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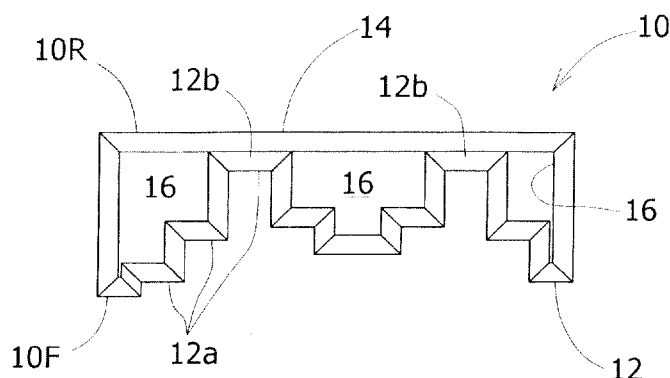


Fig. 1

(57) Abstract: An acoustic unit (10) comprises a first gypsum layer (12) forming a front surface (10F) of the acoustic unit (10), and a second gypsum layer (14) forming a rear surface (10R) of the acoustic unit (10). The first gypsum layer (12) has a step shape, which includes a plurality of steps (12a) and defines one or more cavities (16) between the first gypsum layer (12) and the second gypsum layer (14). The plurality of steps (12a) extend in a same direction along the cavity (16).



5 **Acoustic unit, acoustic wall structure, gypsum board, and method of
 manufacturing acoustic unit**

Field of the Invention

10 The invention relates to a technique for improving an acoustic environment in music schools, concert halls, home cinemas, recording studios, offices, restaurants and the like, and in particular to an acoustic unit used to construct an acoustic wall structure.

Background of the Invention

15 In order to realize an optimal acoustical environment, it is necessary to design two acoustical elements, namely, the sound diffusion property and sound absorption property, particularly in a balanced manner.

20 These properties are usually treated separately. For example, a typical sound diffusor (see Fig. 14) known as Schroeder diffusor consists of wells having a given width and depth due to a pseudo-random sequence and vertical dividers separating the wells. The basis of its operation is to change the phase of the reflected sound.

A two-dimension diffusor, known by the name of skyline diffusor, having a large number of prisms with different heights is also provided. This diffusor is omnidirectional and the sound is diffused in an effective way.

25 These diffusors are typically made of wood-based materials, having little or no effect on sound absorption or insulation. In Addition, they are flammable and even prohibited in some public buildings due to the inadequate fire protection.

Several attempts to provide a sound diffusor with low frequency sound absorption have been made. U.S. patent 2006/0231331 A1 suggests an acoustical device, which consists of a plurality of diffusors and has a T-shaped well between the adjacent

diffusors in such a manner that a small spacing is created therebetween. This spacing is configured to act as a Helmholtz absorber to absorb low frequency sound. Such diffusors cannot be easily manufactured due to their complex shapes. Moreover, the desired sound absorption cannot be obtained unless the diffusors are installed at the accurate positions to create said spacing with a precise predetermined distance therebetween. On the installation site, the formation of such precise spacing between the adjacent diffusors requires skilled works and much time. Furthermore, it is not possible to change the sound absorbing property after the installation.

U.S. patent 2003/0006092 A1 also aims to provide a sound diffuser with low frequency sound absorption. The sound diffuser disclosed in this document has a plurality of wells that are vertically elongated and have differing depths according to a calculation pattern designed to optimize diffusion. A number of holes are formed through the wells through which sounds travel. The sound diffuser requires a soft absorptive covering such as fiber glass or wool on the rear side of the device. Since the soft covering cannot be directly mounted on the wall, an additional rigid housing is required, meaning an increase in size and weight of the device. Furthermore, the sound absorbing property of the device is already fixed when manufactured and it is not possible to change it afterward.

Therefore, it is an object of the invention to suggest an acoustic unit, which overcomes or at least greatly reduces the disadvantages known from the prior art, that is to say an inexpensive acoustic unit which exhibits both of the sound diffusion property and sound absorption property, and further has excellent fire resistance performance. A further object is to provide an acoustic unit particularly capable of adjusting the sound absorption property after the installation. Another object is to provide a method for manufacturing an acoustic unit.

Summary of the Invention

The object is achieved by an acoustic unit as it is characterized by the features of independent claims. Advantageous embodiments become evident from the features of dependent claims.

In particular, an acoustic unit comprises a first gypsum layer forming a front surface of the acoustic unit, and a second gypsum layer forming a rear surface of the acoustic unit. The gypsum layer has a step shape, which includes a plurality of steps and

defines one or more cavities between the first gypsum layer and the second gypsum layer. The plurality of steps extend in a same direction along the one or more cavities.

The acoustic unit is capable of diffusing sound propagating in a room by that the sound reflects on the step-shaped front surface of the acoustic unit. In general, gypsum materials are not only more flame retardant than wood materials, but also have a better absorbency in sound. A higher sound absorption degree is achieved by the enlarged area of the step-shaped first gypsum layer, than a flat surface. In addition, the fireproof property is further improved by the step-shaped first gypsum layer whose area is larger than that of a flat wall surface.

Furthermore, the one or more cavities formed behind the first gypsum layer further attenuate the sound transmitted through the first gypsum layer. In addition, gypsum materials are inexpensive and readily available.

Thus, the invention advantageously provides an inexpensive acoustic unit, which exhibits both of the sound diffusion property and sound absorption property, and further provides higher fire resistance as compared to conventional wooden or plastic acoustic devices.

In a particular advantageous arrangement, the first gypsum layer may have folded portions, which form the plurality of steps. This allows providing an acoustic unit that can be easily manufactured.

Preferably, the first gypsum layer may be made of a gypsum board. The gypsum board is commercially available. Thus, the acoustic unit can be provided at low cost. The second gypsum layer may be made of the gypsum board, which forms the first gypsum layer. In other words, the first gypsum layer and the second gypsum layer may be made from one and same gypsum board. Preferably, the gypsum board (or gypsum plasterboard), which is known to the skilled person, is essentially made of gypsum, typically between two sheets of (thick) paper on the front side and the back side.

In a case where higher fire protection is required, a gypsum board conforming to EN 520 + A1 (2009) standard may be used to configure the first gypsum layer and/or the second gypsum layer.

Between the two lateral ends of the first gypsum layer, one or more portions of the first gypsum layer may be in contact with or fixed to the second gypsum layer. The one or more portions extend along the cavity. The portion where the first gypsum layer

and the second gypsum layer are in contact or fixed enhances the strength of the acoustic unit as a whole.

Advantageously, the acoustic unit may further comprise a first cover, which closes one or more first opening ends of the one or more cavities in an openable manner, and/or a second cover, which closes one or more second opening ends of the one or more cavities in an openable manner. The apparent volume of the cavity behind the first gypsum layer is changed by opening and closing the cover. Thus, the sound absorption coefficient can be changed by opening and closing the cover even after the installation of the acoustic unit. The cover may be configured to be held at any angle or at any opening degree. The cover may be configured to be adjustable in its angle or opening degree by an actuator or the like.

The cover, particularly configured by a rotatable flap, may also function as a sound diffuser. Therefore, the balance between the sound diffusion performance and the sound absorption performance can be adjusted even after installation of the acoustic unit by changing the opening degree of the cover.

Preferably, an area of the front surface may be twice or more, more preferably three times or more of an area of the rear surface. As the area of the front surface of the acoustic unit increases via the step shape, the sound absorption surface as well as the volume of the cavity behind the first gypsum layer increase, resulting in further improved sound absorption and fireproof performances.

Preferably, some of or all of the steps may be configured to have different widths and/or heights. Since each step changes the face of the reflected sound, the steps having different widths and/or depths provide an effective sound diffusion.

Another aspect of the invention provides an acoustic wall structure. In particular, the acoustic wall structure comprises a base wall, and one or more of the acoustic units described above. The one or more acoustic units are supported on the base wall such that the rear surface of each acoustic unit faces the base wall. It should be noted that such the acoustic wall structure can be used not only for inner walls of buildings, but also for partition walls, suspended ceilings, or the like.

Preferably, the base wall may comprise two or more stud frames, a first gypsum board layer fixed to one side of each stud frame, and a second gypsum board layer fixed to the other side of each stud frame. A cavity is defined among the first gypsum board layer, the second gypsum board layer, and the adjacent stud frames. The one or more

acoustic units may be attached directly or indirectly to an outer surface of the second gypsum board layer. In addition to the acoustic unit, these additional first and second gypsum board layers, as well as the cavity therebetween, further improve both of the sound absorption and of fireproof performances. However, it is also possible to have two (or more) gypsum board layers fixed to one side of each stud frame. In an alternative arrangement, the base wall may be made of brick, concrete, metal board, etc.

In a preferred arrangement, the acoustic wall structure may further comprise one or more acoustic units described above, which are attached directly or indirectly to an outer surface of the first gypsum board layer. According to this arrangement, an improved acoustic environment can be provided on both sides of the base wall. In addition, an increase of the mass of the gypsum material in the acoustic wall structure further improves the sound absorption and fireproof performances. In particular, this arrangement may be particularly advantageous when the acoustic wall structure is applied to a partition wall. According to the acoustic wall structure in which the acoustic unit is placed on both sides of the base wall, the sound insulation may be further improved by a destructive interference in sounds from both sides, that is, a noise canceling effect.

Preferably, when a total volume of the one or more cavities in the acoustic unit is V_2 [m^3], an area of the front surface of the acoustic unit is A_2 [m^2], a volume of the cavity of the base wall in a region corresponding to the acoustic unit is V_1 [m^3], and an area of a surface portion of the base wall facing the acoustic unit is A_1 [m^2], a cavity area ratio V_2/A_2 [m^3/m^2] of the acoustic unit may be smaller than a cavity area ratio V_1/A_1 [m^3/m^2] of the base wall. This difference in cavity area ratio has a positive effect on sound absorption in the whole wall system that is the degree of the sound absorption increases in the wide frequency range. These two cavities may be connected via one or more holes or openings.

It may be possible to adjust the height of the front surface, i.e., the distance from the base wall to the front surface of the acoustic unit by arranging a height adjustment unit between the base wall and the acoustic unit. Preferably, the height adjustment unit may be made of a gypsum board having a rectangular hollow cross-section. By using the height adjustment unit, it is possible to easily change the height of the front surface as the diffusion surface, i.e., the depth of the well. In addition, the mass of gypsum materials increases. The increase of the mass of gypsum materials further improves the sound absorption and fireproof performances.

According to another aspect of the invention, a gypsum board suitable for constructing the acoustic unit described above is provided. In particular, the gypsum board comprises a first region corresponding to the first gypsum layer of the acoustic unit, a second region corresponding to the second gypsum layer of the acoustic unit, and a plurality of grooves formed at least in the first region and extending in a same direction with each other. The plurality of grooves may be formed so that the one or more cavities are formed between the first region and the second region when the first region is folded at positions of the plurality of grooves.

Preferably, each of the grooves may have a V-shape whose two side surfaces are connected at a bottom of the groove; and each of the two side surfaces may be set to an angle of 45 degrees with respect to a main surface of the gypsum board. Preferably, the connection at a bottom of the groove is the paper sheet of the gypsum board. By setting the angle of each side surface of the groove to 45 degrees, a bonding area at which the side surfaces are mated is maximized. Therefore, when the first region is folded at the groove, and the side surfaces of the groove are joined, preferably with an adhesive (e. g. "white glue" (polyvinyl acetate (PVA)) or "yellow glue" (aliphatic resin)), improved bonding strength can be achieved. However, also a double-sided tape or a fastener such as a screw or an anchor is possible for joining the side surfaces of the groove.

According to yet another aspect of the invention, a method of manufacturing an acoustic unit is provided. In particular, the method comprises a step of preparing a gypsum board which includes a first and second region arranged adjacently, a step of forming a plurality of grooves in the first region so as to extend in a same direction with each other, a step of applying an adhesive (or using any other of the above-mentioned possibilities) into each of the grooves, a step of forming the first region into a step shape which has a plurality of steps and defines one or more cavities between the first region and the second region by folding the first region at positions of the grooves, and a step of fixing the steps with the adhesive (or using any other of the above-mentioned possibilities) in each of the grooves. The plurality of steps extend in the same direction along the cavity.

According to the method of the invention, an acoustic unit having both of diffusion and absorption properties in sound, as well as an improved fireproof property can be easily manufactured at a low cost. Furthermore, since the unfolded gypsum board extends in a continuous manner via the plurality of grooves, in other words, the gypsum board is not divided into separate parts, it is convenient to be handled in a field. In addition,

assembly errors can be prevented. No special tools and skills are required to assemble the acoustic unit from the gypsum board.

5 It is preferable that each of the grooves may have a V-shape whose two side surfaces are connected at a bottom of the groove, and/or each of the two-side surface may be set to an angle of 45 degrees with respect to a main surface of the gypsum board. By setting the angle of each side surface of the groove to 45 degrees, a bonding area at which the side surfaces are mated is maximized. Therefore, when the first region is folded at the groove and the side surfaces of the groove are joined with an adhesive (or using any other of the above-mentioned possibilities), improved bonding strength
10 can be achieved.

Brief description of the Drawings

In the following, the invention will be explained in more detail with reference to the drawings. Like reference numerals denote similar features throughout the drawings.
15 Aspects shown in the drawings can be connected and combined with each other in any technically possible way.

The accompanying drawings of which:

Fig. 1 is a plan view of an exemplary acoustic unit;

20 Fig. 2 is a front view of the acoustic unit of Fig. 1 in which the middle portion thereof is omitted to show;

Fig. 3 is a plan view of another exemplary acoustic unit;

Fig. 4 is a front view of the acoustic unit of Fig. 3 in which the middle portion thereof is omitted to show;

Fig. 5 is a side view of yet another exemplary acoustic unit;

25 Fig. 6 is a cross-sectional view of an exemplary acoustic wall structure;

Fig. 7 is a cross-sectional view of another exemplary acoustic wall structure;

Fig. 8 is a cross-sectional view of yet another exemplary acoustic wall structure;

Fig. 9A is a front view of yet another exemplary acoustic wall structure;

Fig. 9B is a side view of the acoustic wall structure of Fig. 9A;

Fig. 10A is a front view of yet another exemplary acoustic wall structure;

Fig. 10B is a side view of the acoustic wall structure of Fig. 10A;

5 Fig. 11 is a plan view of an exemplary gypsum board suitable for constructing the acoustic unit of Fig. 1;

Fig. 12 is a plan view of another exemplary gypsum board suitable for constructing the acoustic unit of Fig. 3;

Fig. 13 illustrates a exemplary method of manufacturing the acoustic unit of Fig. 1; and

10 Fig. 14 shows a cross-sectional view of a diffusor according to Schroeder diffusor.

Detailed Description of the Invention

15 Fig. 1 illustrates a plan view of an acoustic unit 10 according to the invention. The acoustic unit 10 comprise a first gypsum layer 12, which forms a front surface 10F of the acoustic unit 10, and a second gypsum layer 14, which forms a rear surface 10R of the acoustic unit 10.

An excellent fireproof performance is achieved due to the fact that the first and second gypsum layers 12 and 14 constituting the majority of the acoustic unit 10 are made of gypsum material which is more flame retardant than wood or plastic material.

20 Furthermore, a superior sound absorption or insulation performance is achieved due to the fact that the first and second gypsum layers 12 and 14 constituting the majority of the acoustic unit 10 are made of gypsum material which is more sound absorbing than wood or plastic material.

25 Fig. 2 illustrates a front view of the acoustic unit 10. In the illustrated example, the acoustic unit 10 is elongated in the vertical direction. The vertical length of the acoustic unit 10 can be, for example, 1 m to 3 m. In an alternative example, the acoustic unit 10 may have a lateral dimension greater than the longitudinal dimension. There is no limitation on the height and width of the acoustic unit 10.

As shown in Figs. 1 and 2, the first gypsum layer 12 has a step shape. The step shape includes a plurality of steps 12a.

The step-shaped front surface 10F constitutes a sound diffusion surface according to e.g. the Schroeder diffuser. The heights, widths and number of steps 12a are designed in an appropriate manner in accordance with the desired sound diffusion property. Thus, the heights, widths and number of steps 12a are obviously not limited to the illustrated example. For the purpose of obtaining an effective sound diffusion, some of or all of the steps 12a may be configured to have different widths and heights.

The step shape also defines one or more cavities 16 between the first gypsum layer 12 and the second gypsum layer 14. In the illustrated example, the acoustic unit 10 has three cavities 16 but is not limited thereto. All steps 12a extend in the same direction along the one or more cavities 16. As shown in Fig. 2, the all steps 12a and cavities 16 extend in the vertical direction. In an alternative example, the all steps 12a and cavities 16 may extend in the lateral direction.

The sound absorption performance and fireproof performance are further enhanced by the increased area of the front surface 10F via the step shape of the first gypsum layer 12, as well as the presence of the one or more cavities 16. Preferably, the area [m²] of the front surface 10F may be twice or more, more preferably three times or more of the area [m²] of the rear surface 10R. As the area of the front surface 10F increases via the step shape of the first gypsum layer 12, the sound absorption surface as well as the volume of the cavity 16 behind the first gypsum layer 12 increase, resulting in further improved sound absorption and fireproof performances.

It may be advantageous in terms of the strength of the acoustic unit 10 if one or more portions 12b between the lateral two ends of the first gypsum layer 12 is in contact with or fixed to the second gypsum layer 14. The portion 12b may be fixed to the second gypsum layer 14 with an adhesive, double-sided tape, or a fastener such as a screw or an anchor. The adhesive, double-sided tape or fastener is preferably flame retardant.

In the one or more cavities 16, a flame-retardant and low-density filler such as glass wool or rock wool may be disposed. By this filler, further improvement in the sound absorption and fireproof performances can be expected.

It is preferable that the first gypsum layer 12 and/or the second gypsum layer 14 may be made of a single gypsum board. In addition, the step shape may be formed by a plurality of folded portions.

5 In the illustrated example, the second gypsum layer 14 has a flat shape. That is, the rear surface 10R of the acoustic unit 10 is flat. Thereby, a sufficient surface, which will be supported by a base wall described later, can be obtained. In addition, the acoustic unit 10 having the flat second gypsum layer 14 is easy to manufacture.

10 Figs. 3 and 4 show an acoustic unit 10 based on the same idea but different in shape. With the same reference numerals assigned to the same or similar elements, duplicate descriptions are appropriately omitted.

15 In the acoustic unit 10 shown in Figs. 3 and 4, the first gypsum layer 12 is not in contact with the second gypsum layer 14. In addition, only one cavity 16 is formed between the first gypsum layer 12 and the second gypsum layer 14. According to this arrangement, the cavity 16 with the increased volume can be obtained, allowing the improved sound absorption and fireproof performances. Other features and effects of this acoustic unit 10 are the same as the acoustic unit 10 shown in Figs. 1 and 2.

Fig. 5 shows a side view of an acoustic unit of another embodiment, according to the invention. With the same reference numerals assigned to the same or similar elements, duplicate descriptions are appropriately omitted.

20 The acoustic unit 10' shown in Fig. 5 further may comprise a first cover 18, in a form of a rotatable flap, which closes one or more first opening ends 16a of the one or more cavities 16 in an openable manner. Additionally or alternatively, the acoustic unit 10' may comprise a second cover 19, in a form of a rotatable flap, which closes one or more second opening ends 16b of the one or more cavities 16 in an openable manner.

25 The apparent volume of the cavity 16 behind the first gypsum layer 12 is changed by opening and closing the cover 18, 19. Thus, the sound absorption coefficient can be changed by opening and closing the cover 18, 19 even after the installation. Laboratory measurements according to the standard DIN EN ISO 11654 (1997) shows that the sound absorption coefficient α_w in the condition that both ends of all the
30 cavities 16 were closed was 0.25; and the sound absorption coefficient α_w in the condition that the both ends of all the cavities 16 were open was 0.35.

The covers 18, 19, particularly configured by a rotatable flap, also function as a sound diffuser. Therefore, the balance between the sound diffusion performance and the sound absorption performance can be adjusted even after installation of the acoustic unit by changing the opening degree of at least one of covers 18, 19.

- 5 Any of known gypsum boards can be applied to the first and second covers 18, 19. Preferably, gypsum (plaster)boards, which have paper layers on both sides, are used. In a case where higher fireproof performance is required, fire-resistant gypsum boards conforming to EN 520+A1 (2009) standard may be used.

The covers 18, 19 may be attached to the second gypsum layer 14 via hinges 21, 22.

- 10 The covers 18, 19 may be configured to be held at any angle, i.e., at any opening degree. For this purpose, the hinges 21, 22 may be configured to have an increased rotational resistance. Additionally or alternatively, stoppers may be provided to hold the covers 18, 19 at an arbitrary angle.

- 15 The covers 18, 19 may be configured to be adjustable in its angle by an actuator or the like.

- 20 Referring Fig. 6, an exemplary acoustic wall structure according to the invention is illustrated. The illustrated acoustic wall structure 50 comprises one or more acoustic units each according to the invention, and a base wall 30 supporting the one or more acoustic units. In Fig. 6, the acoustic wall structure 50 comprising more than one acoustic units 10 exemplary illustrated in Figs. 1 and 2. However, the shape or structure of the acoustic unit applied to the acoustic wall structure 50 is not limited to this, and the acoustic unit 10 shown in Figs. 3 and 4, the acoustic unit 10', or a further different acoustic unit may be applied.

- 25 In Fig. 6, although only a part of the acoustic wall structure 50 is shown due to the limited space of the drawing, the acoustic wall structure 50 is further continued in the lateral direction. Thus, in the illustrated area, two acoustic units 10 are visible. With regard to the acoustic unit 10, with the same reference numerals assigned to the same or similar elements, duplicate descriptions are appropriately omitted.

- 30 The acoustic units 10 may be fixed to the base wall 30 with a fastener such as a screw or an anchor, or an adhesive, double-sided tape etc. The fastener, adhesive, or double-sided tape is preferably flame retardant.

The acoustic units 10 mounted to the base wall 30 may be of the same structure and shape, but may be different from each other. Adjacent acoustic units 10 are preferably arranged such that their side surfaces are in contact with each other, that is, no gap is provided therebetween. As a result, the base wall 30 is completely covered by the sound units 10 having excellent fire resistance as described above, thereby the fireproof performance, as a whole wall system is further improved.

Adjacent acoustic units 10 may be fixed to each other with an adhesive, double-sided tape, or a fastener such as a screw or an anchor. The adhesive, double-sided tape or fastener is preferably flame retardant.

In the illustrated example, the base wall 30 comprises two or more stud frames 32, a first gypsum board layer 34 fixed to one side of each stud frame 32, and a second gypsum board layer 36 fixed to the other side of each stud frame 32. A cavity 38 is defined among the first gypsum board layer 34, the second gypsum board layer 36, and the adjacent stud frames 31, 32. The one or more acoustic units 10 are attached directly or indirectly to an outer surface of the second gypsum board layer 36. In an alternative example, the base wall 30 may be a brick wall, concrete wall, metal wall, or the like.

Any of known gypsum boards can be applied to the first gypsum board layer 34 and the second gypsum board layer 36. Preferably, gypsum (plaster)boards, which have paper layers on both sides, are used. In a case where higher fireproof performance is required, fire-resistant gypsum boards conforming to EN 520+A1 (2009) standard may be used.

Due to the presence of at least four layers of gypsum layers 12, 14, 34, 36 and at least two layers of cavities 16, 38 in the wall thickness, extremely high fireproof performance and sound insulation are achieved. Furthermore, sound diffusion is simultaneously achieved by the front surface 10F of the acoustic unit 10. Therefore, a multi-functional drywall structure 50 is provided.

Any of known drywall profiles, such as CW, UW, CD, UD profiles, may be used as the stud frames 32. Additionally or alternatively, prismatic profiles or angles may be used.

In the cavity 38, a flame-retardant and low-density filler 39 such as glass wool or rock wool may be disposed. By this filler 39, further improvement in the sound absorption and fireproof performances can be expected.

It is preferable that when a total volume of the one or more cavities 16 in one acoustic unit 10 is $V2 [m^3]$, an area of the front surface 10F of the acoustic unit 10 is $A2 [m^2]$, a volume of the cavity 38 of the base wall 30 in a region corresponding to this acoustic unit 10 is $V1 [m^3]$, and an area of a surface portion of the base wall 30 facing the acoustic unit 10 is $A1 [m^2]$, a cavity area ratio $V2/A2 [m^3/m^2]$ of the acoustic unit 10 may be smaller than a cavity area ratio $V1/A1 [m^3/m^2]$ of the base wall 30. This difference in cavity area ratio has a positive effect on sound absorption in the whole wall system, that is, the degree of the sound absorption increases in the wide frequency range. It is also possible to connect the two cavities, namely the cavity 16 of the acoustic unit 10 and the cavity 38 of the base wall 30 via one or more holes or openings.

Referring to Fig. 7, an acoustic wall structure of another embodiment according to the invention is shown. In the acoustic wall structure 50', with the same reference numerals assigned to the same or similar elements, duplicate descriptions are appropriately omitted.

In this embodiment, the acoustic wall structure 50' comprises one or more acoustic units 10 and/or 10' described above on both side of the base wall 30. Hereinafter, only reference numeral 10 is shown as a representative. The additional acoustic units 10 are mounted directly or indirectly to an outer surface of the first gypsum board layer 34.

According to this arrangement, the improved acoustic environment can be provided on both sides of the base wall 30. In addition, an increase of the mass of the gypsum material in the acoustic wall structure 50' improves the sound absorption and fireproof performances. In particular, this arrangement may be particularly advantageous when the acoustic wall structure 50' is applied to a partition wall, which divides a room. According to the acoustic wall structure 50' in which one or more the acoustic units 10 are placed on both sides of the base wall 30, the sound insulation is further improved by a destructive interference in sounds from both sides, that is, a noise canceling effect.

Referring to Fig. 8, an acoustic wall structure of yet another embodiment according to the invention is shown. In the acoustic wall structure 50'', with the same reference numerals assigned to the same or similar elements, duplicate descriptions are appropriately omitted.

In this embodiment, the height of the front surface 10F of the acoustic unit 10, i.e., the distance from the base wall 30 to the front surface 10F is adjustable with one or more height adjustment unit 40 arranged between the base wall 30 and the acoustic unit 10 or 10'. Hereinafter, only reference numeral 10 is shown as a representative.

5 The height adjustment unit 40 may be made of a gypsum board having a rectangular hollow cross-section. By using the height adjustment unit 40, it is possible to easily change the height of the front surface 10F as the diffusion surface, i.e., the depth of the well. In addition, the mass of gypsum materials increases. The increase of the mass of gypsum materials further improves the sound absorption and fireproof
10 performances. In the hollow 40a of the height adjustment unit 40, a flame-retardant and low-density filler such as glass wool or rock wool may be disposed. By this filler, further improvement in the sound absorption and fireproof performances can be expected.

Two or more height adjustment units 40 may be stacked in the thickness direction of
15 the acoustic wall structure 50".

Needless to say, the height adjustment unit 40 can also be applied to the acoustic wall structure 50' shown in Fig. 7.

Referring to Figs. 9A and 9B, an acoustic wall structure of yet another embodiment according to the invention is shown. In the acoustic wall structure 50"', with the same
20 reference numerals assigned to the same or similar elements, duplicate descriptions are appropriately omitted.

In this example, in the vertical direction, different types of acoustic units having different diffusion property are installed. That is, the steps 12a of the upper acoustic unit group 10U and the steps 12a of the lower acoustic unit group 10L are not
25 continuous. A further improvement in sound diffusion can be expected.

A gap 52 may be formed between the upper acoustic unit group 10U and the lower acoustic unit group 10L. In the gap 52, a cover or dividing wall 54 made of a gypsum board may be disposed, preferably in a removable manner. By sliding in or out the cover 54, that is, by closing or opening the one or more cavities 16, the apparent
30 volume of the one or more cavities 16 in the acoustic unit 10 is changed. Therefore, the same effect as the effect by the covers 18, 19 described with reference to FIG. 5 is expected. Of course, the slidable cover 54 and the rotatable cover 18, 19 may be used in combination.

Further referring to Figs. 10A and 10B, an acoustic wall structure of yet another embodiment according to the invention is shown. In the acoustic wall structure 50''', with the same reference numerals assigned to the same or similar elements, duplicate descriptions are appropriately omitted.

- 5 In this arrangement, the sound wall structure 50''' comprises three or more, preferably four or more, more preferably five or more acoustic unit groups 10-1,...10-N (N is an integer of 2 or more). A further improvement in sound diffusion efficiency can be expected.

- 10 In addition, a gap 52 may be formed between the adjacent acoustic unit groups 10-1,...10-N. In each of the gaps 52, a cover or dividing wall 54 made of a gypsum board may be disposed, preferably in a removable manner. According to this configuration, a two-dimensional diffuser with excellent fire resistance can be easily manufactured at a low cost.

- 15 Furthermore, by inserting in or out the cover 54, the apparent volume of the one or more cavities 16 in the acoustic unit 10 is changed. Therefore, the same effect as the effect by the cover 18, 19 described with reference to FIG. 5 is expected. Of course, the slidable cover 54 and the rotatable cover 18, 19 may be used in combination.

Now referring to Fig. 11, a gypsum board 70 suitable for constructing the acoustic unit 10 shown in Figs. 1 and 2 can be seen.

- 20 Any of known gypsum boards can be applied to the gypsum board 70. Preferably, gypsum (plaster)boards, which have paper layers on both sides, are used. In a case where higher fireproof performance is required, fire-resistant gypsum boards conforming to EN 520+A1 (2009) standard may be used.

- 25 The gypsum board comprises a first region 70a corresponding to the first gypsum layer 12 of the acoustic unit 10, a second region 70b corresponding to the second gypsum layer 14 of the acoustic unit 10. At least in the first region 70a, a plurality of grooves 72 are formed. The grooves 72 extend in a same direction. That is, the grooves 72 extend parallel to one another in a direction perpendicular to the drawing sheet of Fig. 11.

- 30 The grooves 72 are formed so that the one or more cavities 16 (see Fig. 1) are formed between the first region 70a and the second region 70b when the first region is folded at positions of the grooves 72.

In a preferable arrangement, each of the grooves 72 has a V-shape whose two side surfaces 72a and 72b are connected at a bottom 72c of the groove 72. More preferably, each of the two side surfaces 72a, 72b is set to an angle of 45 degrees with respect to a main surface of the gypsum board 70.

- 5 By setting the angle of each side surface of the groove 72 to 45 degrees, a bonding area at which the side surfaces are mated is maximized. Therefore, when the first region is folded at the groove and the side surfaces 72a, 72b of the groove 72 are joined with an adhesive (or any other of the above-mentioned possibilities), improved bonding strength can be achieved. In an alternative example, the angle between the
10 side surface 72a, 72b and the main surface of the gypsum board 70 may be less or greater than 45 degrees.

It is preferable that widthwise ends of the gypsum board 70 are also cut at a predetermined angle, preferably 45 degrees with respect to the main surface of the gypsum board 70.

- 15 Referring to Fig. 12, another exemplary gypsum board 70 suitable for constructing the acoustic unit 10 shown in Figs. 3 and 4 can be seen. With the same reference numerals assigned to the same or similar elements, duplicate descriptions are appropriately omitted.

- Now referring to Fig. 13, an example of a method of manufacturing an acoustic unit,
20 according to the invention will be described. In the exemplary method, the acoustic unit 10 shown in Fig 1 is manufactured. However, the invention is not limited to this. Further, the acoustic unit may be manufactured or assembled on a site where the acoustic wall structure is to be constructed, but may alternatively also be manufactured or assembled elsewhere, e.g., in the factory where the gypsum plaster
25 boards are made. The acoustic units made of the gypsum material can be easily stacked and shipped.

- In a first step, a gypsum board 70' is prepared. The gypsum board 70' includes first and second regions 70a', 70b' arranged adjacently. In the gypsum board 70', the first region 70a' and the second region 70b' may be not distinguished in a visible manner,
30 but it should be understood that the first region 70a' corresponds to the first gypsum layer 12 of the acoustic unit 10; and the second region 70b' corresponds to the second gypsum layer 14 of the acoustic unit 10.

In the next step, a plurality of grooves 72 are formed at least in the first region 70a' so as to extend in a same direction with each other. The grooves 72 may be formed by known milling or cutting techniques. By this process, the gypsum board 70 shown in Fig. 11 is formed.

- 5 In the next step, an adhesive 76 is applied into each of the grooves 72. Preferably, any of known adhesives for constructing drywall systems is used.

10 In the following step, the first region 70a (see Fig. 11) is folded at positions of the grooves 72. The first region 70a is formed into the step shape, which has the plurality of steps 12a and defines one or more cavities between the first region 70a and second region 70b. The folding of the first region 70a and the application of the adhesive 76 to the groove 72 may be alternately performed. In this case, the step of applying the adhesive into the groove 72 and the step of folding the first region 70a can be regarded as one step.

15 In the next step, the steps 12a are fixed with adhesive. The acoustic unit 10 in which the plurality of steps 12 extend in the same direction along the one or more cavities 16 is completed.

20 In a preferable method, each of the grooves 72 has a V-shape whose two side surfaces 72a, 72b are connected at a bottom 72c of the groove 72, and each of the two side surface 72a, 72b is set to an angle of 45 degrees with respect to a main surface of the gypsum board 70.

Although the invention has been derived with reference to particular illustrative embodiments thereof, many changes and modifications of the invention may become apparent to those skilled in the art without departing from the spirit and scope of the invention.

5

Claims

1. An acoustic unit, comprising:

- a first gypsum layer forming a front surface of the acoustic unit; and
- a second gypsum layer forming a rear surface of the acoustic unit,

10

wherein the first gypsum layer has a step shape which includes a plurality of steps and defines one or more cavities between the first gypsum layer and the second gypsum layer,

and the plurality of steps extend in a same direction along the one or more cavities.

15

2. The acoustic unit according to claim 1, wherein the first gypsum layer has folded portions, which form the plurality of steps, and/or wherein the second gypsum layer has a flat shape.

20

3. The acoustic unit according to claim 1 or 2, wherein the first gypsum layer is made of a gypsum board.

4. The acoustic unit according to claim 3, wherein the second gypsum layer is made of the gypsum board.

25

5. The acoustic unit according to any one of claims 1 to 4, wherein between lateral ends of the first gypsum layer, one or more portions of the first gypsum layer is in contact with or fixed to the second gypsum layer.
- 5 6. The acoustic unit according to any one of claims 1 to 5, further comprising a first cover, which closes one or more first opening ends of the one or more cavities in an openable manner, and/or a second cover, which closes one or more second opening ends of the one or more cavities in an openable manner.
- 10 7. The acoustic unit according to any one of claims 1 to 6, wherein an area of the front surface is twice or more, more preferably three times or more of an area of the rear surface and/or
- wherein some of or all of the steps are configured to have different widths and/or heights.
- 15
8. An acoustic wall structure, comprising:
- a base wall; and
 - one or more acoustic units according to any one of claims 1 to 7,
- wherein the one or more acoustic units are supported on the base wall such that the rear surface of each acoustic unit faces the base wall.
- 20
9. The acoustic wall structure according to claim 8,
- wherein the base wall comprises two or more stud frames, a first gypsum board layer fixed to one side of each stud frame, and a second gypsum board layer fixed to the other side of each stud frame, whereby a cavity is defined among the first gypsum board layer, the second gypsum board layer, and the adjacent stud frames, and
- 25
- wherein the one or more acoustic units are attached directly or indirectly to an outer surface of the second gypsum board layer.

10. The acoustic wall structure according to claim 9, further comprising one or more acoustic units according to any one of claims 1 to 7, which are attached directly or indirectly to an outer surface of the first gypsum board layer.

5

11. The acoustic wall structure according to claim 9 or 10,
when a total volume of the one or more cavities in the acoustic unit is $V2 [m^3]$,
an area of the front surface of the acoustic unit is $A2 [m^2]$,
a volume of the cavity of the base wall in a region corresponding to the acoustic
unit is $V1 [m^3]$, and
an area of a surface portion of the base wall facing the acoustic unit is $A1 [m^2]$,
a cavity area ratio $V2/A2 [m^3/m^2]$ of the acoustic unit is smaller than a cavity
area ratio $V1/A1 [m^3/m^2]$ of the base wall.

10

12. The acoustic wall structure according to any one of claims 8 to 11, comprising
a height adjustment unit arranged between the base wall and the acoustic unit,
the height adjustment unit being made of a gypsum board having a rectangular
hollow cross-section.

15

13. A gypsum board suitable for constructing the acoustic unit according to any
one of claims 1 to 7, comprising:
- a first region corresponding to the first gypsum layer;
- a second region corresponding to the second gypsum layer; and
- a plurality of grooves formed in the first region and extending in a same
direction with each other,

20

25

wherein the plurality of grooves are formed so that the one or more cavities are formed between the first region and the second region when the first region is folded at positions of the plurality of grooves.

- 5 14. The gypsum board according to claim 13, wherein each of the grooves has a V-shape whose two side surfaces are connected at a bottom of the groove, and each of the two side surfaces is set to an angle of 45 degrees with respect to a main surface of the gypsum board.
- 10 15. A method of manufacturing an acoustic unit, comprising steps of:
- preparing a gypsum board which includes a first and second regions arranged adjacently;
 - forming a plurality of grooves in the first region so as to extend in a same direction with each other;
 - 15 - applying an adhesive into each of the grooves;
 - forming the first region into a step shape which has a plurality of steps and defines one or more cavities between the first region and the second region by folding the first region at positions of the grooves, and
 - fixing the steps with the adhesive in each of the grooves,
- 20 wherein the plurality of steps extend in the same direction along the cavity.
16. The method of manufacturing the acoustic unit, according to claim 15, wherein each of the grooves has a V-shape whose two-side surfaces are connected at a bottom of the groove, and/or
- 25 each of the two side surface is set to an angle of 45 degrees with respect to a main surface of the gypsum board.

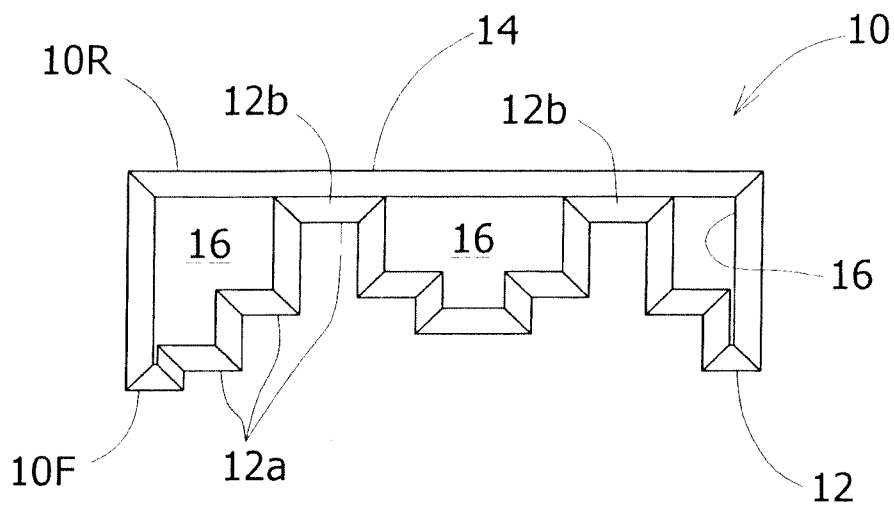


Fig. 1

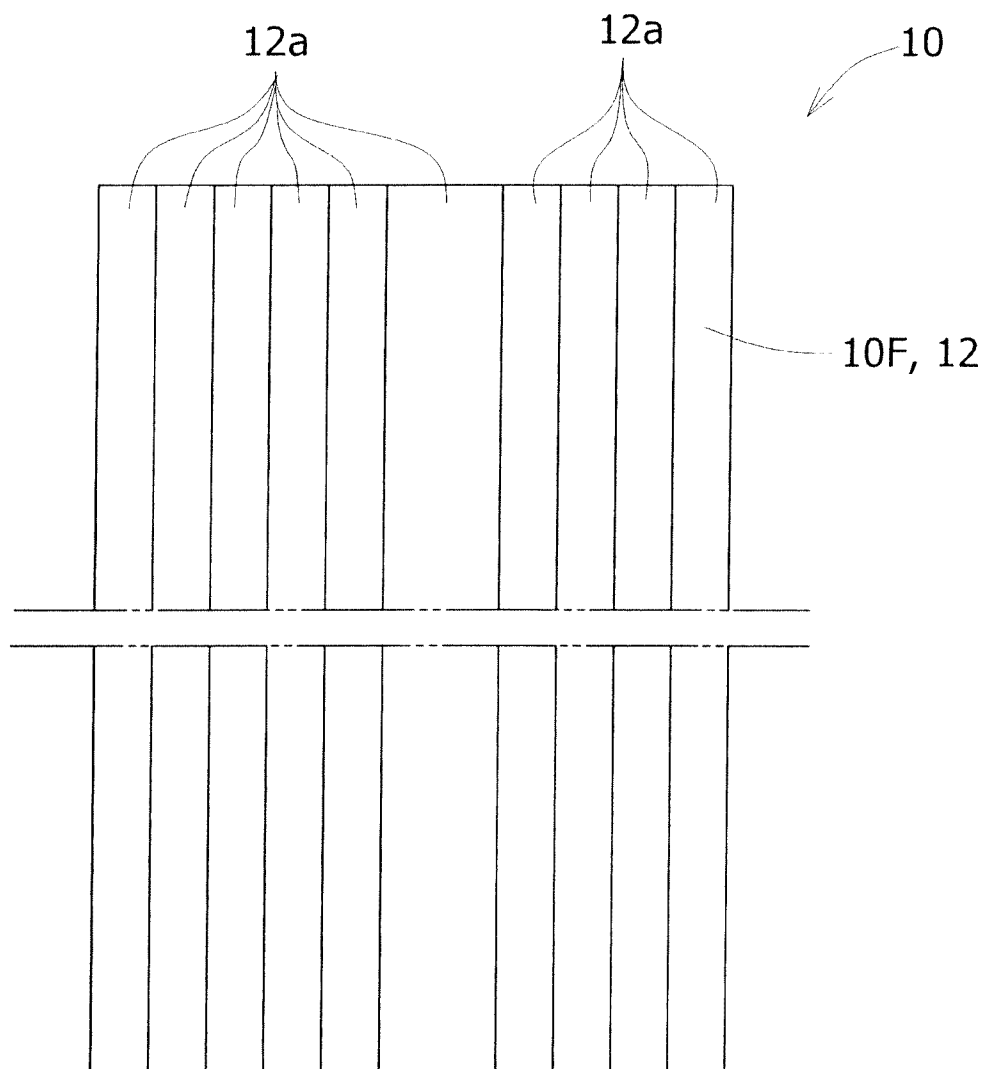


Fig. 2

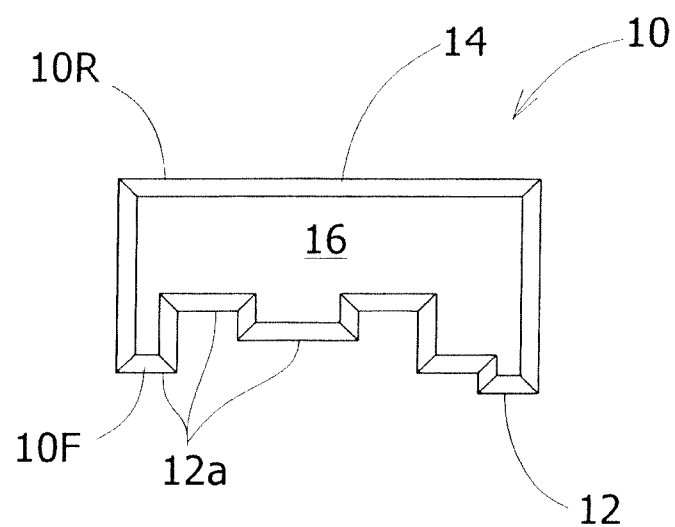


Fig. 3

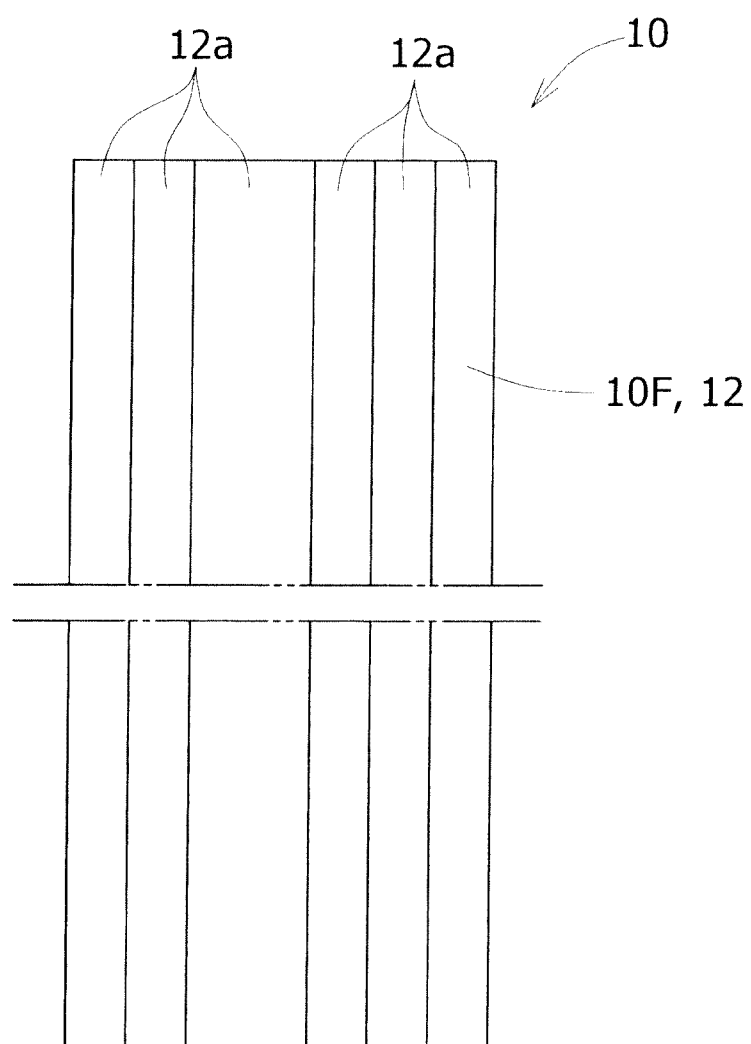


Fig. 4

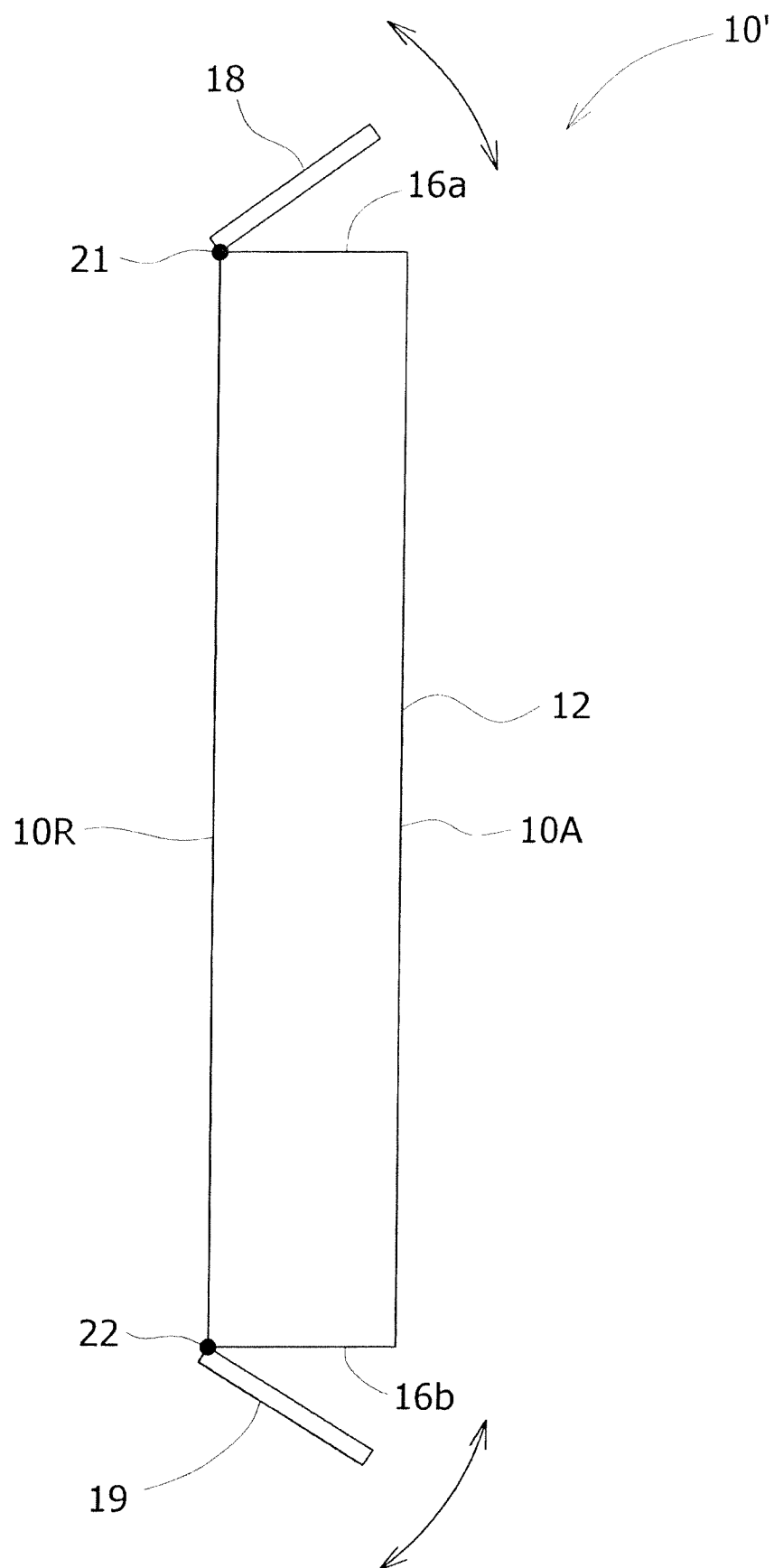


Fig. 5

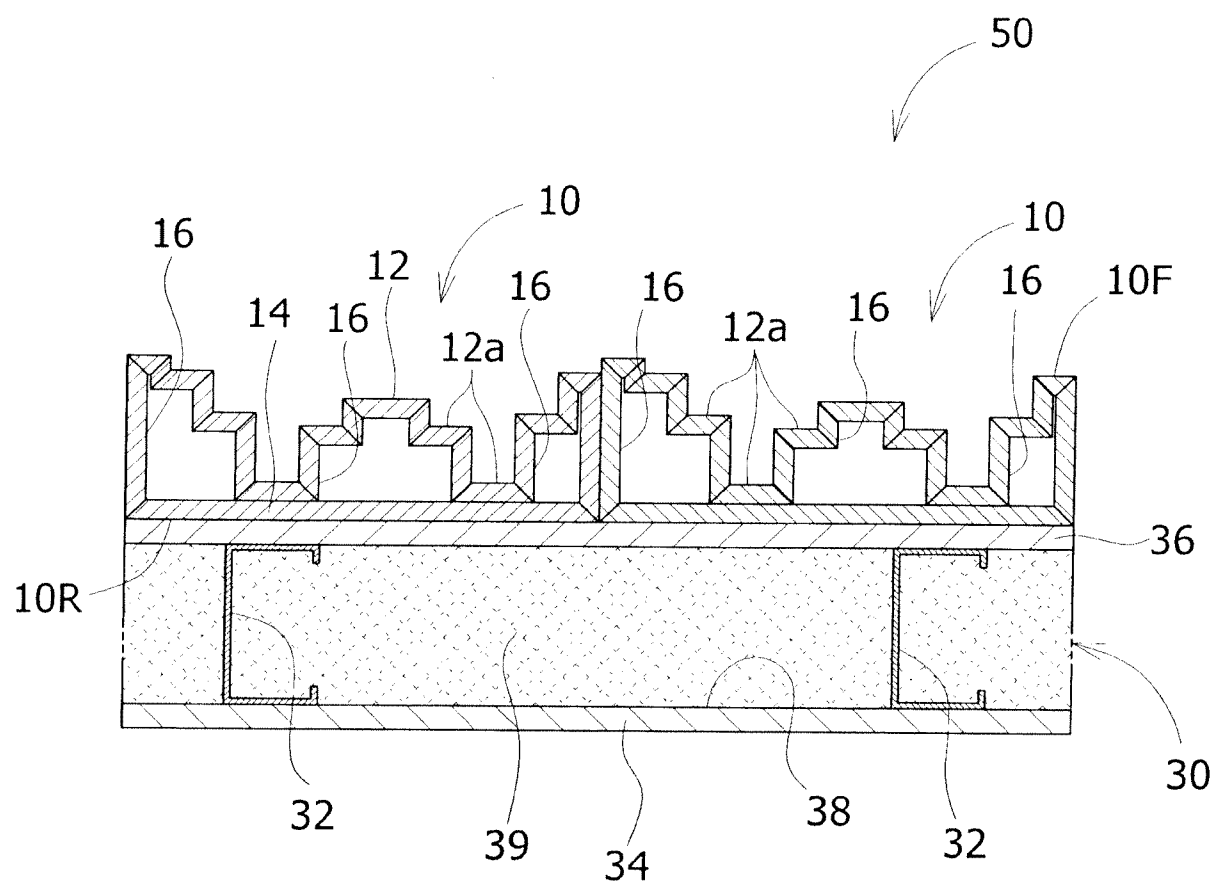


Fig. 6

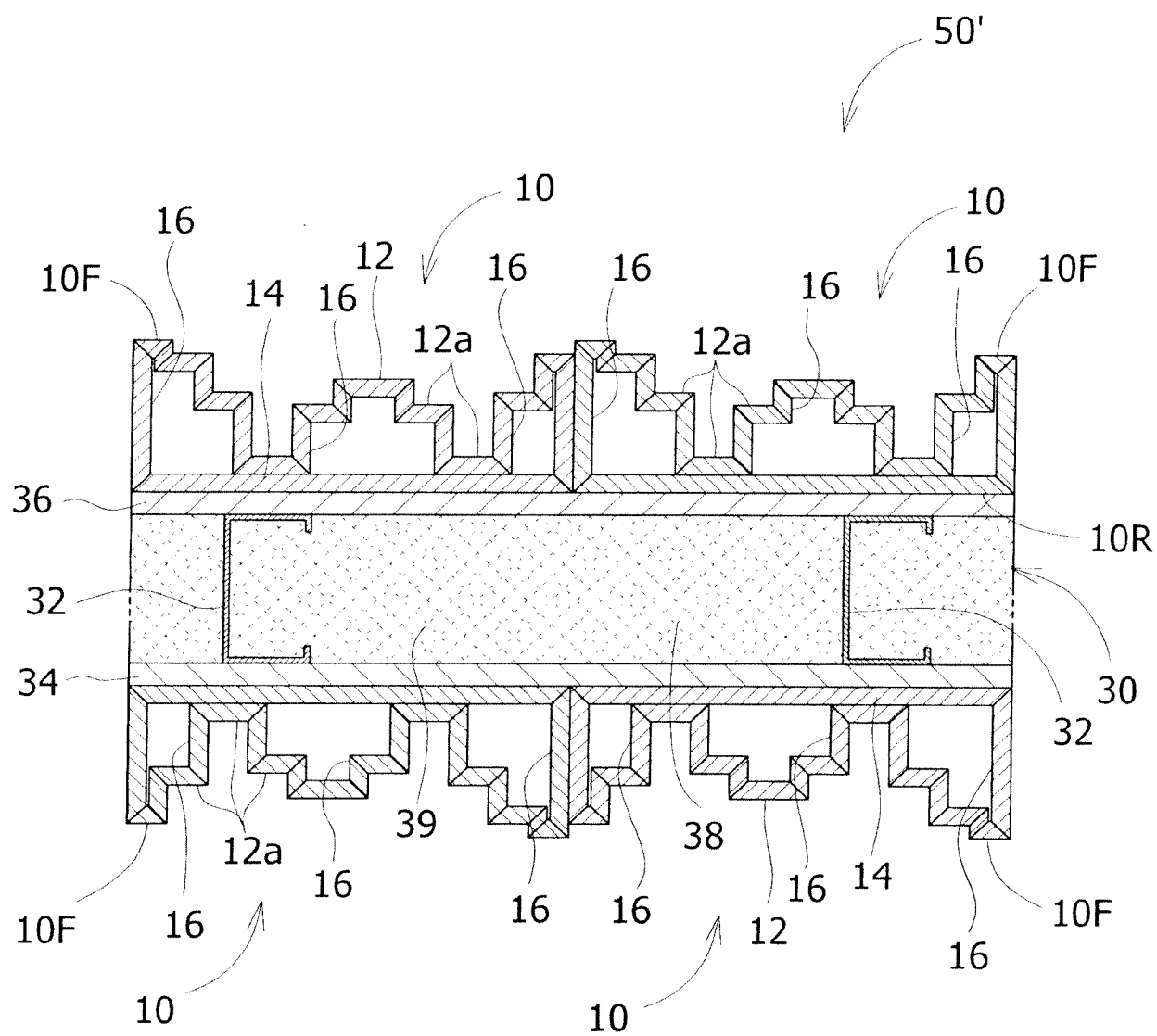


Fig. 7

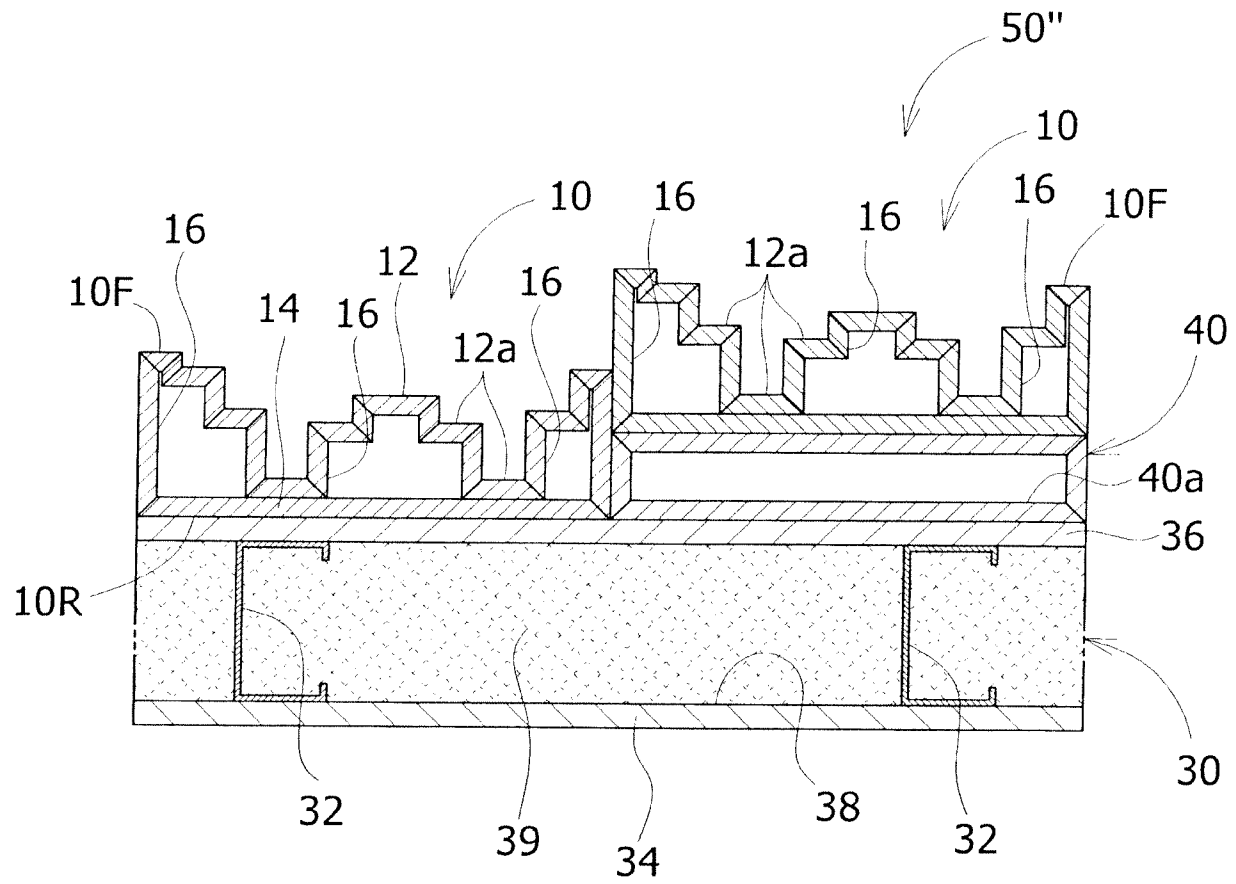


Fig. 8

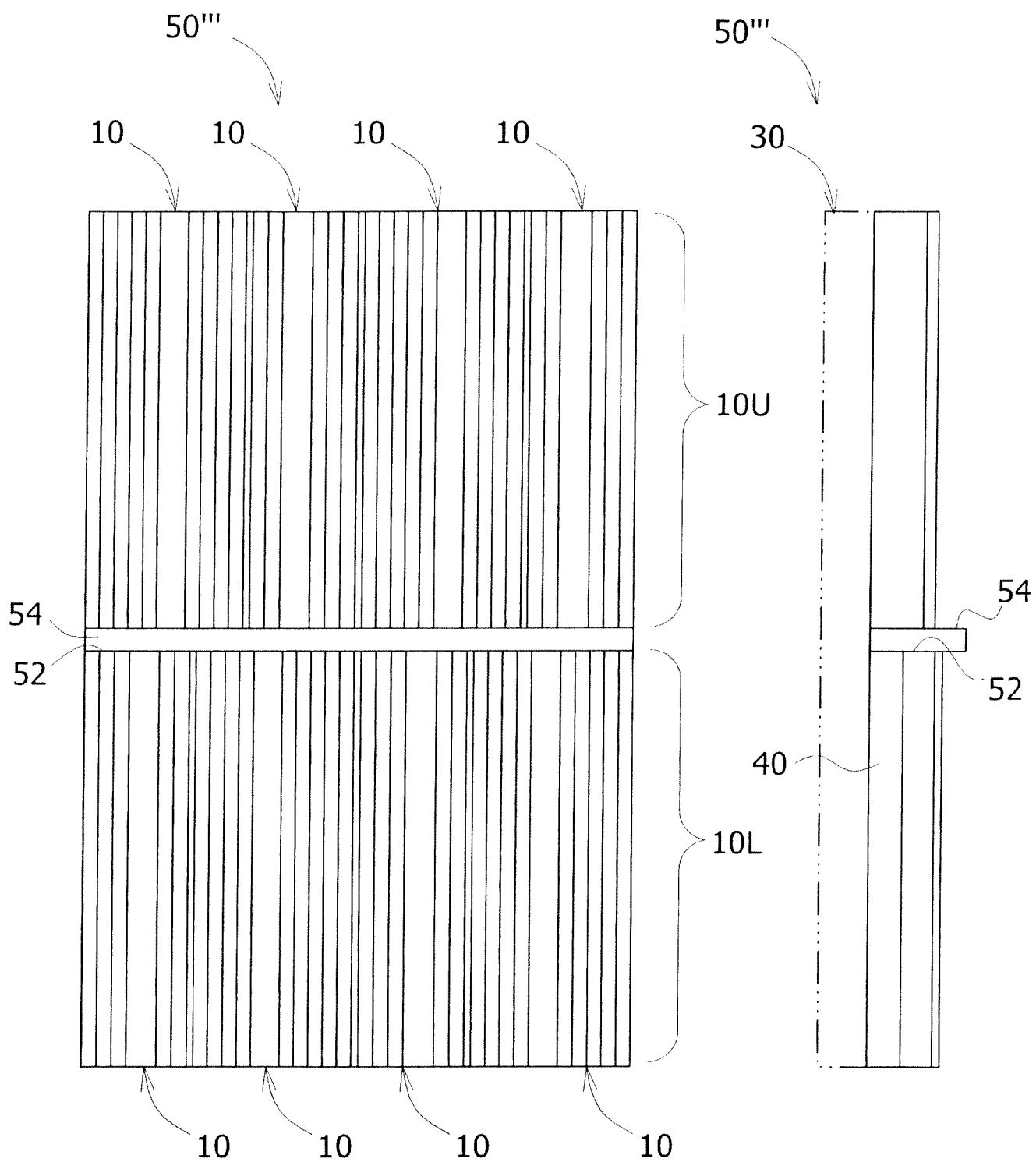


Fig. 9A

Fig. 9B

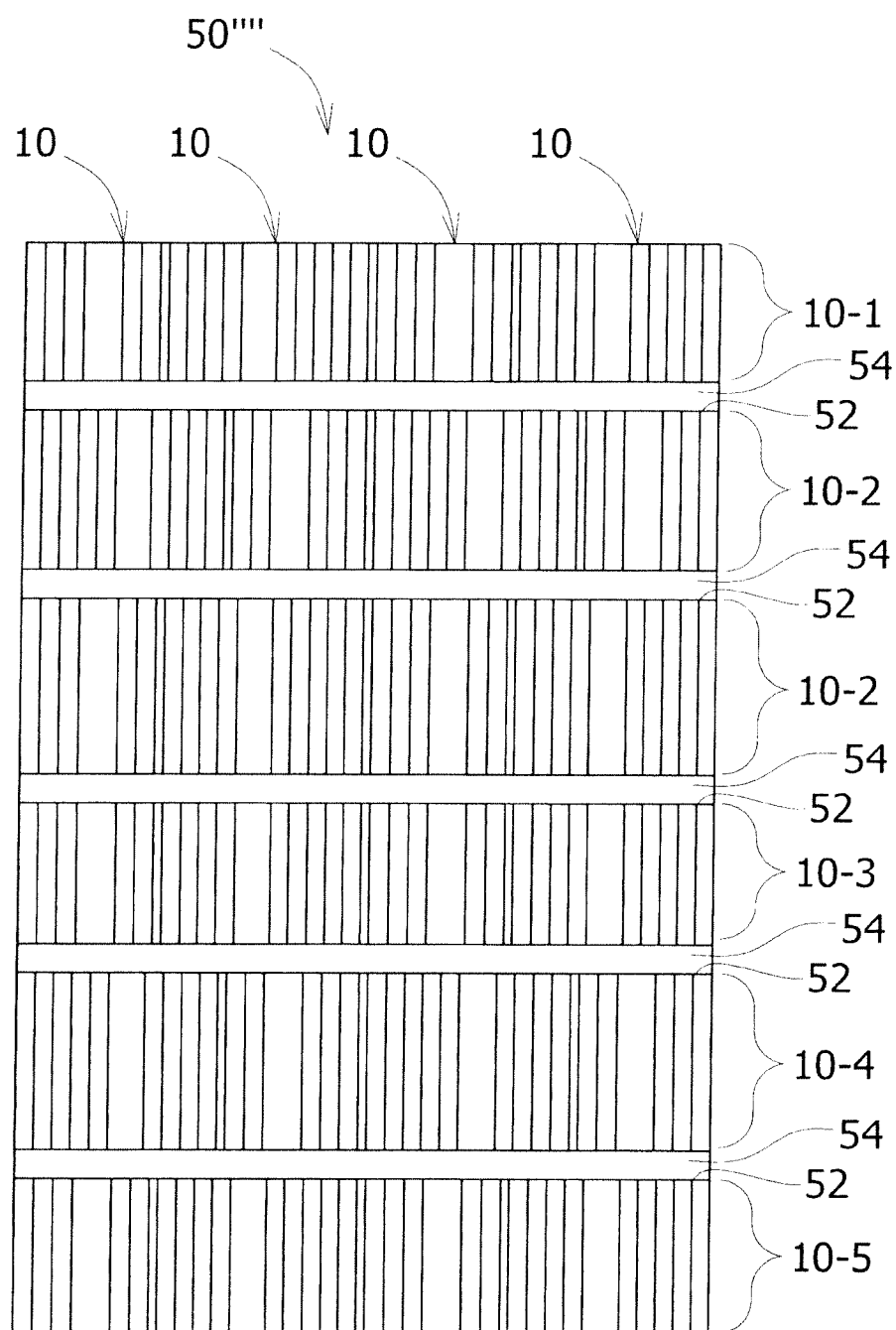


Fig.10A

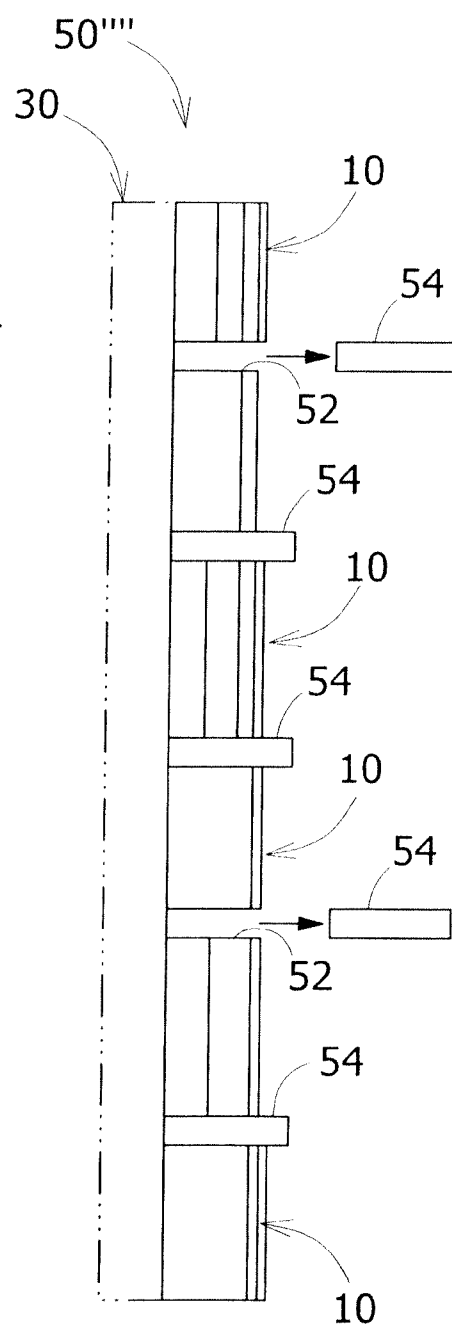


Fig.10B

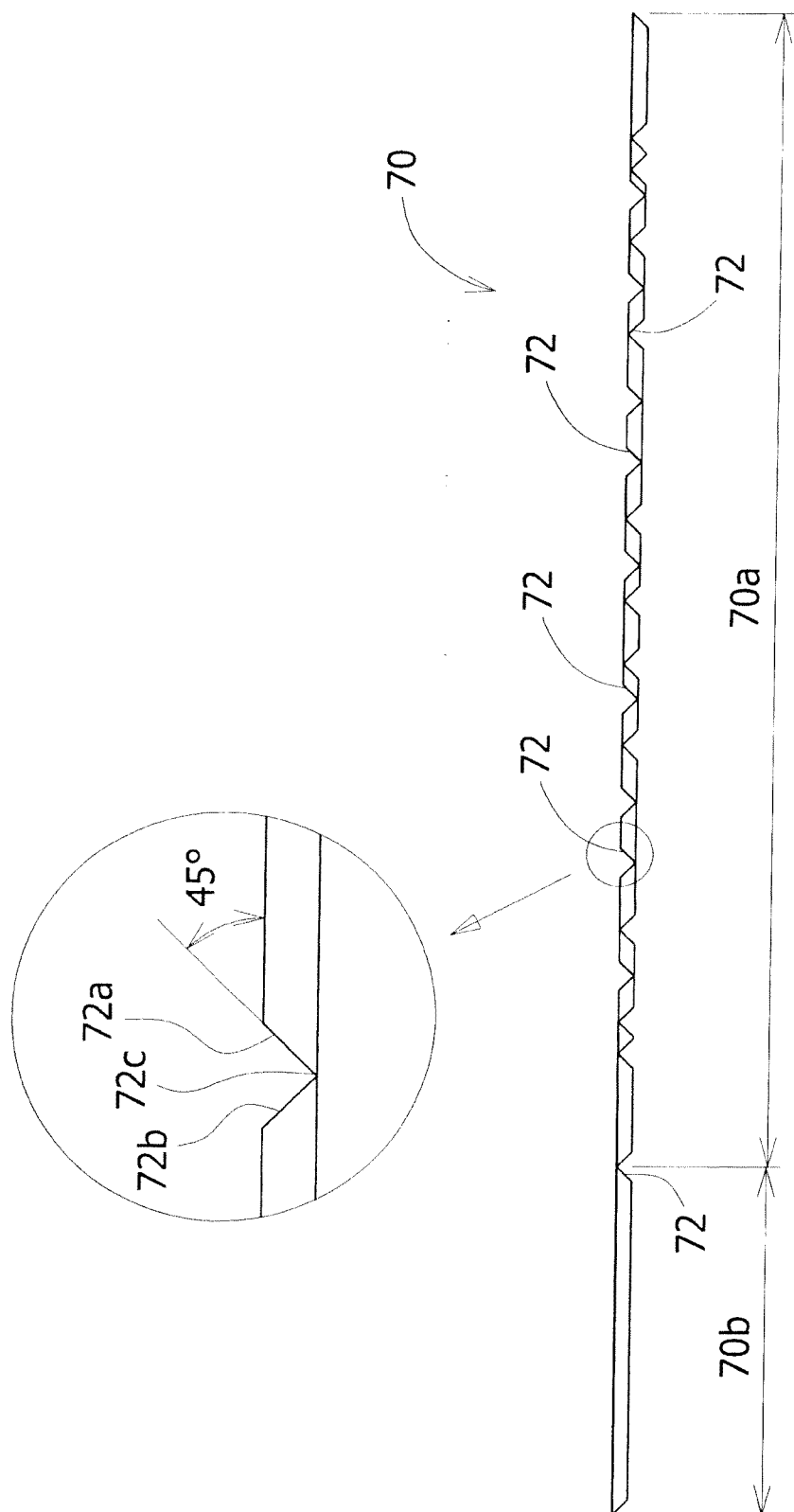


Fig.11

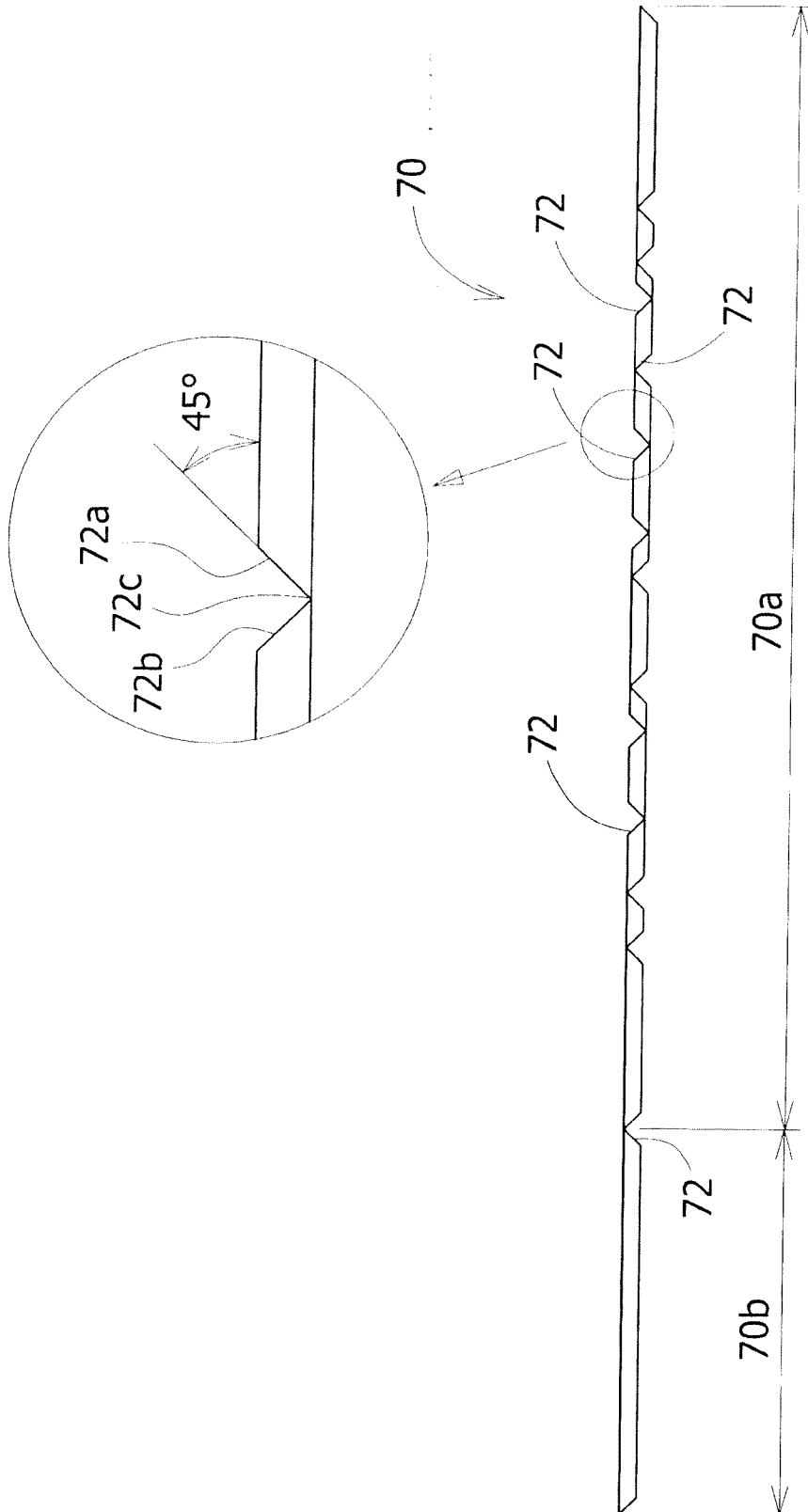


Fig. 12

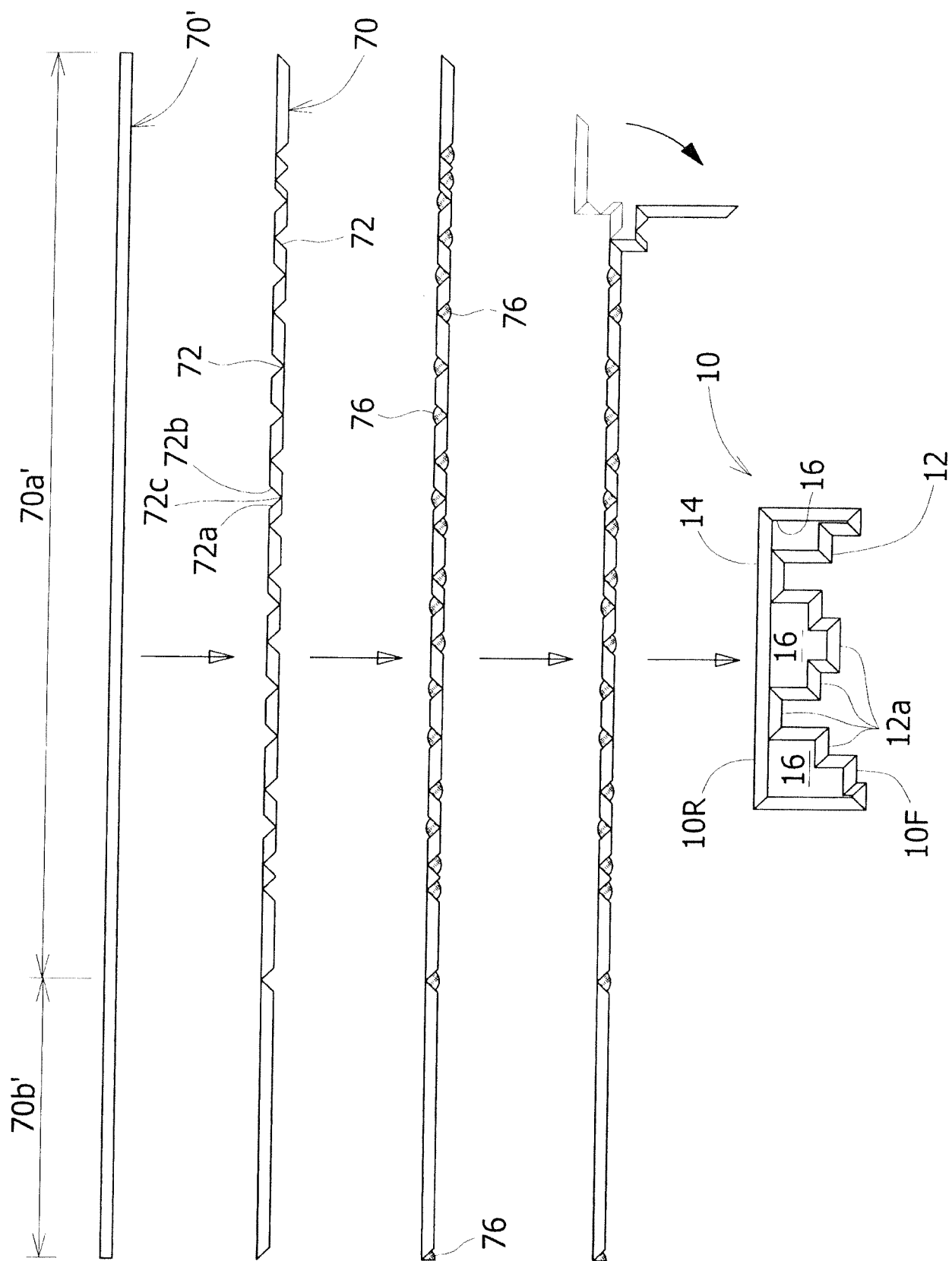


Fig. 13

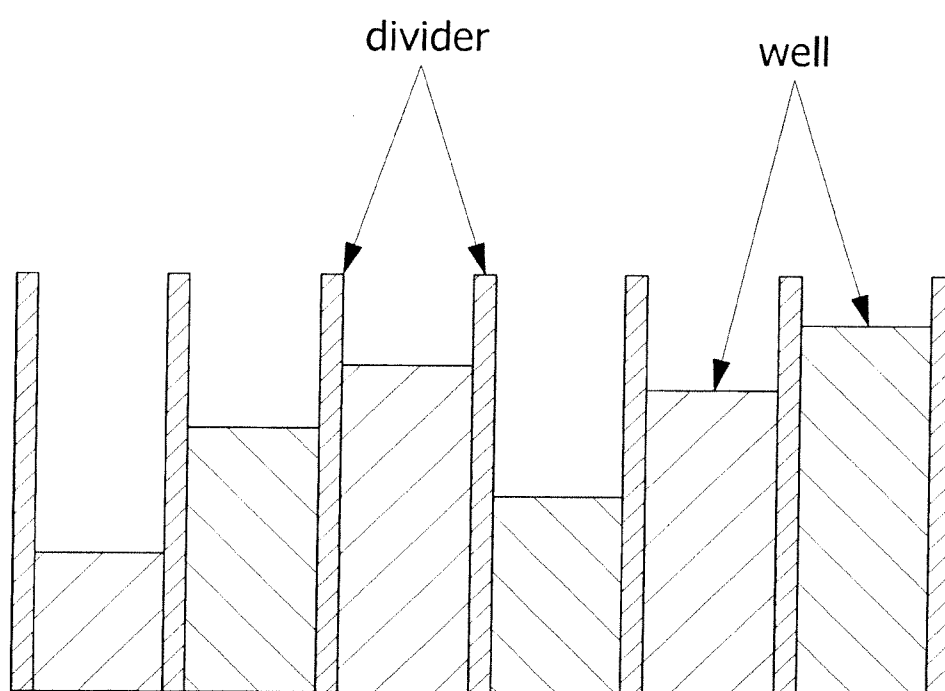


Fig.14

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/000183

A. CLASSIFICATION OF SUBJECT MATTER
INV. E04B1/86
ADD. E04B1/84

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)
E04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02/04760 A1 (RICHTER SYSTEM GMBH & CO KG [DE]; KNAUF ALFONS JEAN [DE]) 17 January 2002 (2002-01-17) figures 1, 2 page 6, line 8 - line 25; figures 10, 11 -----	1-16
X	US 2 308 942 A (TEASDALE WILLIAM C) 19 January 1943 (1943-01-19) page 1, line 33 - page 2, line 64; figures 1-4, 10, 11 -----	1-16
X	WO 00/08271 A1 (BACCHIELLI PAOLO [IT]) 17 February 2000 (2000-02-17) page 3, line 21 - page 4, line 1; figures 1-3, 14-26 -----	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search

24 February 2020

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2019/000183

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