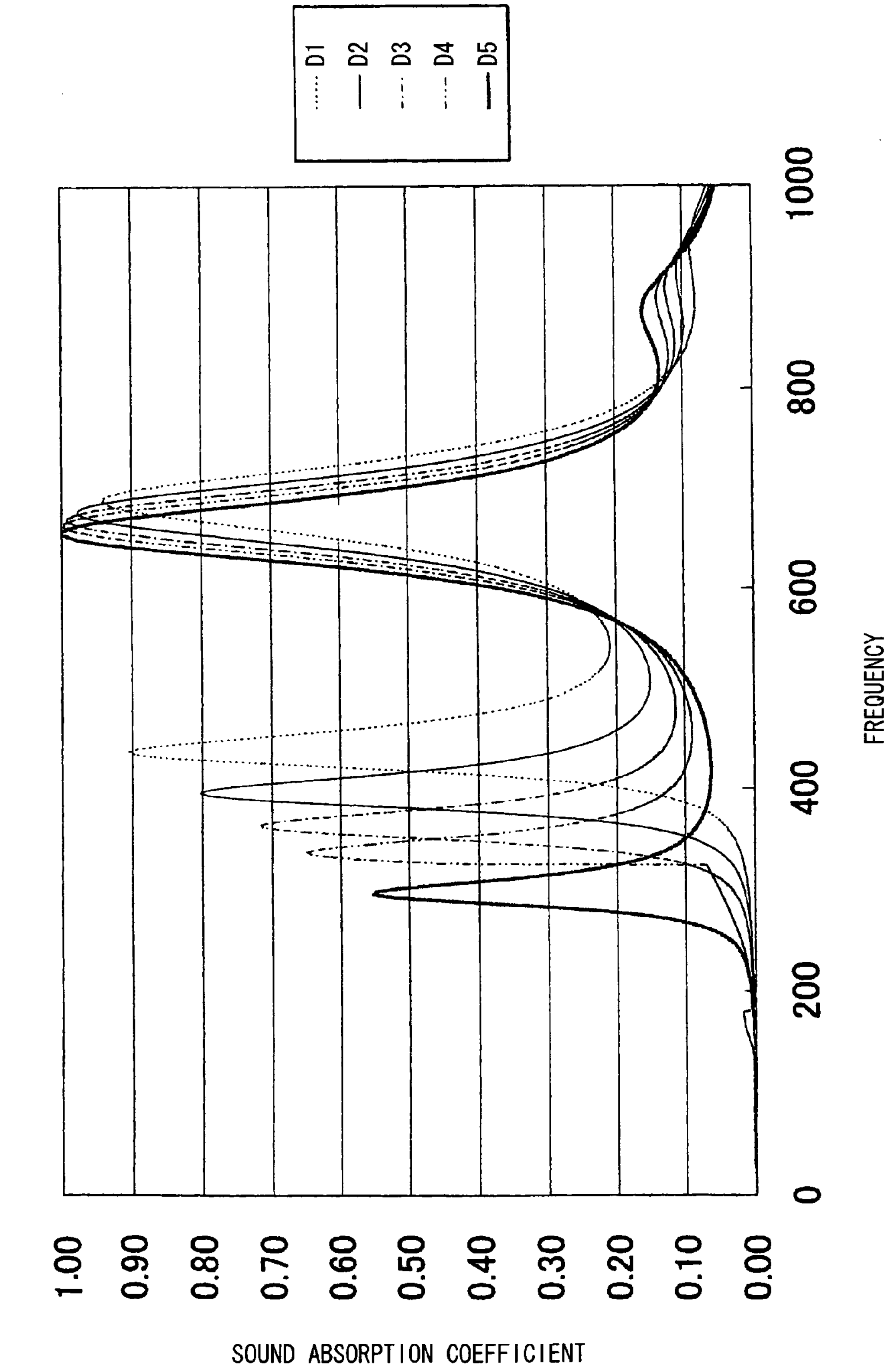
FREQUENCY
A
B

FIG. 11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D2
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D4
D5
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0.50
0.40
0.30
0.20
0.10
0.00
0
200
400
600
800
1000
FREQUENCY
SOUND ABSORPTION COEFFICIENT

REFERENCES CITED IN THE DESCRIPTION

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- JP 2008211972 A **[0002]**
- JP 2003316364 A **[0004]**