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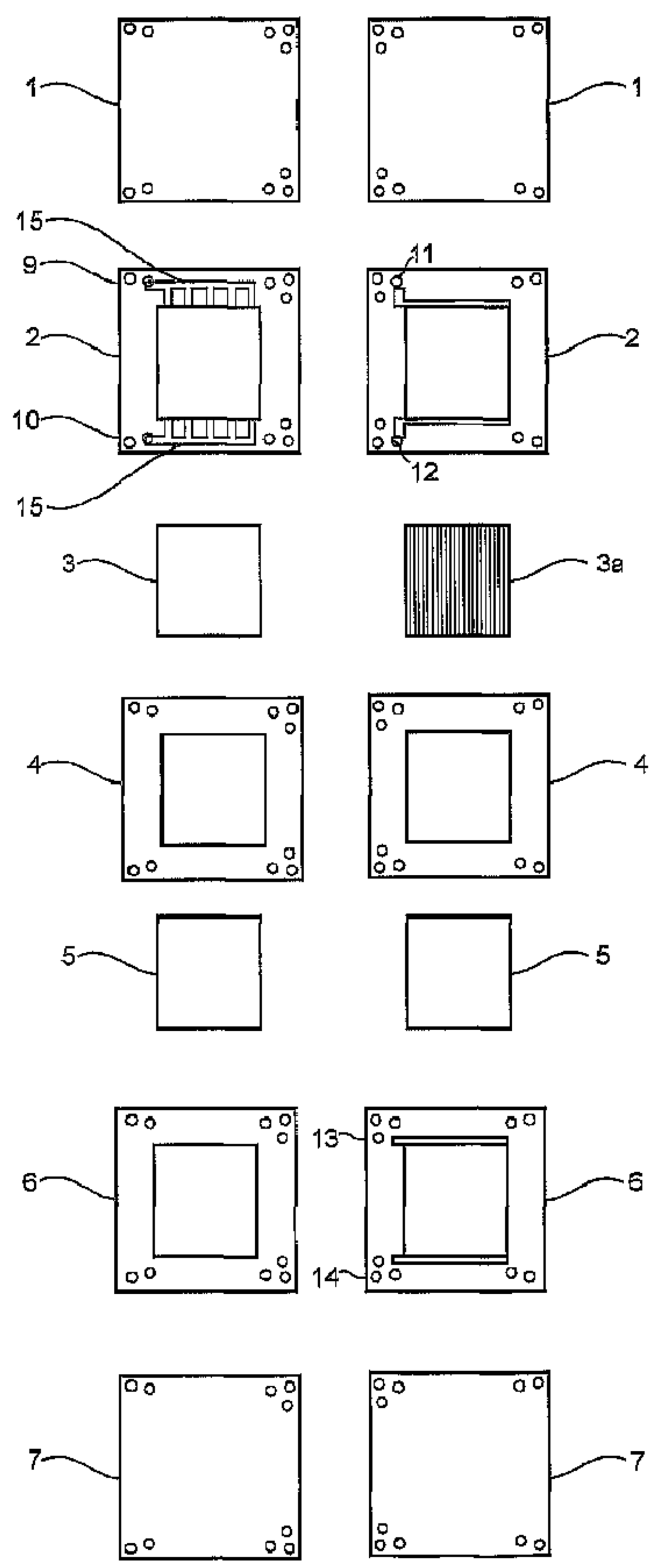
(54) **Titre** : STRUCTURE DE PILE A COMBUSTIBLE POLYMERE, MUNIE D'UNE COUCHE AMELIOREE DE REPARTITION DES GAZ
(54) **Title**: POLYMER FUEL CELL STRUCTURE WITH IMPROVED GAS DISTRIBUTION LAYER



(57) **Abrégé/Abstract:**
The invention discloses a polymer electrolyte fuel cell structure comprising a proton exchange membrane (4). An anode catalyst layer (1; 16) is located on one side of the proton exchange membrane. A cathode catalyst layer (7) is located on the opposite side

(57) Abrégé(suite)/Abstract(continued):
of the proton exchange membrane, and a gas distribution layer (3, 5) is arranged on each side of the proton exchange membrane (4). The anode side gas distribution layer (3) is a flat, porous structure having water channels (3a) formed in the surface facing the membrane (4). The anode side gas distribution layer (3) is enclosed by a coplanar, sealing plate (2) with water inlet channels coupled to said water channels (3a) in the gas distribution layer.

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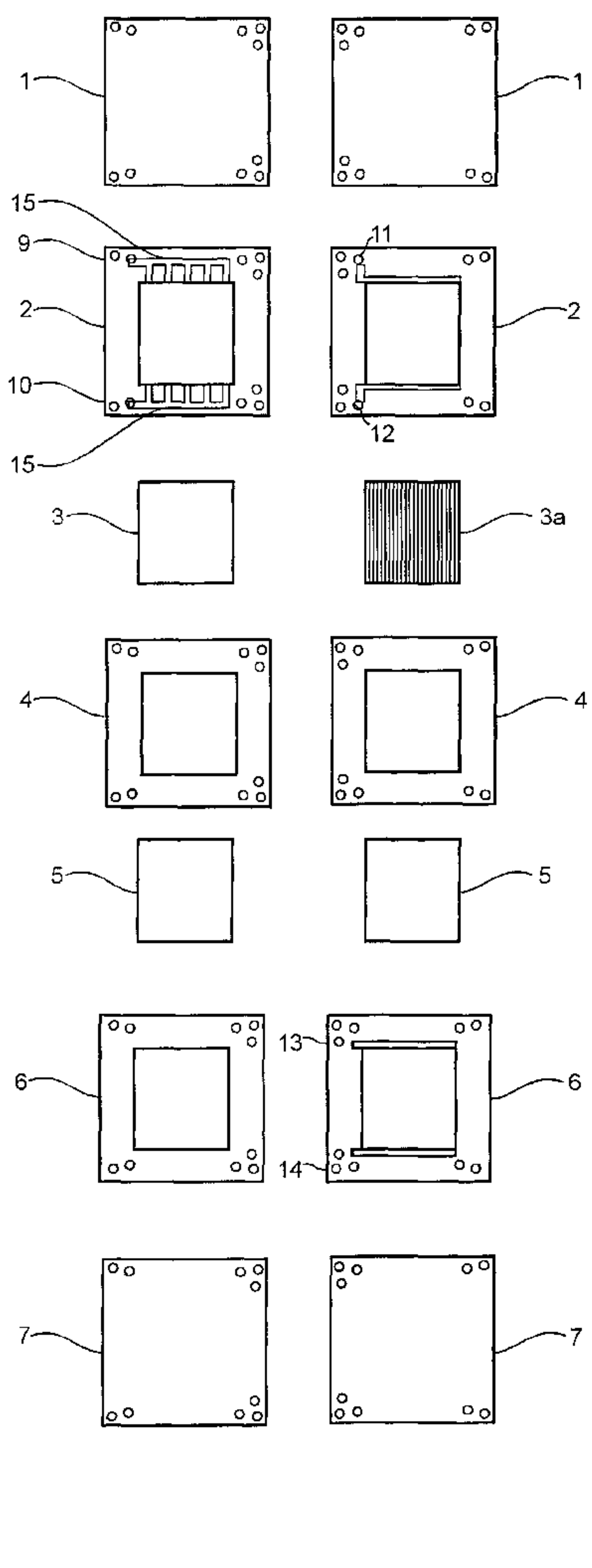
(54) Title: POLYMER FUEL CELL STRUCTURE



(57) Abstract: The invention discloses a polymer electrolyte fuel cell structure comprising a proton exchange membrane (4). An anode catalyst layer (1; 16) is located on one side of the proton exchange membrane. A cathode catalyst layer (7) is located on the opposite side of the proton exchange membrane, and a gas distribution layer (3, 5) is arranged on each side of the proton exchange membrane (4). The anode side gas distribution layer (3) is a flat, porous structure having water channels (3a) formed in the surface facing the membrane (4). The anode side gas distribution layer (3) is enclosed by a coplanar, sealing plate (2) with water inlet channels coupled to said water channels (3a) in the gas distribution layer.

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TITLE:
POLYMER FUEL CELL STRUCTURE WITH IMPROVED GAS DISTRIBUTION LAYER

TECHNICAL FIELD

The present invention generally relates to fuel cells, and in particular to improvements in performance of polymer fuel cells.

BACKGROUND OF THE INVENTION

Polymer fuel cells are on the fringe of commercialization. The progress made in catalyst and membrane research in the last few years has enabled very high power densities (>1W/cm^2) with moderate efficiencies for the fuel cell (40%). The catalyst loading of electrodes has been reduced to 0.1 mg Pt/cm^2 while maintaining a high performance. The price of the perfluorinated sulfonic acid membranes such as Nafion (R) is expected to decrease, with increasing production, whilst other proton conducting membrane candidates have been discovered.

However, serious problems are encountered when polymer fuel cell technology is scaled up to larger cells and stacks. One of the main problems, in the stacks themselves, is the water management, since the proton conducting membrane must be kept well humidified under operating conditions.

The dominating component, at the internal resistance loss in the stack, is due to the limiting proton conductivity of the membrane. Membranes tend to dry out, especially on the anode side, at high current densities, since proton migration drags water molecules away from the anode.

Drying of anode does not only affect resistance but also the kinetics of hydrogen reduction reaction (HRR) at the anode.

Therefore, in attempts to remedy this problem the anode side is often humidified more intensively than the cathode side. The cathode side of the cell can also be pressurized to use the pressure gradient over the membrane to press the water back to the anode. However, it is important that the water management does not impede the gas flow inside the cells.

One solution for this problem would be to use thinner membranes, but this approach has limitations since mechanical rigidity of the membrane must be sufficient.

Another solution is to have a direct water contact with the membrane at the anode side, since the water content and conductivity of the membrane are much higher when membrane is in equilibrium with water. Also, when liquid is evaporated inside the fuel cell a considerable amount (40-50%) of the heat can be removed from the cell with the produced water vapor.

In US-5,958,613 (Hamada et al) relates to such direct water humidification of fuel cell membranes. Therein is disclosed a polymer fuel cell system with a capability to moisten the solid-polymer film without providing a special humidifier which humidifies the fuel gas or the oxidizer gas, and that cools down the main cell body without providing cooling channels. In this patent there is no disclosure of specified operation principles for a fuel cell stack, when the direct humidification is applied.

In US-5,935,726 (Chow et al) there is disclosed a method and apparatus for improved humidification of membranes in polymer fuel cells, by periodically reversing the flow direction of the oxidant stream through a fuel cell flow field. However, this patent is not concerned with cooling of the fuel cell.

SUMMARY OF THE INVENTION

Despite the numerous attempts to improve the water management in polymer fuel cells, there is still room for improvements.

Thus, the object of the present invention is to provide means for achieving better humidification, at low cost and low cell complexity. The trade off between performance and cost should be acceptable.

In the cell structure of the present invention, an aqueous phase, preferably water, is used for direct humidification of the membrane. The polymer electrolyte fuel cell structure according to the invention comprises a proton exchange membrane, an anode catalyst layer on one side of the proton exchange membrane, a cathode catalyst layer on the opposite side of the proton exchange membrane and a gas distribution layer on each side of the proton exchange membrane. It is characterized in that the anode side gas distribution layer is a flat, porous structure having water channels formed in the surface facing the membrane, and that the anode side gas distribution layer is enclosed by a coplanar, sealing plate with water inlet channels coupled to said water channels in the gas distribution layer.

Thereby, it is possible to maintain a direct water contact with the membrane at the anode side. This is beneficial for the operation of the cell, since the water content and the conductivity of the membrane are much higher when the membrane is in equilibrium with water. Also, when water is evaporated inside the fuel cell, a considerable amount of the heat, produced in the cell, can be removed from the cell by means of the produced water vapor.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be further described in the following, in a non-limiting way with reference to the accompanying drawings in which:

Fig. 1 is a perspective explosion view showing the elements of a polymer fuel cell structure in accordance with the invention,

Fig. 2 shows in plane view from above and below, all elements of the structure in Fig. 1,

Fig. 3 is a section in larger scale, through a gas distribution layer which is included in the structure of Fig. 1 and 2,

Fig. 4 shows a second embodiment of the gas distribution layer,

Fig. 5 shows a third embodiment of the gas distribution layer,

Fig. 6 shows, in the same manner as Fig. 2, an alternative structure layout, and

Fig. 7 shows still another embodiment of the gas distribution layer.

DETAILED DESCRIPTION OF THE INVENTION

A preferred embodiment of the fuel cell structure according to the invention is shown in figure 1 and 2. The fuel cell comprises a conductive bipolar anode plate 1. An anode sealing frame 2 is provided adjacent the bipolar anode plate 1. This frame is provided with a central, rectangular opening for an anode gas distribution layer 3. The frame 2 is also provided with an anode gas inlet 9 and an outlet 10 and distribution channels are formed as well as water inlets and outlets 11, 12 respectively. The anode gas distribution layer 3 is provided with a plurality of narrow water channels 3a on the opposite side of the layer 3, with reference to the anode plate 1. A proton exchange membrane 4 is arranged for cooperation with the plate 1 for sandwiching the frame 2 and the diffusion layer 3 between themselves.

The cathode side of the fuel cell is structured in a similar manner as the anode side. Thus, the opposite side of the membrane 4 is arranged for cooperation with a conductive cathode plate 7 for sandwiching a cathode sealing frame 6 and a cathode gas distribution layer 5 between themselves. The cathode diffusion layer 5 is not provided with any water channels as the anode diffusion layer 3. The cathode sealing frame 6 is provided with a cathode gas inlet 13 and an outlet 14.

In figure 2 the detailed structure of water channels and how the water distribution is organized in a stack is shown. The left-hand side of the figure shows the upside and the right-hand side of the figure shows the down side.

Each sealing frame 2 in a stack has a number of holes made through it. The holes located in the corners are for clamping bolts used when assembling a number of cell units to a cell stack. The remaining holes, together with corresponding holes in the other components of a stack, form channels through the stack for water, fuel gas and oxidant gas respectively.

Furthermore, the upper side (as defined above) of the sealing 2 has gas channels 15 running along the inner edge of the frame like structure. A number of distribution apertures (in the figure there are five) are diverted from each channel 15, so as to distribute incoming gas into the diffusion/distribution material located in the frame. The second hole from left (in the figure) in the upper array of holes is the inlet channel 9 for incoming gas, and the second hole from left in the lower array of holes is the outlet channel 10 for gas exiting from the cell on the anode side. The anode sealing 2 has the same configuration of gas channels regardless of position in the stack.

On the down side (as defined above) of each sealing 2 there are provided channels for water, having a common water inlet 11 and a common water outlet 12.

In the middle of the stack the membrane 4 is arranged, separating the anode and cathode parts of the stack. On the cathode side, a cathode gas distribution layer 5 is provided, and then there is sealing 6 for cathode wherein cathode gas inlet and outlet 13, 14 are formed, in a similar way as in the anode sealing 2.

Figure 3 shows a more detailed structure of a gas distribution layer. The layer 3 is provided with water channels 3a adjacent the membrane 4. In a typical embodiment of the invention, the water channels 3a may have a width of about 50-100μm, a depth of about 100-300μm and the channels may be separated by a distance of about 200-1000μm. By making the water channels narrow, blocking of the channels due to membrane expansion is avoided. One possible method of producing the channels 3a would be to press the gas distribution layer against a template having a ridge structure surface corresponding to the desired water channel structure.

Figure 4 shows an embodiment of the invention, where the gas distribution layer 3 is provided with a catalyst layer 16. A non-porous or almost non-porous proton conducting polymer layer 17 is arranged so that it lines the water channel.

In this embodiment, a hydrogen peroxide or other oxygen evolving compounds may be added to the humidification and cooling water, which is fed into the cell on the anode side. Since the oxygen is released in the vicinity of the catalyst, CO adsorption at the anode catalyst may be avoided, in a manner which is effective and which leads to less consumption of oxygen. Part of the hydrogen peroxide will be decomposed at the electrode surface to generate oxygen with the reaction $H_2O_2 \rightarrow H_2O+1/2O_2$. In this system possible benefits of hydrogen peroxide are achieved even if the decomposition is not complete. The path of the hydrogen peroxide and evolved oxygen is marked as arrows in Fig. 4. However, this method can be applied to other direct water humidification systems in polymer fuel cells.

Figure 5 shows a gas distribution layer 3, the edges of which has been treated with a hydrophobous polymer to prevent the water from entering the cell gas chamber. In this structure there are no gas channels in the bipolar anode plate 1, the bipolar cathode plate 7 or in the gas distribution layers 3, 5. The gas distribution layers can have a porosity exceeding 90% and they should be good electrical conductors and have proper corrosion resistance against acid proton conducting membrane.

The present invention may be combined with the conventional serpentine channel structure. The principle of this is illustrated in figure 6. The same reference numbers has been used as in the embodiment according to Fig. 2. The anode layer side of each bipolar plate 1, 7 may be provided with an anode gas channel 19 and at least one water inlet 20. A water outlet 21 may also be provided. The cathode layer side of each bipolar plate is provided with at least one cathode gas channel 22.

An alternative structure for the water channels is presented in Fig. 7. In this embodiment of the invention, the catalyst layer 16 is located on top of the membrane 4. A hydrophobous layer 18 is positioned between the membrane and the gas distribution layer. The function of this layer 18 is to let gas diffuse to the electrode (catalyst layer) but not let the water to escape from the water channel 3a.

The embodiment according to Fig. 7 may be used for operation of a liquid-gas direct methanol fuel cell. In such an embodiment of the invention, the anode side of the cell is fed with a liquid water-methanol mixture, which is totally or partially evaporated in the cell. The liquid mixture is fed in such a way that most part of the anode electrode is in contact with a thin film of liquid methanol-water mixture. The remaining area of the anode electrode is in contact with the gas phase free from liquid. This in order to enable both fast release of gaseous carbon dioxide as well as for humidifying of membrane by water vapor reactant to remaining part of the anode area. Water and methanol are transferred from fuel feeding channels to the anode electrode both directly and via gas phase. This is illustrated by means of arrows in Figure 7. The above described method may also be applied to other types of fuel cell structures which are direct liquid cooled.

The water channel structure is preferably applied to the anode side. However, this structure can also be applied to the cathode side or to both sides simultaneously.

The invention is not limited to the above described embodiments, instead several modifications are possible within the scope of the following patent claims.

CLAIMS:

1. A polymer electrolyte fuel cell structure comprising:

a proton exchange membrane having an anode side and an opposite, cathode side;

an anode catalyst layer;

a cathode catalyst layer;

a gas distribution layer located on each of the anode side and the cathode side of the proton exchange membrane,

wherein the anode catalyst layer is located on the anode side of the proton exchange membrane or on the anode side of the gas distribution layer;

the cathode catalyst layer is located on the cathode side of the proton exchange membrane or on the cathode side of the gas distribution layer; and

wherein at least one of the gas distribution layers has a flat, porous structure with aqueous phase channels being formed in a surface of said at least one gas distribution layer that faces toward a corresponding surface of the proton exchange membrane, the aqueous phase channels extending generally parallel to the surface of said at least one gas distribution layer in which they are formed and being bounded by a sealing plate having aqueous phase inlet channels that are in communication with the aqueous phase channels in said at least one gas distribution layer;

said aqueous phase channels being open-sided along the lengths thereof but, at the same time, bounded by corresponding portions of said corresponding surface of the proton exchange membrane such that aqueous-phase material that enters the aqueous phase channels from the aqueous phase inlet channels is directly exposed to and in direct contact with said corresponding portions of said corresponding surface of the proton exchange membrane.

2. A structure according to claim 1, wherein the aqueous phase channels have a width of about 50 pm to about 100 pm.

3. A structure according to claim 1, characterized in that the aqueous phase channels have a depth of about 100 pm to about 300 pm.

4. A structure according to claim 1, characterized in that the aqueous phase channels are separated by a distance of about 200 pm to about 1000 pm.

5. A structure according to claim 1, wherein said aqueous phase channels are formed in the gas distribution layer that is located on the anode side of the proton exchange membrane.

6. A structure according to claim 5, characterized in that the gas distribution layer that is located on the cathode side of the proton exchange membrane is a porous structure bounded by a sealing plate.

7. A structure according to claim 6, characterized in that the gas distribution layer that is located on the cathode side of the proton exchange membrane has aqueous phase channels that are formed in a surface of the cathode-side gas distribution layer that faces

toward a corresponding surface of the proton exchange membrane and that extend generally parallel to the surface of the cathode-side gas distribution layer in which they are formed, the cathode-side aqueous phase channels being bounded by a sealing plate having aqueous phase inlet channels that are in communication with the aqueous phase channels in the cathode-side gas distribution layer.

8. A structure according to claim 1, characterized in that aqueous phase channels are lined with a hydrophobic coating.

9. A structure according to claim 1, characterized in that a bipolar plate is located on the side of each sealing plate that is distal from the proton exchange membrane.

10. A structure according to claim 9, characterized in that each bipolar plate has the anode catalyst layer on one side and the cathode catalyst layer on the opposite side.

11. A structure according to claim 10, characterized in that the cathode catalyst layer side of each bipolar plate has at least one cathode gas channel and the anode catalyst layer side of each bipolar plate has an anode gas channel and at least one aqueous phase material inlet.

12. A structure according to claim 1, characterized in that the anode catalyst layer is located on the surface of

the anode side gas distribution layer that faces toward the proton exchange membrane.

13. A structure according to claim 12, characterized in that a comparatively non-porous layer of a proton-conducting material is provided in the aqueous phase channels by means of which water can be retained within the aqueous phase channels.

14. A structure according to claim 12, characterized in that the cathode catalyst layer is located on the surface of the cathode-side gas distribution layer that faces toward the proton exchange membrane.

15. A structure according to claim 1, characterized in that at least one of the anode catalyst layer and the cathode catalyst layer is located on the surface of the proton exchange membrane.

16. A structure according to claim 15, characterized in that a comparatively non-porous layer of a highly gas permeable material is provided in the aqueous phase channels.

17. A polymer electrolyte fuel cell structure comprising:
an anode catalyst layer;
a cathode catalyst layer;
a proton exchange membrane located between said anode catalyst layer and said cathode catalyst layer,
a gas distribution layer positioned between said proton exchange membrane and said anode catalyst layer or said

cathode catalyst layer, said gas distribution layer having a flat, porous structure with aqueous phase gas-distribution-layer channels formed in a surface thereof that faces toward a corresponding surface of the proton exchange membrane, the aqueous phase gas-distribution-layer channels extending generally parallel to each other and generally parallel to the surface of said gas distribution layer and being bordered along edge surfaces thereof by a sealing frame having aqueous phase inlet channels that are in communication with the aqueous phase gas-distribution-layer channels in said gas distribution layer.

18. The polymer electrolyte fuel cell structure of claim 17, wherein said gas distribution layer is located between said proton exchange membrane and said anode catalyst layer.

19. The polymer electrolyte fuel cell structure of claim 18, further comprising a second gas distribution layer that is located between said proton exchange membrane and said cathode catalyst layer.

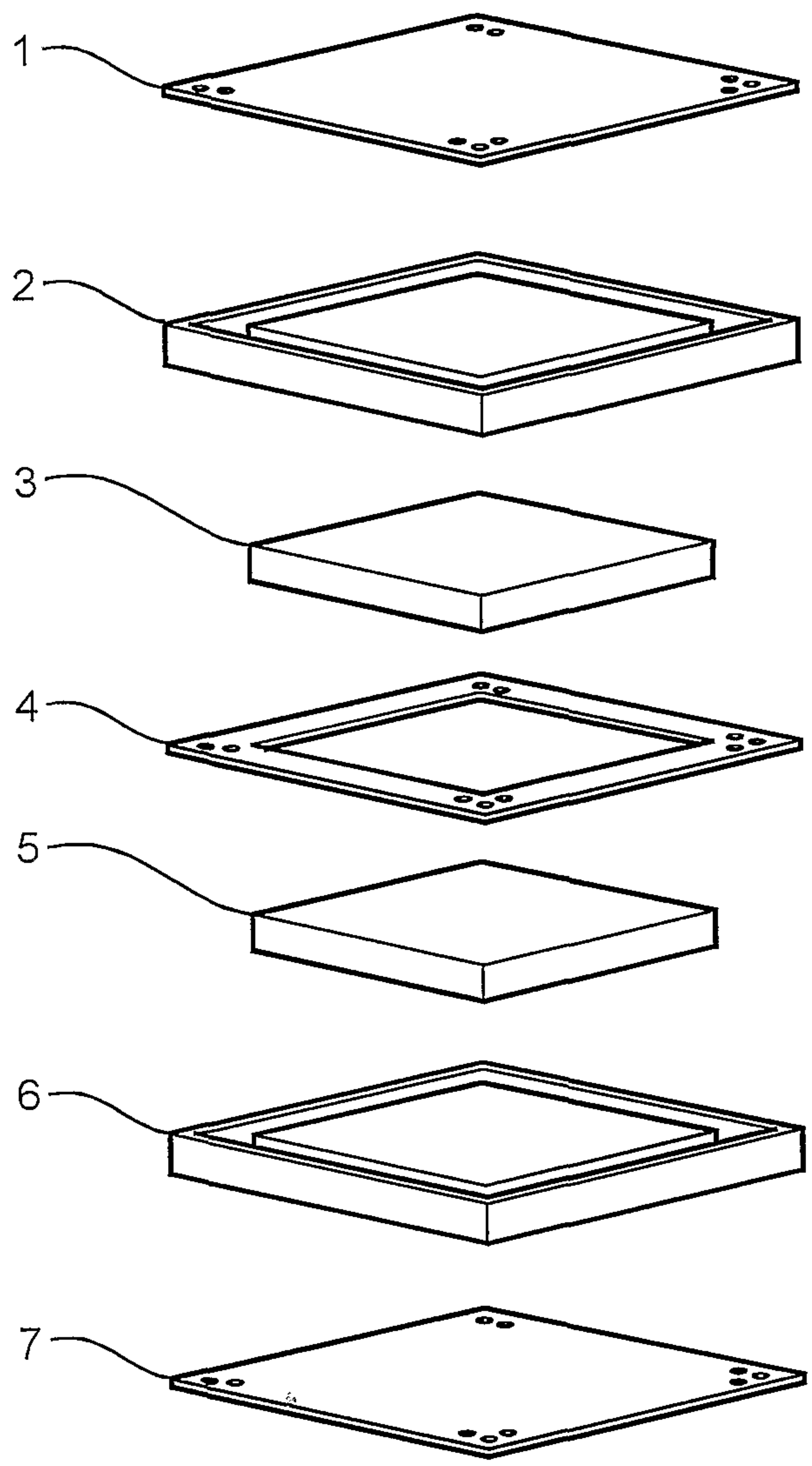


Fig.1

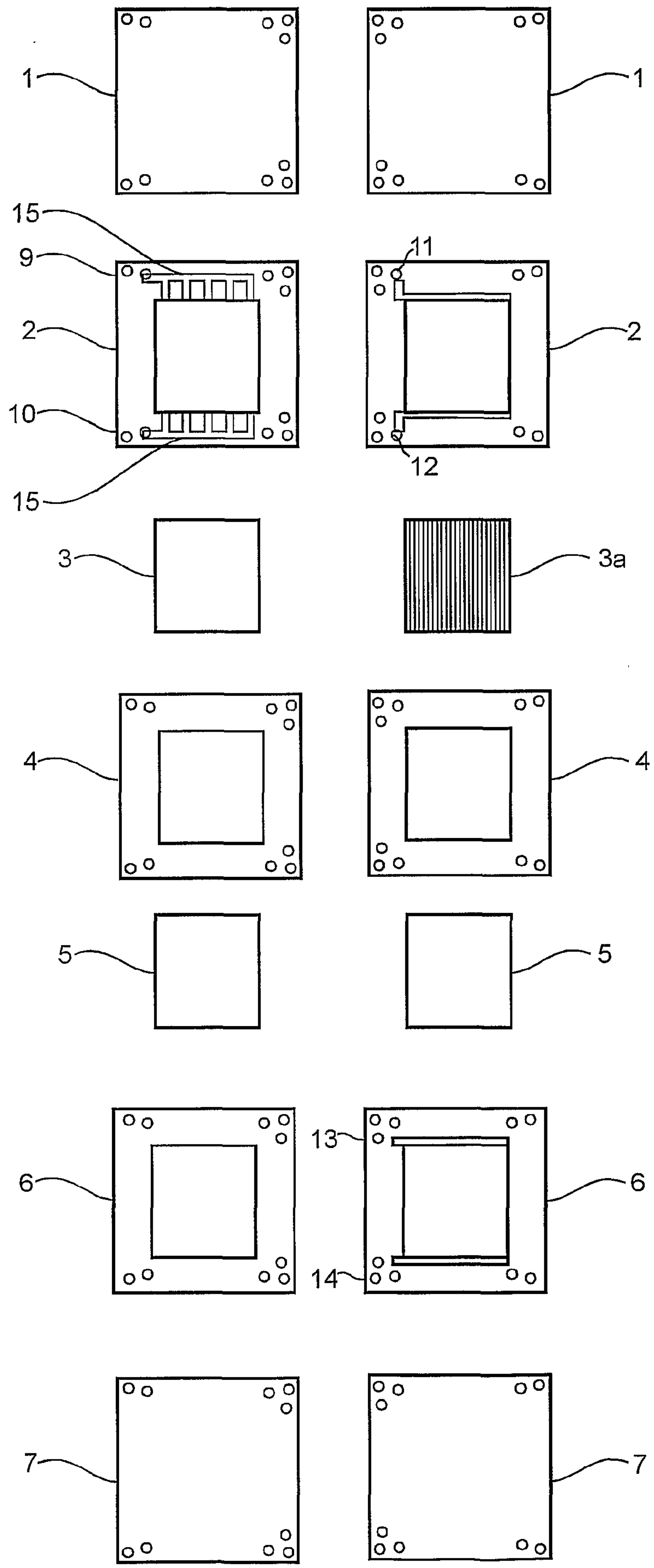


Fig.2

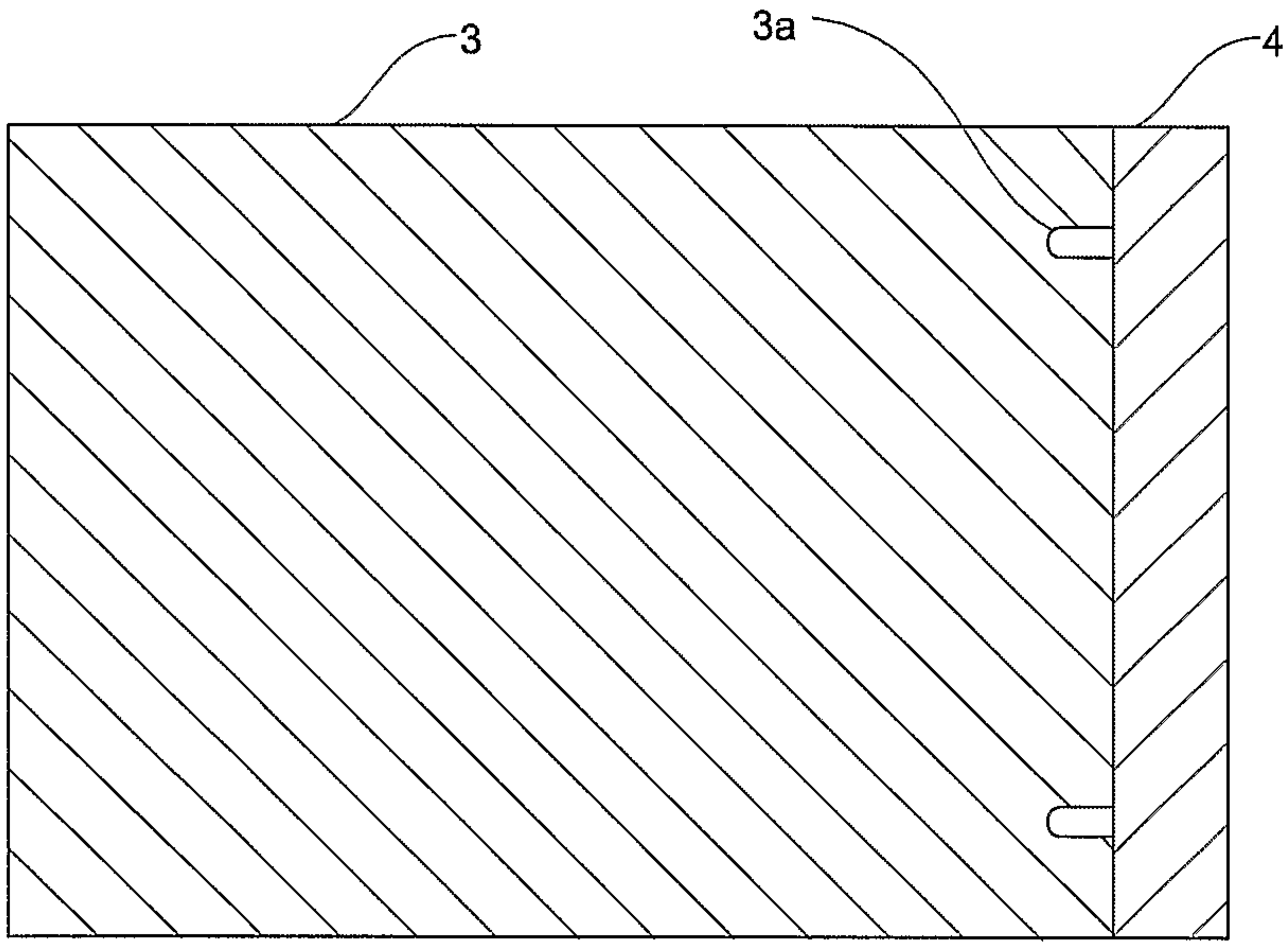


Fig.3

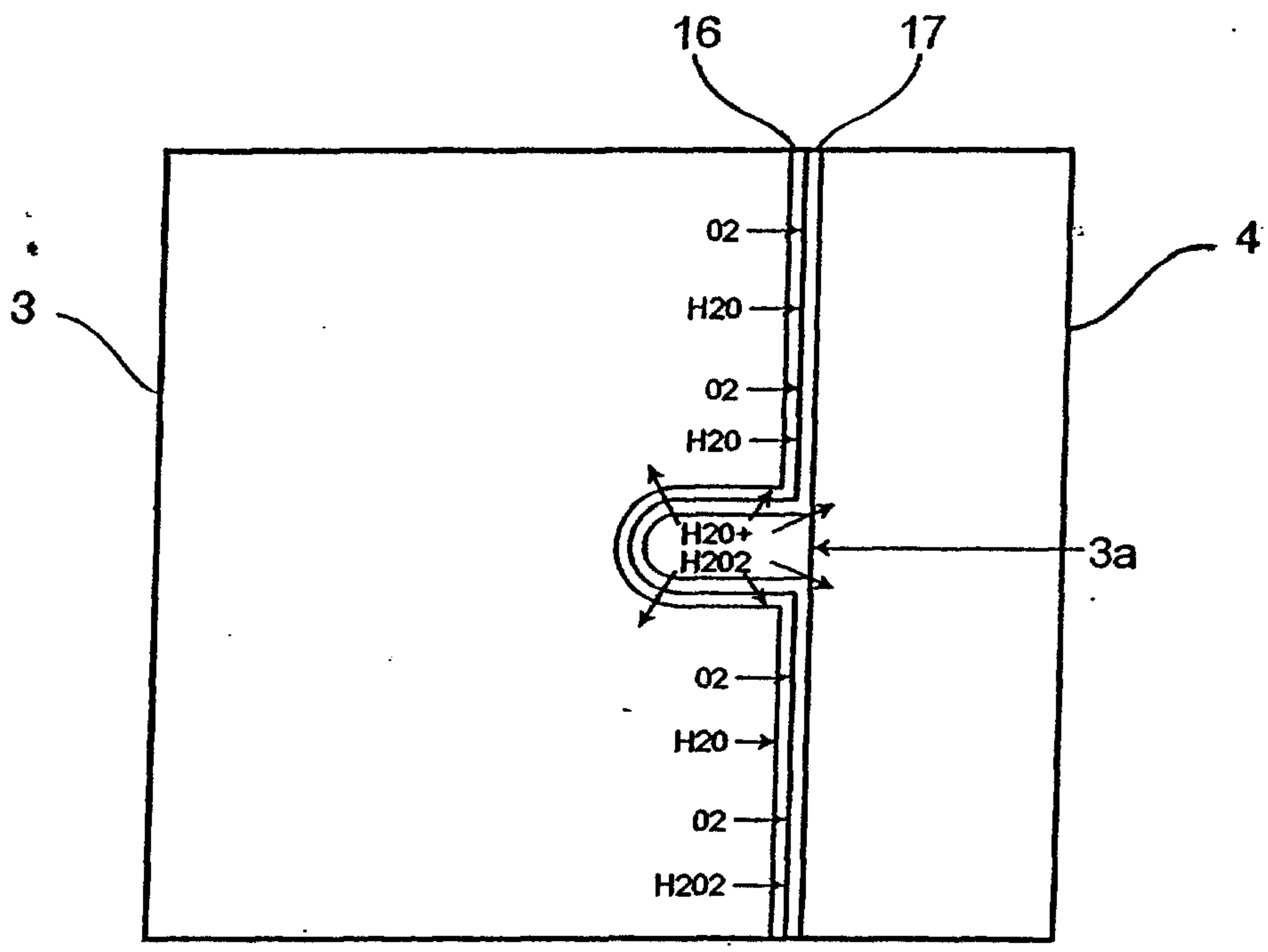


Fig.4

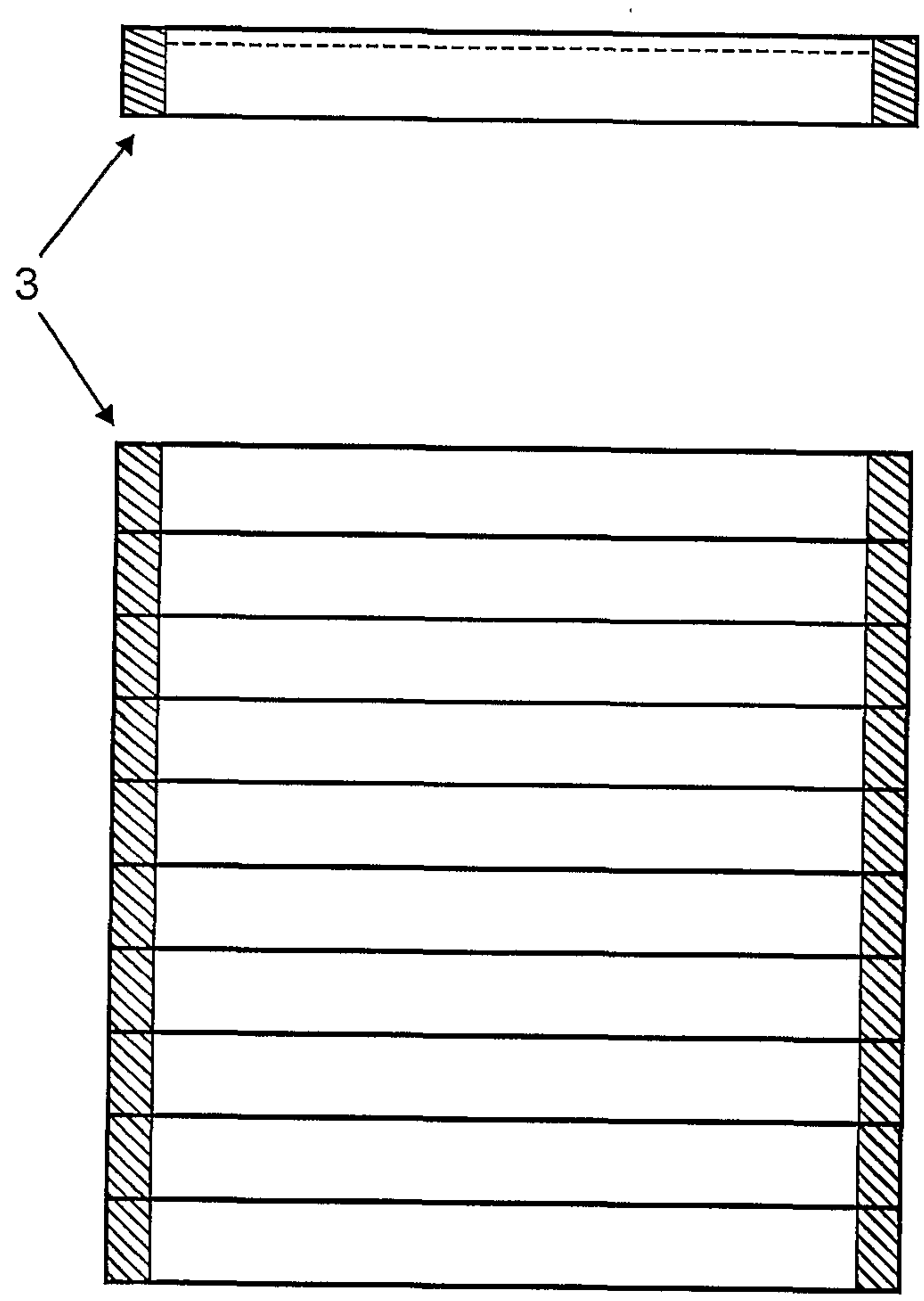


Fig.5

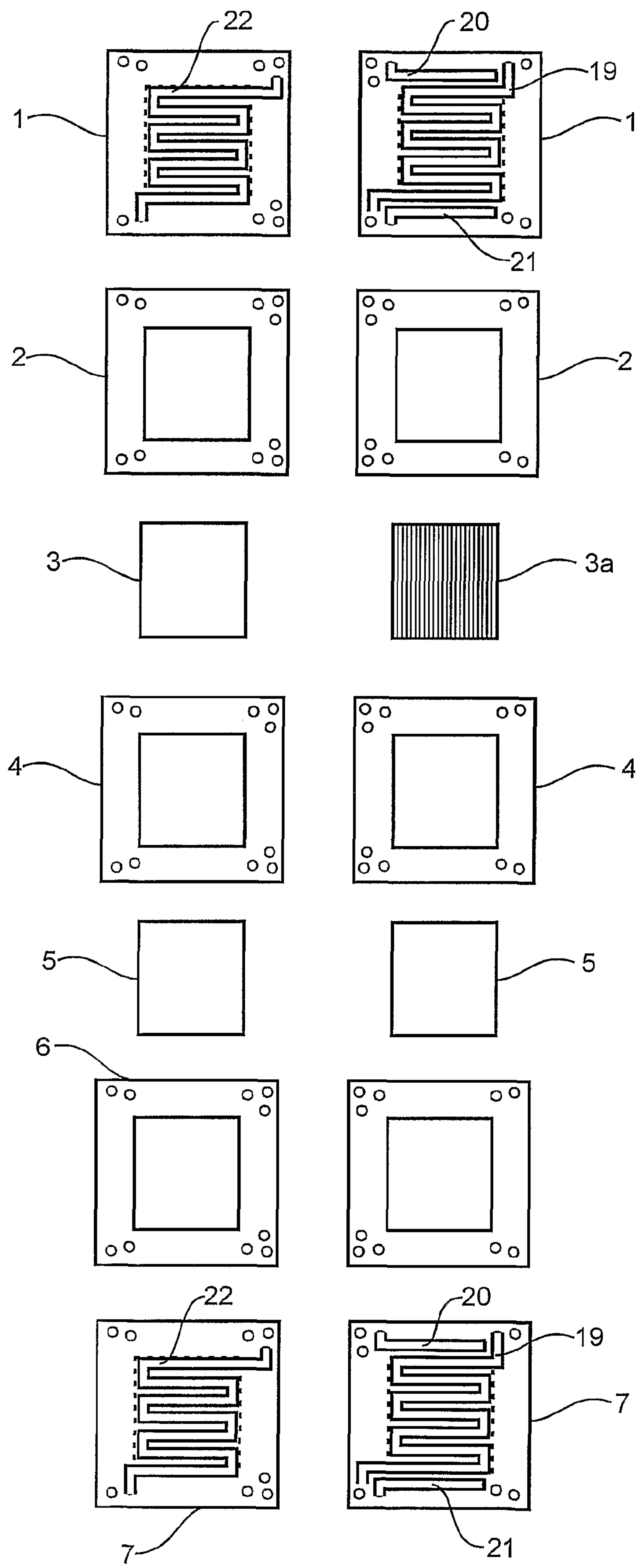


Fig.6

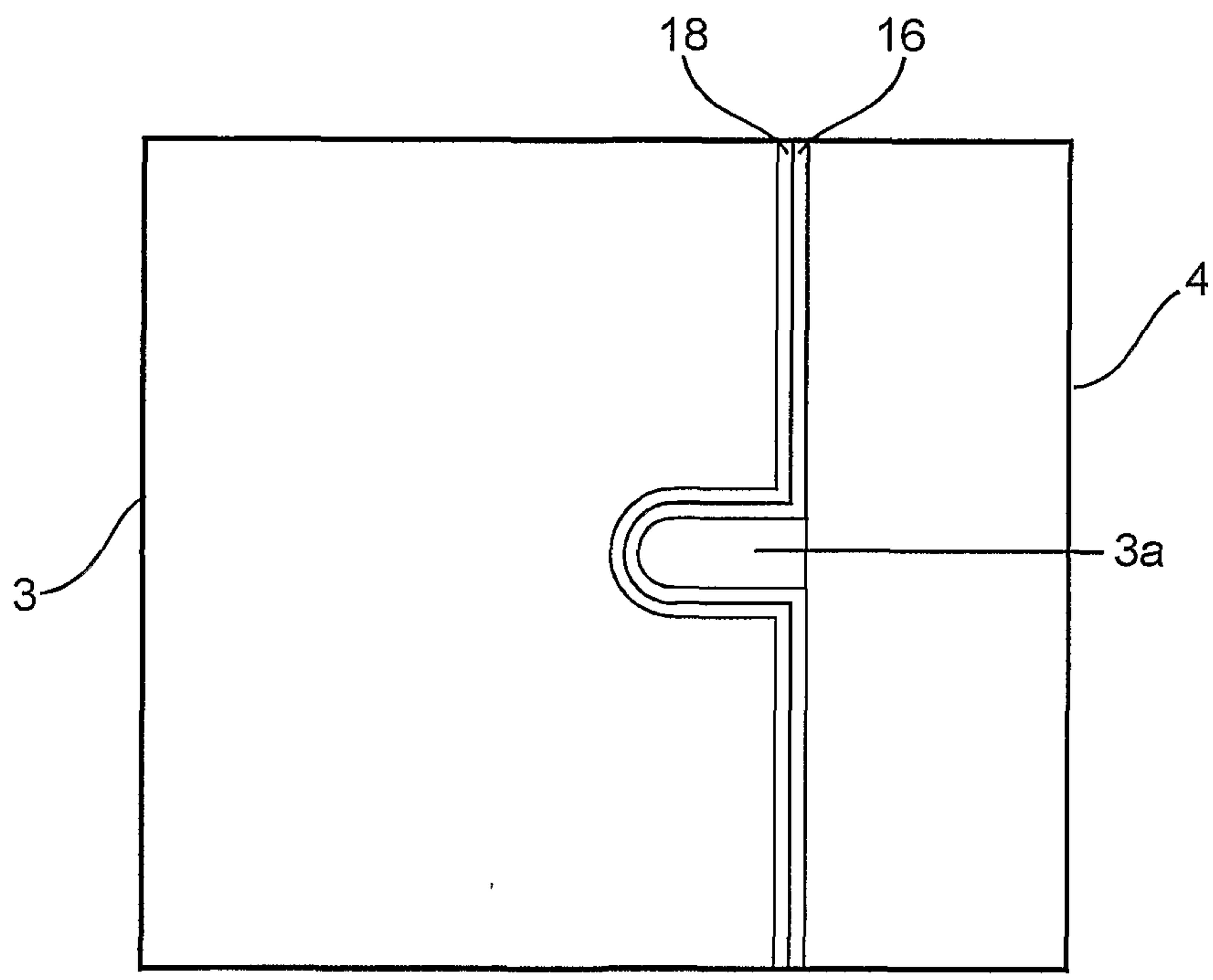
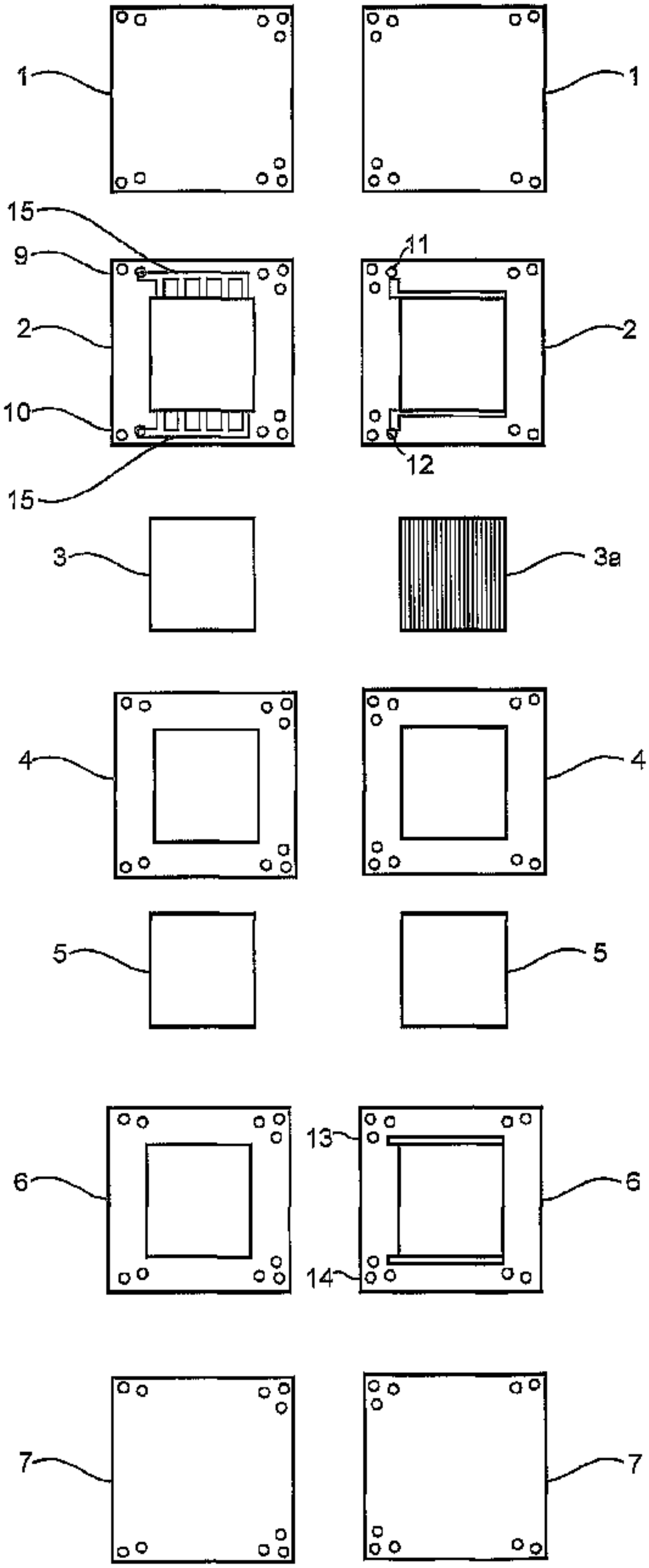


Fig.7



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