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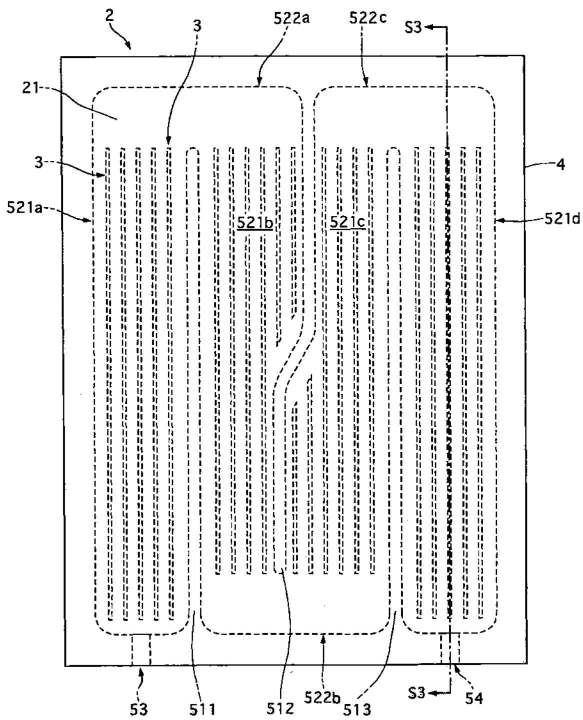
(54) **Heat exchanger**

(57) A heat exchanger (2) includes a first member (4) and a second member (5). The first member (4) is provided with a main body (4a) and a heat transfer accelerating portion (3) formed on the main body (4a) as one unit. The second member (5) is formed with a recess (5a) dented from a reference surface (51) and functioning as a flow channel (21). The first member (4) and the second member (5) are joined with each other at the reference surface (51) in a state where a part, which deviates from the recess (5a) when the first and second members (4, 5) are joined, of the heat transfer accelerating portion (3) of the first member (4) is cut off and the rest of the heat transfer accelerating portion (3) is inserted into the recess of the second member (5).

FIG. 1



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Description

[0001] The present invention relates to a heat exchanger which has an inner fin that is placed in a stream of flowing medium to cool or warm an object, and it also relates to a heat exchanger manufacturing method thereof.

[0002] A conventional heat exchanger is disclosed in Japanese Patent Application Laid-Open Publication No. 2002 - 170915. This conventional heat exchanger is used for cooling silicon-controlled rectifiers, various electric power condensers and others, and it includes a pan-like casing, a base plate attached to the casing, a corrugated inner fin inserted into an inner space of the casing and the base plate, and a partition plate holding the fin. The case and the fin are formed by using press working, and they assembled, then being integrally formed by brazing.

[0003] Another conventional heat exchanger is disclosed in Japanese Patent Application Laid-Open Publication No. 2007 - 202309. This heat exchanger is used for cooling an inverter, which converts direct current power into alternate current power, and others of a hybrid electric vehicle, and it has an aluminum body formed therein with a plurality of fins as one unit and a cover plate attached to the body. The body is formed by using die casting and fins are formed by means of machining the body.

[0004] The above known conventional heat exchangers, however, encounter a problem in that they are expensive due to long manufacturing time.

[0005] It is, therefore, an object of the present invention to provide a heat exchanger which overcomes at least one of the drawbacks of the prior art and preferably which can decrease manufacturing cost, ensuring a necessary heat transfer efficiency and water tightness thereof.

[0006] It is another object of the present invention to seek to provide a heat exchanger manufacturing method which overcomes the foregoing drawbacks and can decrease manufacturing cost, ensuring a necessary heat transfer efficiency and water tightness thereof.

[0007] According to a first aspect of the present invention there is provided a heat exchanger including a first member and a second member. The first member is provided with a main body and a heat transfer accelerating portion formed on the main body as one unit. The second member is formed with a recess dented from a reference surface and functioning as a flow channel. The first member and the second member are joined with each other at the reference surface in a state where a part, which deviates from the recess when the first and second members are joined, of the heat transfer accelerating portion of the first member is cut off and the rest of the heat transfer accelerating portion is inserted into the recess of the second member.

[0008] Therefore, the heat exchanger of embodiments of the present invention can decrease manufacturing cost, ensuring a necessary heat transfer efficiency and water tightness thereof.

[0009] According to a second aspect of the present invention there is provided a heat exchanger manufacturing method including the following steps: a first step of preparing blocks to be a first member and a second member, a second step of forming a heat transfer accelerating portion on a main body of the first member as one unit so that the heat transfer accelerating portion projected from the main body, a third step of forming a recess in the second member so that the recess is dented from a reference surface of the second member and forms a part of a flow channel, a fourth step of cutting off a portion, deviating from the flow channel when the first and second member are joined, of the heat transfer accelerating portion, and a fifth step of joining the first member and the second member with each other at the reference surface of the second member.

[0010] Therefore, the heat exchanger manufacturing method can provide a heat exchanger which can decrease manufacturing cost, ensuring a necessary heat transfer efficiency and water tightness thereof.

[0011] The objects, features and advantages of the present invention will become apparent as the description proceeds when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a plan view showing a heat exchanger of a first embodiment according to the present invention;

FIG. 2 is a front view of the heat exchanger of the first embodiment;

FIG. 3 is a cross sectional side view of the heat exchanger of the first embodiment, taken along a line S3 - S3 in FIG. 1;

FIG. 4 is a plan view of an upper case of the heat exchanger of the first embodiment;

FIG. 5 is a front view of the upper case shown in FIG. 4;

FIG. 6 is a front view of the upper case where a plurality of fin portions are formed thereon as one unit by using an extrusion process method, before their unnecessary parts are not cut off;

FIG. 7 is a front view of the upper case shown in FIG. 6;

FIG. 8 is a plan view of a lower case of the heat exchanger of the first embodiment;

FIG. 9 is a front view showing the lower case shown in FIG. 8;

FIG. 10 is a cross sectional view showing a heat exchanger consisting of two sets of the heat exchangers shown in FIGS. 1 to 5, being formed as one unit, and being provided with a power module to be cooled;

FIG. 11 is an exploded view of the heat exchanger shown in FIG. 10;

FIG. 12 is a plan view of an upper case of a heat exchanger of a second embodiment according to the present invention;

FIG. 13 is a front view of the heat exchanger shown in FIG. 12;

FIG. 14 is a cross sectional side view of the heat exchanger shown in FIGS. 12 and 13, taken along a line S13 - S13 in FIG. 12;

FIG. 15 is a partial cross sectional view of the heat exchanger shown FIGS. 12 to 14, taken along a line S15 - S15;

FIG. 16 is a plan view showing a first turning portion of an upper case of a heat exchanger of a third embodiment according to the present invention;

FIG. 17 is a plan view showing a modification of the first turning portion of the upper case of the heat exchanger of the third embodiment;

FIG. 18 is a partial cross sectional view showing a first modification of a heat-transfer accelerating part formed on the upper cases of the first to third embodiments;

FIG. 19 is a partial cross sectional view showing a second modification of the heat-transfer accelerating part;

FIG. 20 is a partial cross sectional view showing a third modification of the heat-transfer accelerating part;

FIG. 21 is a partial cross sectional view showing a fourth modification of the heat-transfer accelerating part;

FIG. 22 is a partial cross sectional view showing a fifth modification of the heat-transfer accelerating part;

FIG. 23 is a plan view showing a heat exchanger of a fourth embodiment according to the present invention;

FIG. 24 is a front view of the heat exchanger of the fourth embodiment;

FIG. 25 is a cross sectional side view of the heat exchanger of the fourth embodiment, being provided with a power module thereon;

FIG. 26 is a plan view of an upper case of the heat exchanger of the fourth embodiment;

FIG. 27 is a front view of the upper case shown in FIG. 26;

FIG. 28 is a plan view of a lower case of the heat exchanger of the fourth embodiment;

FIG. 29 is a front view of the lower case shown in FIG. 28;

FIG. 30 is an enlarged partial cross sectional view of the lower case, shown in FIGS. 28 and 29, with a second turn portion;

FIG. 31 is an enlarged perspective schematic view showing a flow of cooling water in the second turn portion shown in FIG. 30;

FIG. 32 is a plan view showing a heat exchanger of a fifth embodiment according to the present invention;

FIG. 33 is a front view of the heat exchanger of the fifth embodiment;

FIG. 34 is a cross sectional side view of the heat exchanger of the fifth embodiment, taken along a line S34 - S34 in FIG. 32;

FIG. 35 is an enlarged perspective schematic view showing a flow of cooling water in a third turn portion of the heat exchanger of the fifth embodiment; and

FIG. 36 is a plain view showing a lower case used in a heat exchanger of a sixth embodiment of the present invention;

FIG. 37 is a front view showing the lower case shown in FIG. 36;

FIG. 38 is a bottom view showing the lower case shown in FIGS. 36 and 37;

FIG. 39 is a cross sectional side view of the lower case shown in FIGS. 36 to 38, taken along a line S39 - S39 in FIG. 36:

FIG. 40 is a cross sectional side view of the lower case shown in FIGS. 36 to 38, taken along a line S40 - S40 in FIG. 36:

FIG. 41 is a front view showing an upper case used in the heat exchanger of the sixth embodiment;

FIG. 42 is a bottom view showing the upper case shown in FIG. 41; and

FIG. 43 is a bottom view showing the upper case shown in FIGS. 41 and 42 before a part of fin portions formed on a main body of the upper case is cut off.

[0012] Throughout the following detailed description, similar reference characters and numbers refer to similar elements in all figures of the drawings, and their descriptions are omitted for eliminating duplication.

[0013] As defined herein, the terms upper, lower, upwards, downwards, side, etc. are provided for ease of reference with regard to various relative positions of features. The terms may be considered to relate to the heat exchanger when it is mounted and in use.

[0014] Referring to FIG. 1 to FIG. 3 of the drawings, there is shown a first preferred embodiment of a heat exchanger according to the present invention. In the first embodiment, the heat exchanger 2 is used for cooling a power module with an inverter for supplying electric power to an electric motor of an electric vehicle or a hybrid electric vehicle.

[0015] The heat exchanger 2 includes an upper case 4 and a lower case 5, where the upper case 4 is formed with a plurality of radiation fin portions 3 as one unit, and the upper 4 is coupled with the lower case 5 to form a flow channel 21 for flowing cooling water therein. The upper case 4 corresponds to a first case of an embodiment of the present invention, the lower case 5 corresponds to a second case of an embodiment of the present invention, and the cooling water corresponds to a flowing medium of an embodiment of the present invention.

[0016] As shown in FIG. 4 and FIG. 5, the upper case 4 is made of aluminum, having a main body 4a shaped like a rectangular plate. The radiation fin portions 3 are formed on a lower surface of the main body 4a of the upper case 4 as one unit so that they are projected downward therefrom. The fin portions 3 are provided so as to extend strait in a longitudinal direction of the upper case 4 and be arranged in multi rows at predetermined intervals in a lateral direction thereof. An outer peripheral portion and some portions of the fin portions 3 are removed from the upper case 4, which will be later described.

[0017] The fin portions 3 form side wall portions of the flow channel 21, and a part of bottom surface of the main body 4a form an upper wall portion of the flow channel 21. Consequently, the side and upper wall portions of the flow channel 21 provide wide surfaces through which heat is capable of effectively transferring, which can enhance heat transfer also because the fin portions 3 and the main body 4a of the upper case 4 are formed as one unit made of aluminum with a high heat transfer property.

[0018] These fin portions 3 are formed from the upper case 4 as one unit by using an extrusion process method.

[0019] As shown in FIG. 5 and FIG. 6, in a first process, the upper case 4 shaped in a rectangular plate is formed from an aluminum block to have a plurality of protruded fin portions 3 over the lower surface of the main body 4a by using the extrusion process method, so that the fin portions 3 have a thin rectangular cross-section, projecting downward and extending straight in the longitudinal directions from one edge portion to the other edge portion of the main body 4a. The fin portions 3 are arranged at even intervals in the lateral direction. These shapes and arrangement of the pre-formed fin portions 3 are simple, so that they can be easily formed by using a simple-shaped and inexpensive die.

[0020] In a next process, unnecessary portions of the fin portions 3 are removed therefrom by a machining process so that the fin portions 3 are formed as shown in FIG. 4 and FIG. 5. The unnecessary portions of the fin portions 3 include, for example, the outer peripheral portion, center portions, portions that are not capable of being inserted in the flow channel 21 and portions corresponding to turning portions 522a to 522c of the flow channel 21.

[0021] On the other hand, as shown in FIG. 8 and FIG. 9, the lower case 5 is shaped like a rectangular block provided with a recess 5a which is divided formed downward from an upper surface, as a reference plane 51. The recess 5a is divided by first to third wall portions 511, 512 and 513 of the lower case 5 to form first to fourth straight line portions 521a to 521d arranged parallel to each other and first to third turn portions 522a to 522c as a part of the flow channel 21.

[0022] Specifically, the first wall portion 511 extends in a longitudinal direction of the lower case 5 from a one side portion of the lower case toward the other side portion thereof to have a clearance between an end portion of the first wall portion 511 and the other side portion, where the first turn portion 522a is formed to fluidically communicate the first and second straight line portions 521a and 521b with each other. The second wall portion 512 extends in the longitudinal direction from the other side portion toward the one side portion to have a clearance between an end portion of the second wall portion 512 and the one side portion, where the second turn portion 522b is formed to fluidically communicate the second and third straight line portions 521b and 521c with each other. The second wall portion 512 is offset in a lateral direction of the lower case 5 at its intermediate portion which is gradually slanted along the longitudinal direction so that cooling water can smoothly change its flow volumes and flow speed. The third wall portion 513 extends in the longitudinal direction from the one side portion toward the other side portion to have a clearance between an end portion of the third wall portion 513 and the other side portion, where the third turn portion 522c is formed to fluidically communicate the third and fourth straight line portions 521c and 521d with each other.

[0023] An inlet port 53 and an outlet port 54 are provided on the one side portion of the lower case 5 to be fluidically communicated with the first straight line portion 521a and the fourth straight line portion 521d, respectively.

[0024] The lower surface of on the main body 4a of the upper case 4 and the upper surface of the lower case 5 are fitted to each other, the fin portions 3 of the upper case 4 being inserted into the recess 5a of the lower case 5. Then, they are watertightly joined with each other by using a friction stir welding method. The friction stir welding method is shown in Japanese Patent Application Laid-Open Publication No. 2002 - 210570 for example, and it is used for joining metals without fusion and filler materials, original metal characteristics remaining unchanged as possible. A cylindrical, shouldered tool with a profiled probe is moved, being rotated and plunged, along portions to be joined. This generates frictional heating and mechanical deformation to weld the portions.

[0025] For example, thus manufactured heat exchanger 2 is used for cooling a power module 1 having two inverters, on the upper surface of the upper case 4, on as shown in FIG. 10 and FIG. 11.

[0026] Therefore, in FIGS. 10 and 11, the heat exchanger 2 shown in FIGS. 1 to 3 is slightly modified in such a way that two heat exchangers 2 are formed as one unit. Specifically, the lower case 5 is formed with a large rectangular recess 5b at an upper surface side thereof to receive the upper case 4. The rectangular recess 5b continuously connected with two recesses 5a for receiving the fin portions 3 formed on the upper case 4.

[0027] The upper case 4 is fitted into the rectangular recess 5b of the lower case 5, and then the fitted portions 22 shown in FIG. 10, which do not form the flow channel 21, of the upper and lower cases 4 and 5 are joined together by using the friction stir welding method.

[0028] On the other hand, the lower case 5 is provided a plurality of bolt-holes 55 and 55c on a peripheral portion and a center portion of the lower case 5, respectively. The upper case 4 is provided with a bolt-hole at its center position corresponding to the center bolt-hole 55c. The power module 1 is provided a plurality of bolt-holes 11 and 11c on a peripheral portion and a center portion of the upper case 4. After joining the upper and lower cases 4 and 5, bolts 6 are screw-cramped into the bolt-holes 55 and 55c through the bolt-holes 11, 11c and 41, so that the power module 1, the upper case 4 and the lower case 5 are integrally joined so that a bottom surface of the power module 1 directly contacts with the upper surface of the upper case 4 of the heat exchanger 2.

[0029] The operation and the advantages of the heat exchanger 2 of the first embodiment will be described.

[0030] In the heat exchanger 2 attached with the power module 1, the cooling water is supplied through the inlet port 53 to the flow channel 21, and it runs through the flow channel 21 formed in the heat exchanger 2, then being discharged through the outlet port 54. The cooling water is supplied from and returns to a not-shown air-conditioning system or other cooling system so as to circulate between the heat exchanger 2 and the system.

[0031] Specifically, the cooling water flows in the first straight line portion 521 a, where heat transfer between the power module 1 and the cooling water is accelerated through the fin portion 3 disposed therein because of its wide surfaces. In the straight line portion 521a, the fin portion 3 therein has a plurality of narrow straight channels extending along the longitudinal direction and parallel to each other, providing wider heat-transfer surfaces. There are small amount of the cooling water that flows cross the narrow straight channels.

[0032] When the cooling water reaches the other end portion of the upper and lower cases 4 and 5, it changes its flow direction to turn 180 degrees around to face due to the first turn portions 522a and the center wall portion, then flowing in the second straight line portion 521b. In the first turn portion 522a, there is no fin portion because of cutting-off of the fin portions 3 corresponding thereto, which enables the cooling water to easily and effectively turn. Thus, the heat transfer between the power module 1 and the cooling water flowing through the second to fourth straight line portions 521b to 521d is accelerated, and the second and third turn portions 522b and 522c easily and effectively turn the directions of the cooling water to the next straight line portion. Therefore, the power module 1 is effectively cooled down due to the wide surfaces of the fin portions 3 and the wall portions of the upper and lower cases 4 and 5 and also due to a large flow amount of the cooling water.

[0033] In this cooling operation, the power module 1 directly contacts with the heat exchanger 1 on the upper surface of the upper case 4, thereby its cooling efficiency being improved. In addition, since the fin portions 3 are formed on the upper case 4 as one unit by using the extrusion process method, its thermal conductivity is superior to an aluminum casting formed therewith, due to material properties. This enables the fin portions 3 to be simple in shapes thereof to ensure heat radiation performance, decreasing flow resistance of the cooling water running in the flow channel 21.

[0034] In the first embodiment, the fin portions 3 are formed on the main body 4a of the upper case 4 by using the extrusion process method, which enables the fin portions 3 to be formed thinner and to have closer intervals between the adjacent fin portions, compared to the aluminum casting. This decreases the flow resistance of the cooling water running in the flow channel 21, ensuring the radiation performance thereof.

[0035] In the heat exchanger 2 of the first embodiment, the upper case 4 and the lower case 5 are joined with each other by using the friction stir welding method, so that good water-tightness of the heat exchanger 2 can be obtained without troubles such as a crack caused at high temperature, an expansion and/or burst due to blowhole in a welding process, even when at least one of the upper case 4 and the lower case 5 is an aluminum casting. Incidentally, aluminum castings are obtained at low manufacturing costs and at a high productivity rate.

[0036] By using the friction stir welding method, joining and sealing can be obtained at the same time, which removes bolts and a seal member such as a packing, an O-ring or a liquid gasket, thereby decreasing parts and manufacturing man-hour. In addition, the friction stir welding method can suppress a temperature generated in a joining process and decrease portions exposed to a high temperature generated in the joining process. This can decrease thermal deformation to a negligible extend.

[0037] Next, a heat exchanger of a second embodiment according to the present invention will be described.

[0038] As shown in FIGS. 12 to 15, in the heat exchanger 2 of the second embodiment, fin portions 3 are provided on a main body 4a as one unit, extending in first to fourth straight line portions 521a to 521d and further partially in first to third turn portions 522a to 522c. In addition, the lower case 5 has first to third downward projecting portions 5c to 5e projecting from a lower surface of the lower case 5 at positions corresponding to the first to third turn portions 522a to 522c, respectively. The first to third downward projecting portions 5c to 5e correspond to a projecting turn portion of the present invention.

[0039] The first downward projecting portion 5c is located at the other side portion of the lower case 5, being provided therein with a first downward turn portion 523a as a part of the flow channel 21. The second downward projecting portion 5d is located at the one side portion, being provided therein with a second downward turn portion 523b as a part of the flow channel 21. The third downward projecting portion 5e is located at the other side portion, being provided therein with a third downward turn portion 523c as a part of the flow channel 21. The first to third downward turn portions 523a to 523c correspond to an enlarged turn portion of the present invention.

[0040] The bottom surfaces of the first to third downward turn portions 523a to 523c are lower than those of the first to fourth straight line portions 521a to 521d.

[0041] The fin portions 3 have the same heights at the first to third turn portions 522a to 522c as those at first to fourth straight line portions 521a to 521d. As shown in FIGS. 14 and 15, the heights "h" of the fin portions 3 is set to be smaller than the heights "H" between a lower surface of a main body 4a of an upper case 4 and a bottom surface of a lower case 5 so that parts of a flow channel 21 are formed between clearances therebetween to flow and turn the cooling water to the next straight line portion. The bottom surfaces are formed in such a way that it is gradually slanted downwardly at the first straight line portion side, being flat at an intermediate portion thereof, then being gradually slanted upward. Bottom surfaces of the second and third turn portions 522b and 522c are formed similarly to that of the first turn portion 522a.

[0042] The other parts and portions are similar to those of the first embodiment.

[0043] The operation and the advantages of the heat exchanger 2 of the second embodiment will be described.

[0044] The cooling water is supplied through an inlet port 53 into the first straight line portion 521a, then to the first straight line portion 522a. The fin portions 3 are provided in the first straight line portion 521a and the first turn portion 522a, so that wider heat-transfer surface areas can be obtained to improve a cooling efficiency of the heat exchanger 2. Through the bottom side clearances, namely the first to third downward turn portions 523a to 523c, of the first to third turn portions 522a to 522c, a sufficient amount of the cooling water can flow downward and then upward to the next straight line portion, thereby improving the cooling efficiency. Therefore, the heat exchanger 2 of the second embodiment can improve the cooling efficiency due to the wider heat-transfer surface area and the bottom side surfaces of the first to the third turn portions 522a to 522c, in addition to the advantages of the first embodiment.

[0045] Next, a heat exchanger of a third embodiment according to the present invention will be described.

[0046] As shown in FIGS. 16 and 17, in the heat exchanger of the third embodiment, a main body 4a of an upper case 4 is provided at its lower surface with a plurality of heat radiation portions at its portions corresponding to first to third turn portions 522a to 522c.

[0047] The heat radiation portions consist of first radiation portions 311 and second radiation portions 312 shaped in a plate as shown in FIG. 16, or alternatively they consist of circular column portions 321 as shown in FIG. 17. Incidentally, the first and second radiation portions 311 and 312 and the circular column portions 321 correspond to projecting pieces of the present invention.

[0048] In the former, the first and second radiation portions 311 and 312 are arranged to be inclined against a flow direction of the cooling water, and they are also arranged substantially perpendicular to each other, being offset in longitudinal and lateral directions of the upper case 4. The first and second radiation portions 311 and 312 are arranged in lines at predetermined intervals as indicted by lines 313 and 314. In the latter, the circular column portions 321 are arranged in lines at predetermined intervals as indicated by lines 323 and 324, being offset in the longitudinal and lateral directions. The other parts and portions are similar to those of the first embodiment.

[0049] The operation and advantages of the third embodiment will be described.

[0050] In the heat exchanger 2 having the heat radiation portions shown in FIG. 16, a cooling water entering an inlet port flows through a first straight portion, being heat-transferred through fin portions therein, and then it enters a first turn portion, where some of the cooling water flows straight, namely in the longitudinal direction, between the lines 313 and 314 and between other lines and the other flow in the lateral direction. This enables the cooling water to turn and also to be accelerated in heat transfer through the first and second radiation portions 311 and 312 in the first turn portion. The similar advantages can be also obtained in not-shown second and third turn portions of a flow channel.

[0051] Therefore, the heat exchanger of the third embodiment can obtain the advantage in accelerating the heat transfer between the cooling water and a power module through the fin portions in the straight line portions of the flow channel and the heat radiation portions in the turn portions of the flow channel, in addition to the advantages of the first embodiment.

[0052] Incidentally, in the first to third embodiments, the fin portions 3 may be formed by using a method of partially cutting off the surface of the main body 4a of the upper case 4 to rise therefrom as shown in FIG. 18, or by a method of crimping the surface of the main body 4a to form fin portions as shown in FIG. 19, or a method of ruffling the surface of the main body 4a and fixing fins 36 with brazing material or solder material as shown in FIG. 20. Further, the fin portions 3 may be formed to have a wave shape shown in FIG. 21 or a round corner, along the turn portion, shown in FIG. 22. In these modifications, a part of the fin portions are cut off to be received into the recess 5a of the lower case 5.

[0053] Next, a heat exchanger of a fourth embodiment according to the present invention will be described.

[0054] As shown in FIG. 23 to FIG. 25, the heat exchanger 2 of the fourth embodiment has an upper case 4 and a lower case 5 joined with the upper case 4. The upper case 4 is formed with a plurality of fin portions 3 on its lower surface as one unit, and the lower case 5 is formed with a recess 5a, which forms a part of a flow channel 21 for running cooling water and receives the fin portions 3 of the upper case 4 when the upper and lower cases 4 and 5 are joined with each other.

[0055] Specifically, at first the fin portions 3 are formed on a main body 4a of the upper case 4 as one unit similarly to those shown in FIG. 6, an then the fin portions 3 corresponding to a center portion and first to third turn portions 522a to 522c of the flow channel 21 are cut off similarly to the first embodiment as shown in FIG. 26 and FIG. 27 before the upper and lower case 4 and 5 are joined, while the rest thereof are inserted into first to fourth straight line portions 521a to 521d of the flow channel 21. The first to fourth straight line portions 521a to 521d and the first to third turn portions 522a to 522c are constructed similarly to those of the first embodiment.

[0056] As shown in FIG. 24, FIG. 25, FIG. 28 and FIG. 29, the lower case 5 is provided with a first projecting portion 5c at one end portion with an inlet port 53 and an outlet port 54, a second projecting portion 5d and a third projecting portion 5e at the other end of the lower case 5. The first to third projecting portions 5c to 5e are projected downward from a lower surface of the lower case 5, and they are formed therein with recesses forming first to third downward turn portions 523a to 523c as parts of the flow channel 21, respectively.

[0057] The first downward turn portion 523a of the first projecting portion 5c is fluidically communicated with the first turn portion 522a, the second downward turn portion 523b of the second projecting portion 5d is fluidically communicated with the second turn portion 522b, and the third downward turn portion 523c of the third projecting portion 5e is fluidically communicated with the third turn portion 522c. The first to third downward turn portions 523a to 523c are fluidically connected with the straight line portions 521a, 521b, 521c and 521d by a perpendicular step.

[0058] As shown in FIG. 30, depth "B" at the downward turn portion 523a, 523b, 523c is set to be larger than that at the straight line portion 521a, 521b, 521c, 521d. An outer end side wall portion, defining the first to third downward turn portions 523a to 523c, of the projecting portions 5c, 5d, 5e is on the same plane as that, defining the flow channel 21, of the turn portion 522a, 522b, 522c. An inner end side wall portion, defining the downward turn portion 523a, 523b, 523c, of the projecting portion 5c, 5d, 5e is overlapped by several millimeters "d" with an outer end portion of the fin portion 3. Depth of the downward turn portion 523a, 523b, 523c (= the depth "B" at the downward turn portion 5c, 5d, 5e - a depth "A" at the turn portion 522a, 522b, 522c) is set to be larger than a width "C" of the downward turn portion 523. In this embodiment, (B - A) / C is set to be approximately three. Each of the downward turn portion 523a, 523b and 523c is provided with a first slanted portion 524a at its inlet side, and a second slanted portion 524b at its outlet side as shown in FIG. 31. The first and second slanted portions 524a and 524b extend and are slanted along a lateral direction of the lower case 5.

[0059] Therefore, as shown in FIG. 31, after the cooling water runs strait in the straight line portion 521a of the flow channel 21 as indicated by an arrow 101, it turns its flow direction downward into the first downward turn portion 523a, as indicated by an arrow 102, at the turn portion 522a. Then it runs obliquely downward along the first slanted portion 524a as indicated by an arrow 103, changing its direction horizontally at a bottom of the first downward turn portion 523a as indicated by an arrow 104. The cooling water goes obliquely upward along the second slanted portion 524b as indicated by an arrow 105, then moving up as indicated by an arrow 106. Then the cooling water changes its direction to flow along the second straight line portion 521b. The cooling water flows in the second to fourth straight line portions 521b to 521d and the second to thirds turn portions 522b and 522c similarly to in the first straight line portion 521a and the first turn portion 522a, respectively.

[0060] In the first to third downward turn portions 523a to 523c of the first to third turn portions 522a to 523, some of the cooling water flows through clearances formed between the outer end portions of the fin portions 3 and the inner wall portion of the turn portions 5c to 5e, and the rest thereof flows through the fist to third downward turn portions 523a to 523c.

[0061] Therefore, the heat exchanger 2 of the fourth embodiment has the following advantages in addition to those of the first embodiment.

[0062] A sufficient amount of the cooling water can flow through the flow channel 21 without increasing a longitudinal length of the turn portions 522a to 522c. Therefore, it is advantageous for the heat exchanger 2 to be installed on a motor vehicle when a power module to be cooled has a large cooling area, because the heat exchanger does not need its long portion projecting from the power module. The cooling area of the power module becomes large because of many chips and others of the power module in a case where it supplies electric power to three-phase motor. For example, the power module needs two IGBT chips (including twelve Insulated Gate Bipolar Transistors and twelve Fast Recovery Diodes) or three IGBT chips (including 18 Insulated Gate Bipolar Transistors and 18 Fast Recovery Diodes) in order to increase output power thereof, which causes the cooling area of the power module to become larger.

[0063] In addition, the first and second slanted portions 524a and 524b of the turn portion 522a, 522b, 522c can smoothly flow the cooling water in the turn portions 522a, 522b and 522c, suppressing flow loss generated therein.

[0064] Further, the fin portions 3 extend at positions partially overlapping with the first to third downward turn portions 523a to 523c, which enables the cooling water to start to flow downward in the first to third downward turn portions 523a to 523c before it runs over the end portions of the fin portions 3. Therefore, the cooling water can also smoothly flow in the turn portions 522a, 522b and 52c, with the flow loss being suppressed.

[0065] Next a heat exchanger of a fifth embodiment according to the present invention will be described.

[0066] As shown in FIG. 32 to FIG. 34, the heat exchanger 2 of the fifth embodiment has an upper case 4, formed with fin portions 3, and a lower case 5, coupled with the upper case 4 and formed with a recess 5a for receiving the fin portions 3. The fin portions 3 are formed on a main body 4a of the upper case 4 as one unit, and then a part thereof is cut off so as to be insertable into the recess 5a, similarly to the first embodiment.

[0067] The recess 5a forms a part of a flow channel 21 which includes first to fourth straight line portions 521a to 521d and first to third turn portions 522a to 522c. The first to third turn portions 522a to 522c are provided continuously with first to third downward turn portions 525a to 525c formed in first to third downward projecting portions 5c to 5e that project downward from the lower surfaces thereof. The first to third downward turn portions 525a to 525c correspond to the enlarged turn portion of the present invention.

[0068] As shown in FIG. 34 and FIG. 35, Each of the first to third downward turn portions 525a to 525c is provided on its inner surface forming a part of the flow channel 21 with a third slanted portion 526 that extends and is gradually slanted downward along a longitudinal direction of the lower case 5. The depth of the downward turn portion 525a, 525b, 525c is set to be smaller than that of the fourth embodiment, and a partially overlapped portions of the fin portions 3 and the flow channel 21 of the downward turn portion 525a, 525b, 525c is set to be longer than that of the first embodiment, for example the overlapped portions is from more than ten millimeters and to several tens of millimeters.

[0069] In the fifth embodiment, the cooling water, flowing through the first straight line portion 521a as indicated by an arrow 201 in FIG. 35, flows downward along the third slanted portion 526 toward the bottom of the downward turn portion 525a, 525b, 525c in the longitudinal direction of the lower case 5 as indicated by an arrow 202. It turns its flow direction and runs in the lateral direction of the lower case 5 as indicated by an arrow 203, and then it turns its direction again to go up along the third slanted portion 526 toward the second straight line portion 521b as indicated by an arrow 204. The cooling water flows in a direction opposite to a flow direction in the first straight line portion 521a as indicated by an arrow 205. It flows at the other straight line portions 521c and 521d and the other turn portions 522b and 522c similarly to at the firs and second straight portions 521a and 521b and the first turn portion 522a.

[0070] Therefore, the heat exchanger 2 of the fifth embodiment has the following advantages in addition to those of the first embodiment.

[0071] A sufficient amount of the cooling water can flow through the flow channel 21 without increasing a longitudinal length of the turn portions 522a to 522c. Therefore, it is advantageous for the heat exchanger 2 to be installed on a motor vehicle when a power module to be cooled has a large cooling area, because the heat exchanger does not need its long portion projecting from the power module.

[0072] In addition, the third slanted portion 526 of the turn portion 522a, 522b, 522c can smoothly flow the cooling water in the turn portions 522a, 522b and 522c, suppressing flow loss generated therein.

[0073] Further, the fin portions 3 extend at positions partially overlapping with the first to third downward turn portions 525a to 525c, which enables the cooling water to start to flow downward in the downward turn portions 523 before it runs over the end portions of the fin portions 3. Therefore, the cooling water can also smoothly flow in the turn portions 522a, 522b and 522c, with the flow loss being suppressed.

[0074] Next, a heat exchanger of a sixth embodiment according to the present invention will be described.

[0075] In this sixth embodiment, a flow channel is simplified to have only two straight line portions where flow medium runs at faster speed relative to speeds in the first to fifth embodiments.

[0076] As shown in FIGS. 36 to 40, a lower case 5 has the flow channel 21, mainly consisting of the first straight line portion 521a, the second straight line portion 521b and a turn portion 522a. At one end portion of the lower case 5 is provided with an inlet portion 53, communicating with one end portion of the first straight line portion 521a, and an outlet portion 54, communicating with one end portion of the second straight portion 521b. The turn portion 522a is provided at the other end portion of the lower case 5 to communicate with the other end portions of the first and second straight line portions 521a and 521b.

[0077] The lower case 5 is formed with a fourth downward projecting portion 5f and a sixth projecting portion 5h, which are projected downward from a bottom surface of the lower case 5 at portions corresponding to the one end portions of the first and second straight line portions 521a and 521b, respectively. A fifth downward projecting portion 5g is formed to project downward from the bottom surface of the lower case 5 at a portion corresponding to the other end portions of the first and second straight line portions 521a and 521b.

[0078] The fourth to sixth downward projecting portions 5 f to h are provided therein with recesses to form forth to sixth downward turn portions 523d that constitute a part of the flow channel 21, respectively. As shown in FIGS. 36, 39 and 40, the forth to sixth downward turn portions 523d are deeper than bottom surfaces of the first and second straight line portions 521a and 521b. The inlet port 53 and the outlet port 54 face lower side portions of the forth and sixth downward turn portions 523d and 523f, respectively. The fifth downward turn portions 523e is formed at a lower part of the turn portion 522a, and an intermediate portion thereof is narrowed in a longitudinal direction of the lower case 5 due to formation of an inward projecting portion 510 formed on the end portion of the lower case 5 as shown in FIG. 36 and FIG. 40. The inward projecting portion 510 extends from an upper portion to a bottom portion of the downward turn portion 522a. The inward projecting portion 510 corresponds to a speed-distribution changing means of the present invention.

[0079] On the other hand, as shown in FIG. 42, an upper case 4 is provided with a plurality of radiation fin portions 3, arranged in two rows corresponding to the first and second straight line portions of the lower case 4. The radiation fin portions 3 are formed by using an extrusion process method so that they extend in a longitudinal direction of the upper case 4 from one end portion to the other end portion of a main body 4a of the upper case 4 as shown in FIG. 43, and then both end portions of the fin portions 3 are cut off as shown in FIG. 42. The end portion of the fin portions 3 are extended at intermediate portions of the fourth to sixth downward turn portions 523d to 523f as indicated by dot lines (of the fin portions 3) in FIG. 36.

[0080] The other portions and parts are constructed similarly to those of the first embodiment.

[0081] In the heat exchanger of the sixth embodiment, the flow medium is supplied at high speed to the first straight line portion 521a through the inlet port 53. The fin portions 3 in the first straight line portion 521 draw heat from a power module through the upper case 4 to give the heat to the flow medium. The flow medium, reaching the turn portion 522a through the end portion of the first straight line portion 521a, is turned its flow direction toward downward to be moved into the downward the fifth turn portion 523a due to the existence of extended portions of the fin portions 3, and then it moves toward the second straight line portion 521b. In this movement, flow speed of the flow medium becomes higher at portions near a central wall portion 511 than at portions distant therefrom. This may cause peak speed of a speed distribution of the flow medium in the turn portion 522a to be slanted toward the central wall portion 511 at the first straight line portion 521a side and at the second straight line portion 521b. Consequently, the flow speed of the flow medium that runs in the second straight line portion 521b becomes lower at its outer side portions thereof relative to that at its inner side thereof, deteriorating its heat exchange efficiency.

[0082] However, the inner projecting portion 510 disturbs flow movement of the flow medium, entering the turn portion 522a, at the inner side so as to suppress the flow speed thereof, thereby changing speed distribution of the flow medium so that it can come to be flat as possible after the flow medium runs through the inner projecting portion 510.

[0083] Then, the flow medium goes upward toward the second straight line portion 521b after passing through the inner projecting portion 510, flowing in the second straight line portion 521b with the flatter speed distribution thereof. This efficiently cools the power module. Then, the flow medium is discharged through the outlet port 54.

[0084] The heat exchanger of the sixth embodiment has the following advantage in addition to those of the first to third embodiments.

[0085] In the heat exchanger of the sixth embodiment, the lower case 5 is provided with the inner projecting portion 510 at the turn portion 522a, which suppresses the peak speed of the flow medium at the inner side to change the speed distribution thereof to be close to a flat one as possible after it passes through the inner projecting portion 510. This can improve the heat exchange efficiency and decrease the size of the heat exchanger.

[0086] While there have been particularly shown and described with reference to preferred embodiments thereof, it will be understood that various modifications may be made therein.

[0087] In the embodiments, the fin portions 3 are formed on the main body 4a of the upper case 4 from the one end portion to the other end portion of the main body 4a before they are partially cut off, while the fin portions 3 may be formed without their outer peripheral portions from the beginning as shown in FIG. 36. In this case, the fin portions can be formed easily and at low manufacturing costs by using the extrusion process method.

[0088] The speed-distribution changing means may be a flat plate or others as long as it can suppress the peak speed of the flow medium at the turn portion so that the speed distribution of the flow medium can come to be close to a flat one after the flow medium passes through the speed-distribution changing means.

[0089] In the embodiments described above, although the heat exchangers use the cooling water to cool an object such as the inverter, the cooling water may be replaced with other cooling medium different from water. In addition, the heat exchanger may use a hot water and the like as the flowing medium so as to warm an object.

Claims

1. A heat exchanger (2) comprising:

   a first member (4) which is provided with a main body (4a) and a heat transfer accelerating portion (3) formed on the main body (4a) as one unit; and
   a second member (5) which is formed with a recess (5a) indented from a reference surface (51) and functioning as a flow channel (21), wherein
   the first member (4) and the second member (5) are joined with each other at the reference surface (51) in a state where a part, which deviates from the recess (5a) when the first and second members (4, 5) are joined, of the heat transfer accelerating portion (3) of the first member (4) is cut off and the rest of the heat transfer accelerating portion (3) is inserted into the recess (5a) of the second member (5).

2. The heat exchanger (2) according to claim 1, wherein the flow channel (21) has at least two straight line portions (521a to 521d) parallel to each other and at least one turn portion (522a to 522c) which fluidically communicates end portions of the straight line portions (521a to 521d), and wherein
   a portion, corresponding to the turn portion (522a to 522c), of the heat transfer accelerating portion (3) is cut off.

3. The heat exchanger (2) according to claim 1, wherein the flow channel (21) has a plurality of straight line portions (521a to 521d) parallel to each other and at least one turn portion (522a to 522c) which fluidically communicates end portions of the straight line portions (521a to 521d), and wherein
   a flow depth (H), of the turn portion (522a to 522c), form the reference surface (51) is set to be larger than a height (h), of the heat transfer accelerating portion (3), from the heat-transfer-accelerating-portion side surface of the main body (4a).

4. The heat exchanger (2) according to any one of claims 1 to 3, wherein
   the first member (4) and the second member (5) are joined with each other by using a friction stir welding method.

5. The heat exchanger (2) according to any one of claims 1 to 4, wherein
   at least the second member (5) is an aluminum casting.

6. The heat exchanger (2) according to any one of claims 1 to 5, wherein
   a surface, opposite to the heat transfer accelerating portion (3), of the first member (4) is one of a cooling surface and a warming surface.

7. The heat exchanger (2) according to any one of claims 1 to 6, wherein
   the flow channel (21) has a plurality of straight line portions (521a to 521d) parallel to each other and at least one turn portion (522a to 522c) which fluidically communicates end portions of the straight line portions (521a to 521d), and wherein
   the heat transfer accelerating portion (3) has a plurality of projecting pieces (311, 312; 321, 322), in the turn portion (522a to 522c), which rise from the main body (4a) and allows a flowing medium to flow straight and turn directions thereof.

8. The heat exchanger (2) according to claim 3, wherein the turn portion (522a to 522c) has a projecting turn portion (5c, 5d, 5e) that projects in a direction opposite to the reference surface (51) side and has an enlarged turn portion (523a to 523c; 525a to 525c) forming a part of the flow channel (21) so that a cooling medium flowing through the straight line portion (521a to 521d) can turn toward the adjacent straight line portion (521a to 521d) and in the opposite direction.

9. The heat exchanger (2) according to claim 8, wherein the straight line portion (521a to 521d) and the enlarged turn portion (523a to 523c; 525a to 525c) are fluidically connected by a perpendicular step.

10. The heat exchanger (2) according to claim 8 or claim 9, wherein
    the enlarged turn portion (523a to 523c; 525a to 525c) has a slanted portion (524a, 524b; 526) fluidically connected with the straight line portion (521a to 521d).

11. The heat exchanger (2) according to claim 10, wherein
    the slanted portion (524a, 524b) is slanted along a direction perpendicular to the straight line portion (521a to 521d).

12. The heat exchanger (2) according to claim 10, wherein
    the slanted portion (526) is slanted along a direction of the straight line portion (521a to 521d).

13. The heat exchanger (2) according to any one of claims 8 to 12, wherein
    a corner, perpendicular to the straight line portion (521a to 521d), of the turn portion (522a to 522c) is chamfered.

14. The heat exchanger (2) according to any one of claims 8 to 13, wherein

a part of the enlarged turn portion (523a to 523c; 525a to 525c) is partially overlapped with the heat transfer accelerating portion (3).

15. The heat exchanger (2) according to any one of claims 1 to 14, wherein
the heat transfer accelerating portion is a plurality of fin portions (3).

16. The heat exchanger (2) according to any one of claims 1 to 15, wherein
the heat transfer accelerating portion is fin portions (3) that extends straight and parallel to each other.

17. The heat exchanger (2) according to any one of claims 1 to 16, wherein
the heat transfer accelerating portion (3) is formed by using an extrusion process method.

18. The heat exchanger according to any one of claims 2 to 17, wherein
the turn portion (522a, 522b) is provided with a speed-distribution changing means (510) that suppresses a peak speed of flow medium running through the flow channel (21) to change speed distribution thereof so as to close to be a flat speed distribution after the flow medium passes through the speed-distribution changing means (510).

19. A heat exchanger (2) manufacturing method comprising the steps of:

preparing blocks to be a first member (4) and a second member (5);
forming a heat transfer accelerating portion(3) on a main body (4a) of the first member (4) as one unit so that the heat transfer accelerating portion (3) projects from the main body (4a);
forming a recess (5a) in the second member (5) so that the recess (5a) is indented from a reference surface (51) of the second member (5) and forms a part of a flow channel (21);
cutting off a portion, deviating from the flow channel (21) when the first and second members (4, 5) are joined, of the heat transfer accelerating portion (3); and
joining the first member (4) and the second member (5) with each other at the reference surface (51) of the second member (5).

20. The heat exchanger (2) manufacturing method according to claim 19, wherein
the heat transfer accelerating portion (3) is formed on the main body (4a) by using an extrusion process method.

21. The heat exchanger (2) manufacturing method according to claim 19 or claim 20, wherein
the flow channel (21) has a plurality of straight line portions (521a to 521d) parallel to each other and at least one turn portion (522a to 522c) which fluidically communicates end portions of the straight line portions (521a to 521d), and wherein
the heat transfer accelerating portion is fin portions (3) that extends straight over the straight line portion (521a to 521d) and parallel to each other.

FIG. 1

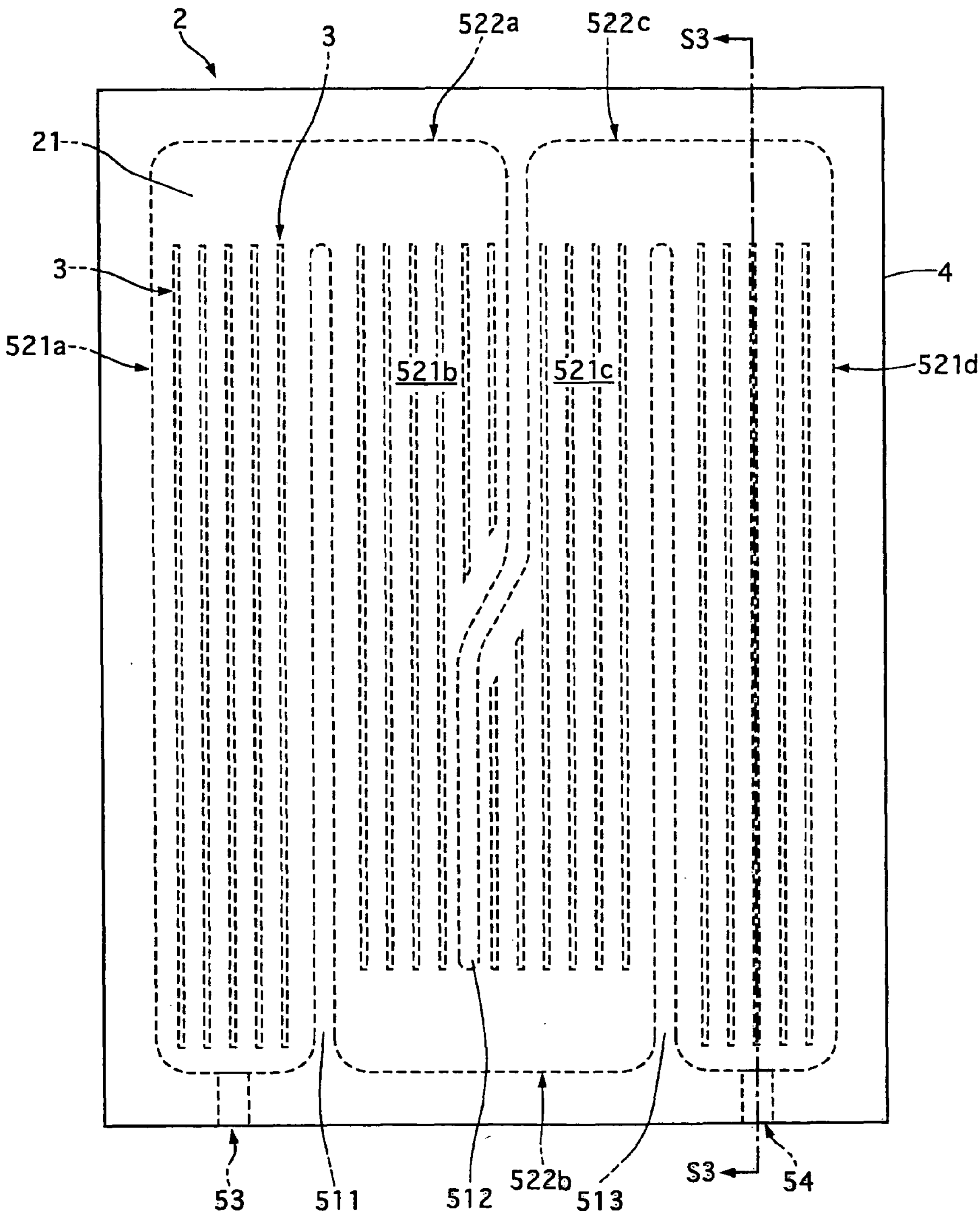

2
3
522a
522c
S3
21
3
4
521a
521b
521c
521d
53
511
512
522b
513
S3
54

FIG. 2

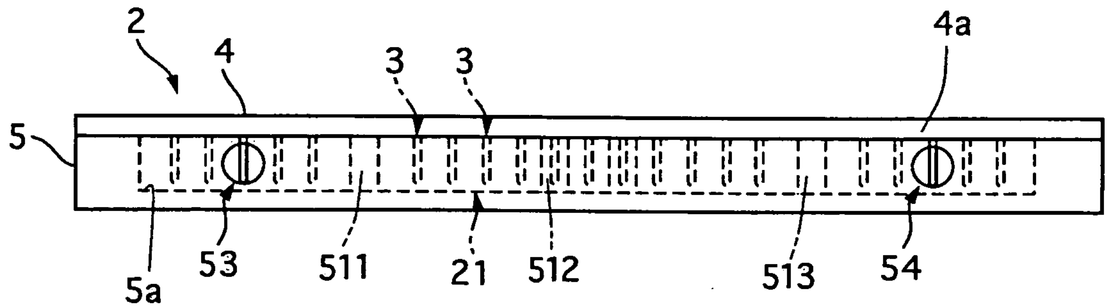
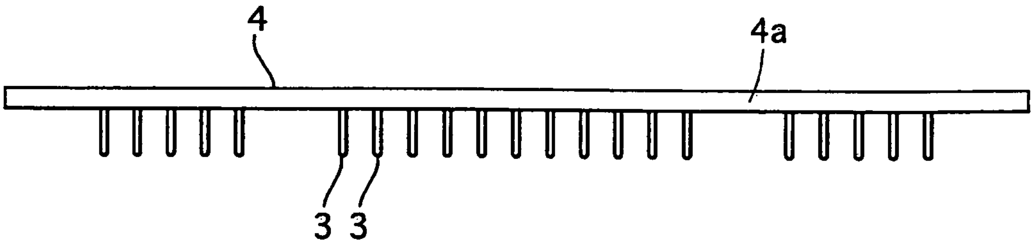


FIG.5



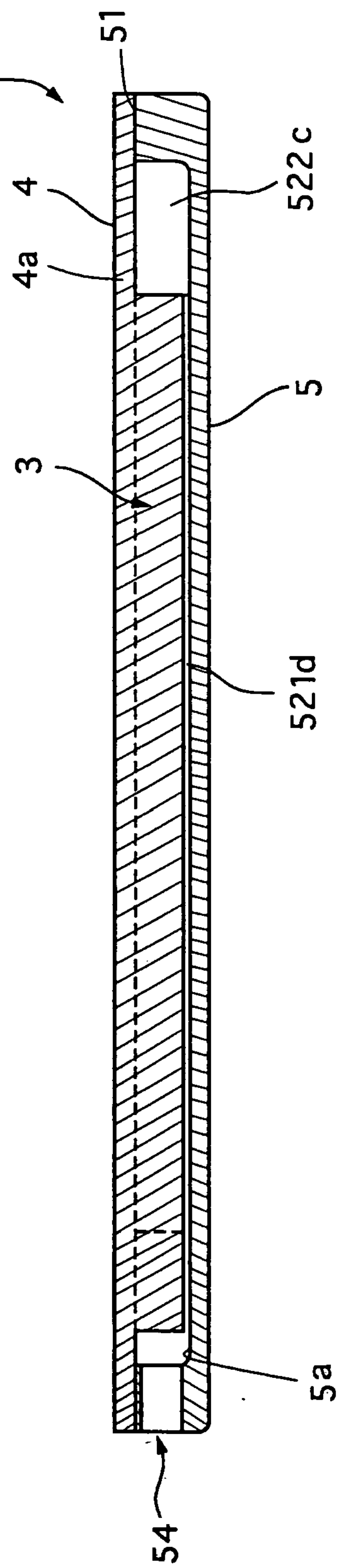


FIG. 3

FIG. 4

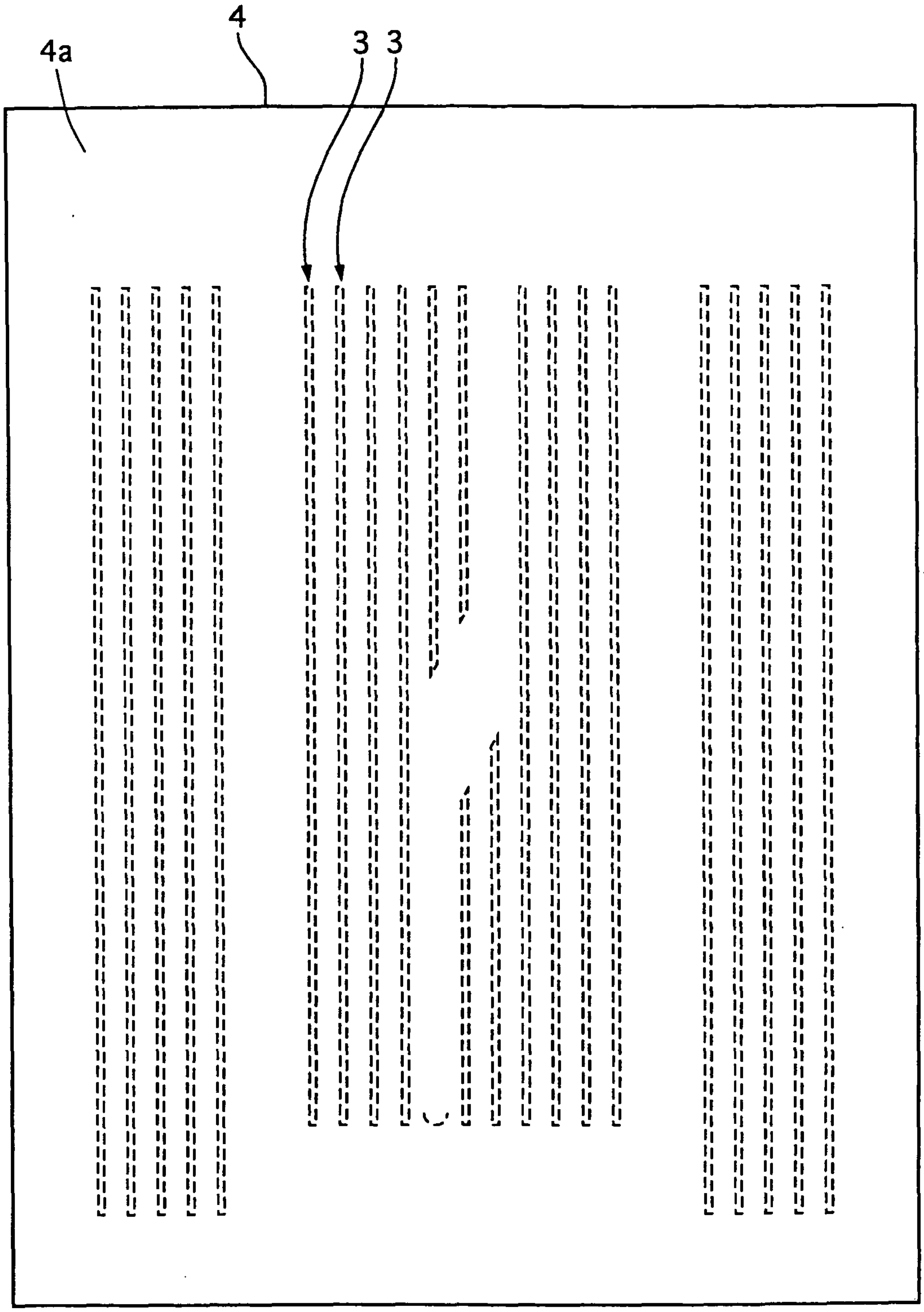


FIG. 6

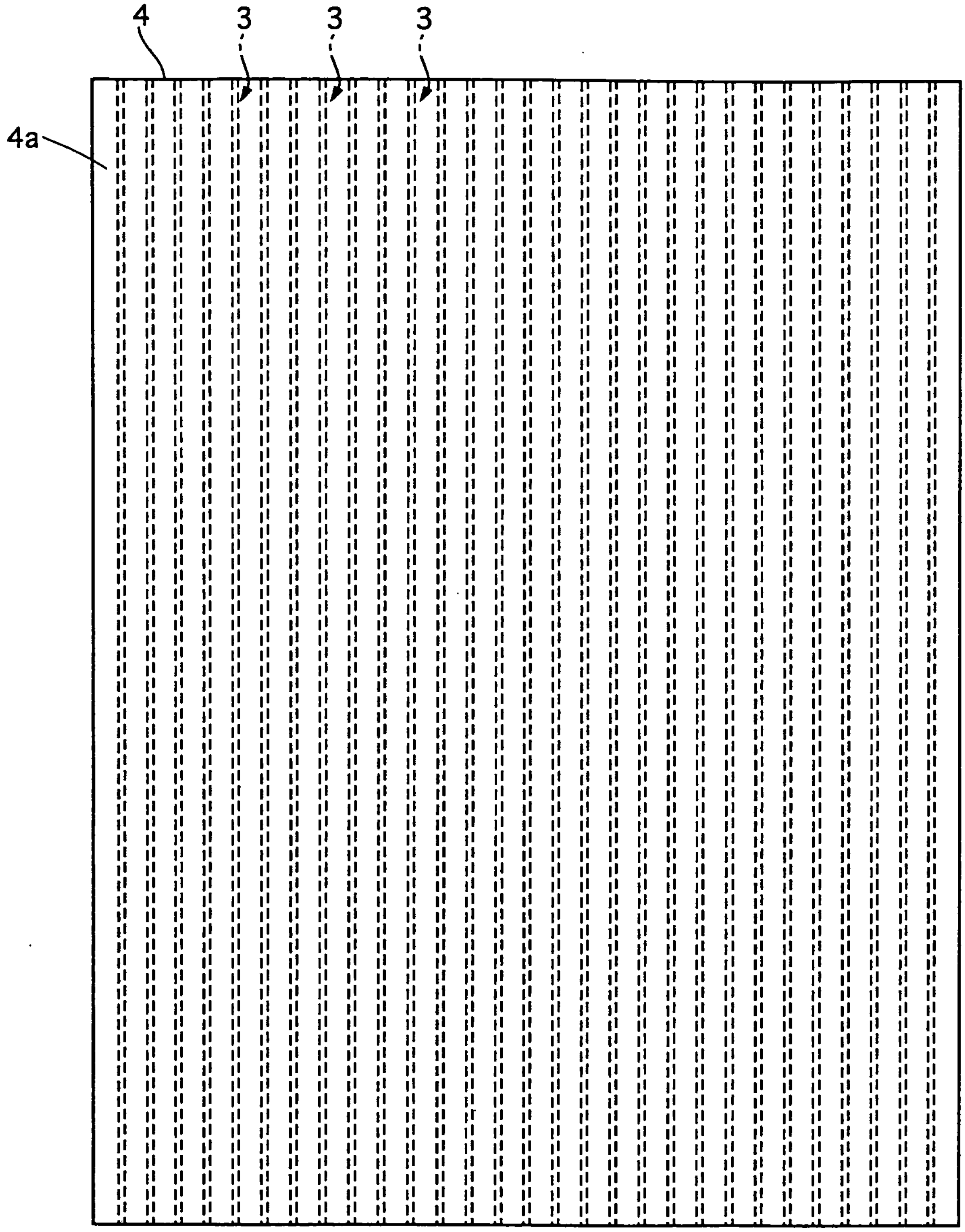


FIG. 7

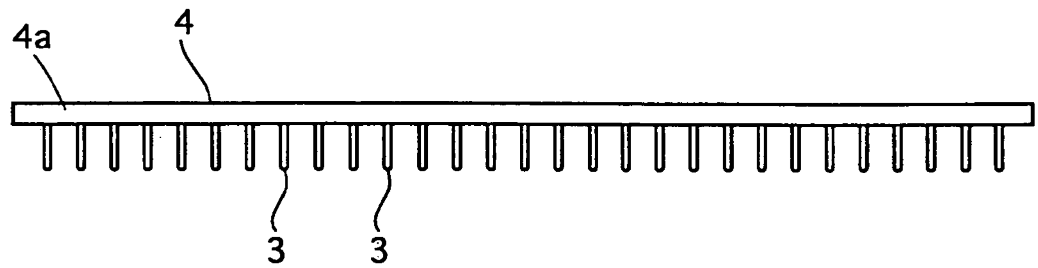


FIG. 9

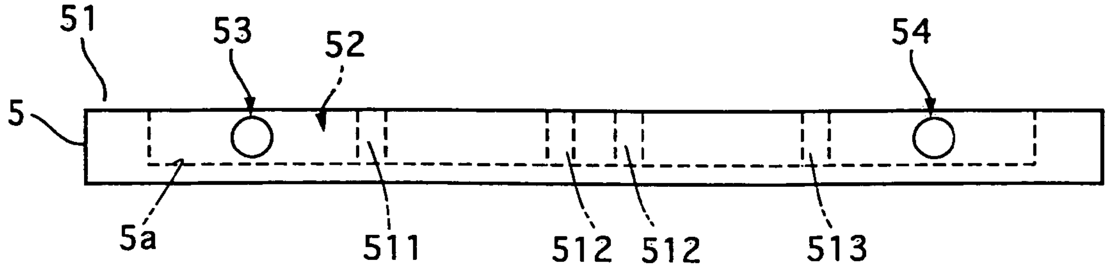


FIG. 8

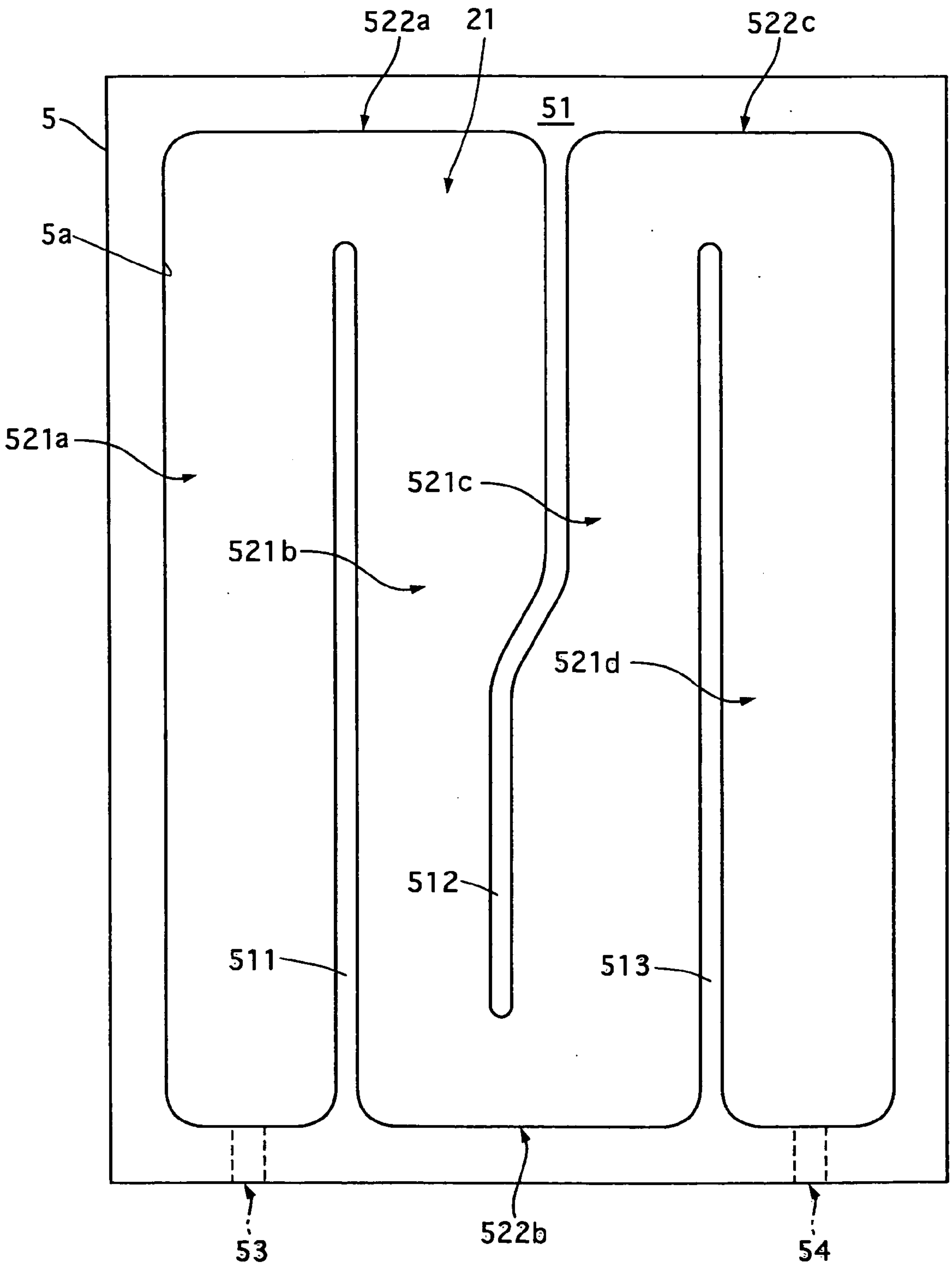


FIG. 10

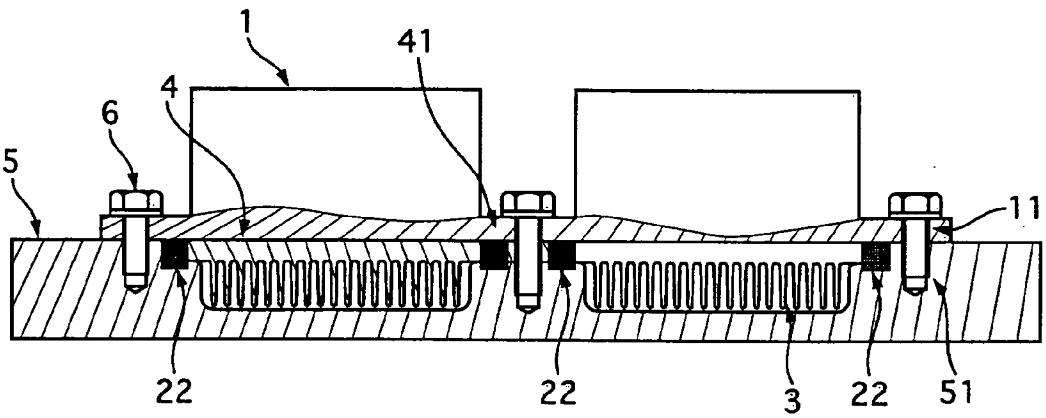


FIG. 11

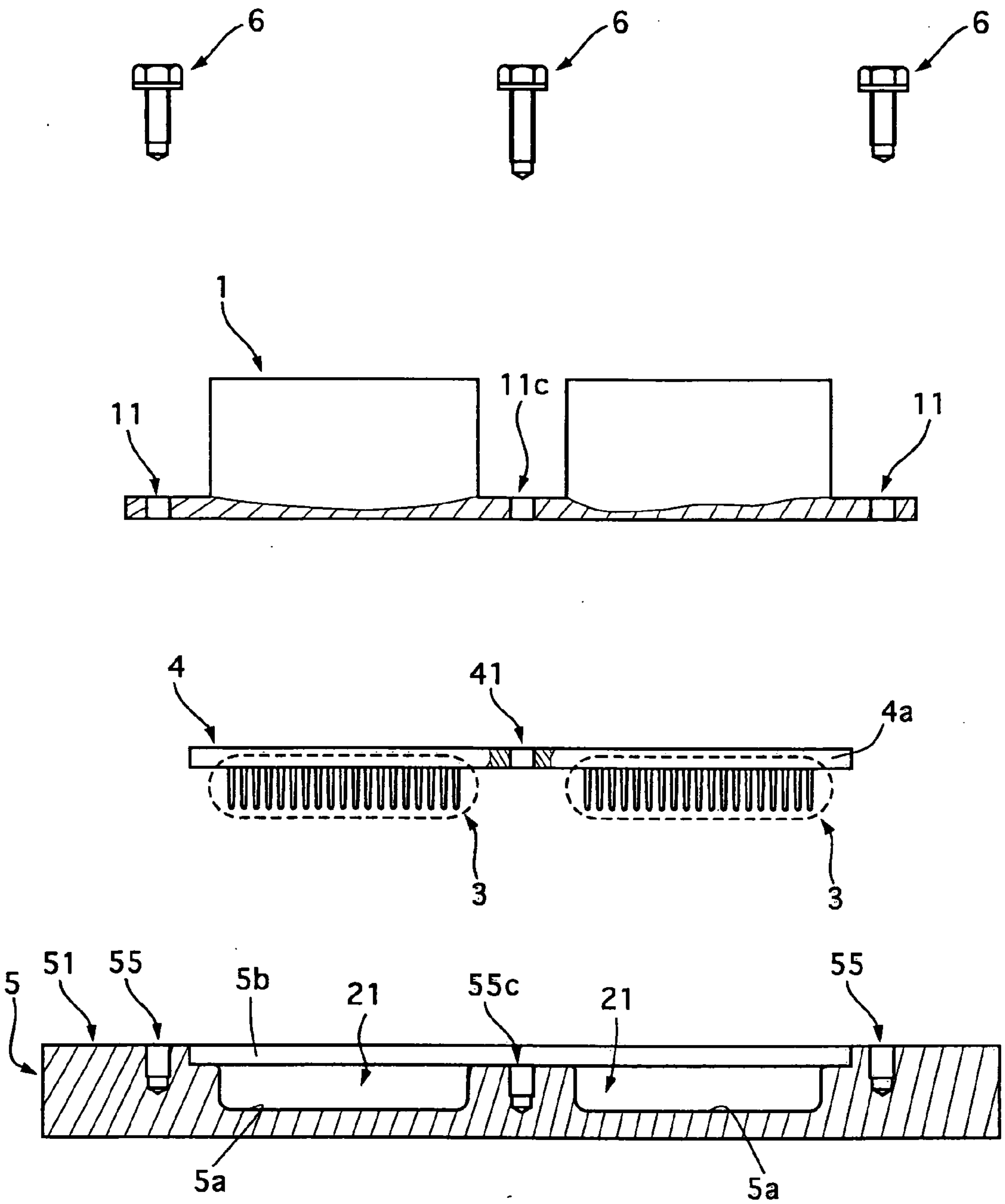


FIG. 12

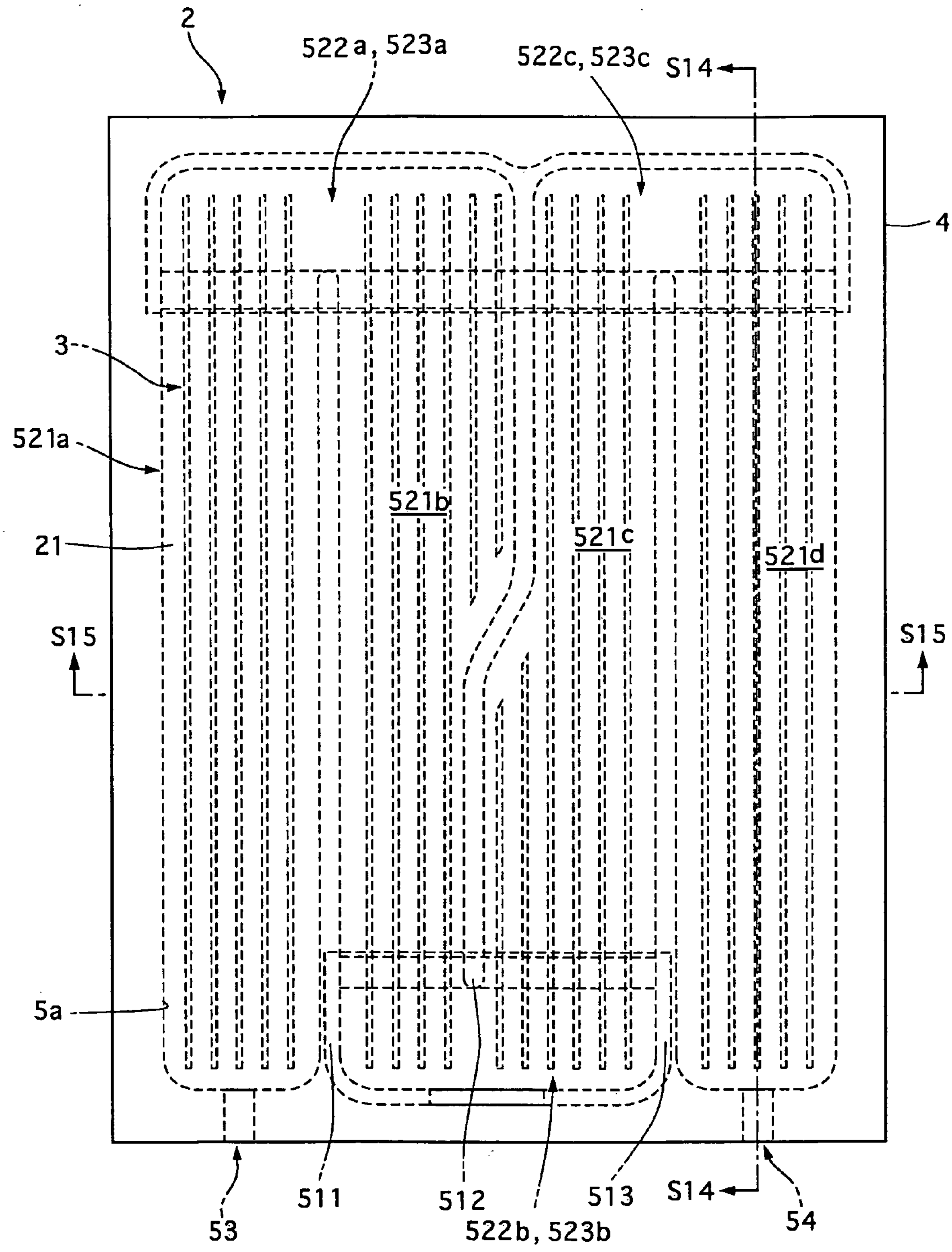

2
522a, 523a
522c, 523c
S14
4
3
521a
21
521b
521c
521d
S15
S15
5a
53
511
512
522b, 523b
513
S14
54

FIG. 13

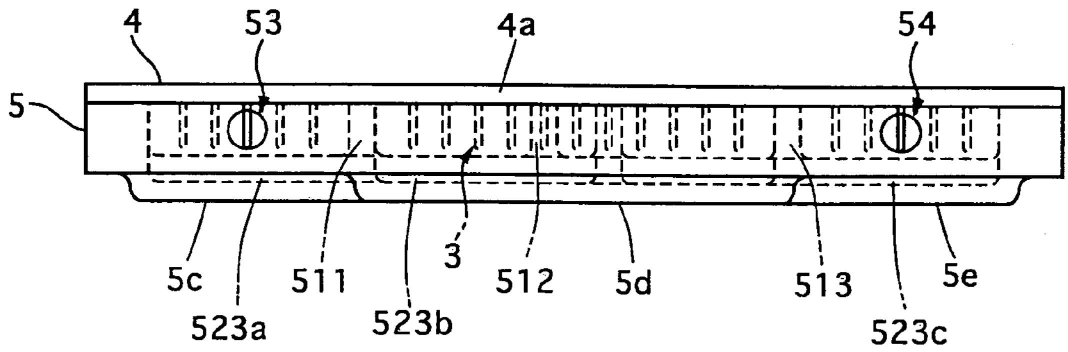
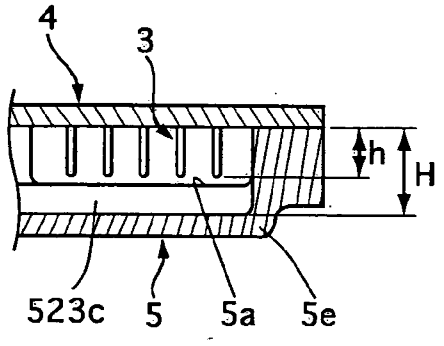


FIG. 15



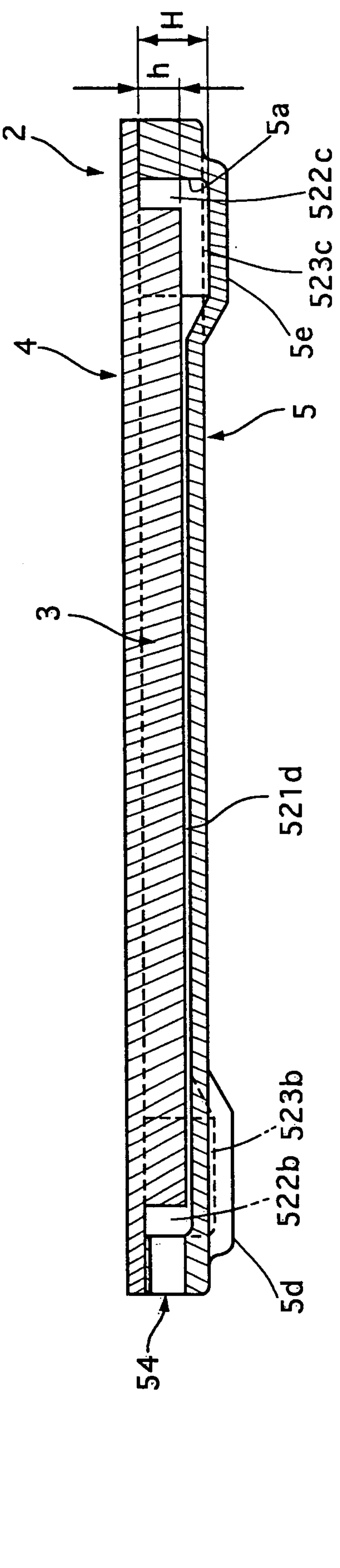


FIG. 14

FIG. 16

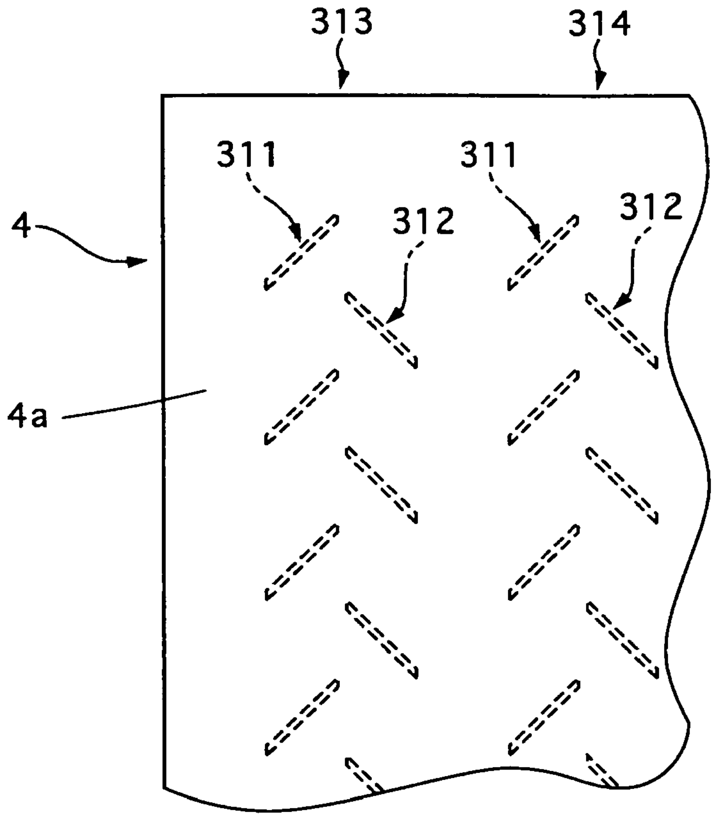


FIG. 17

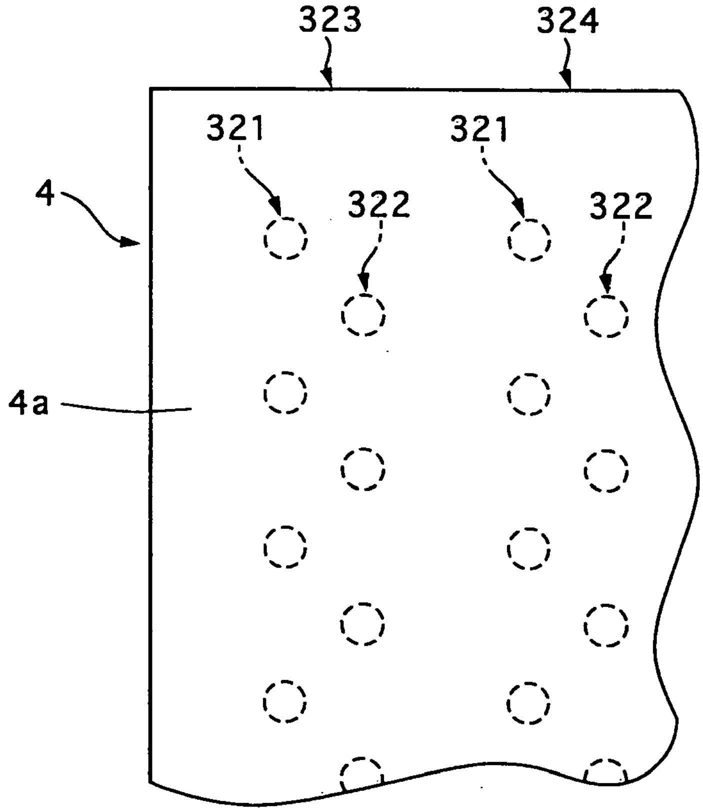


FIG. 18

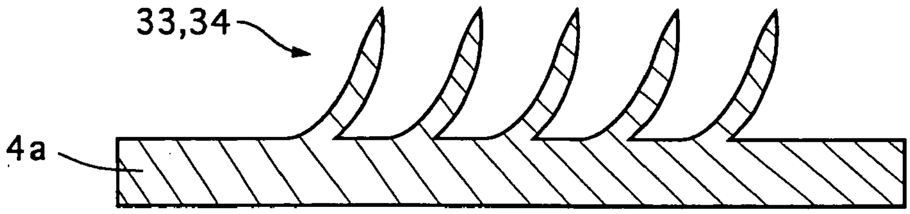


FIG. 19

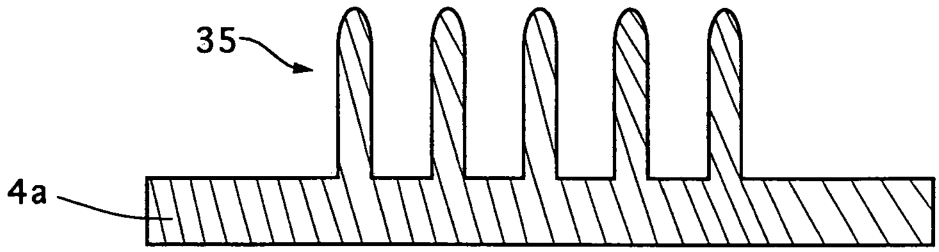


FIG. 20

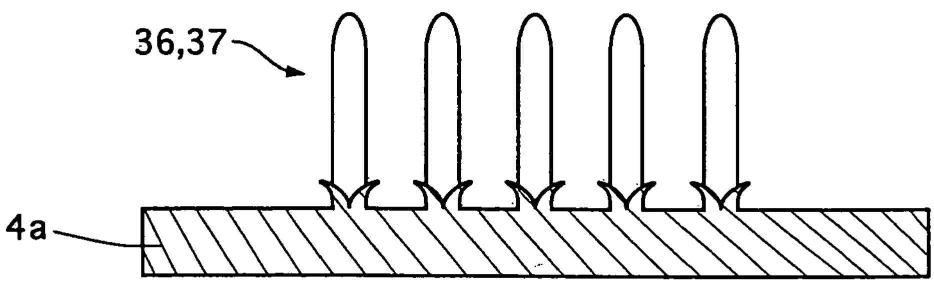


FIG. 21

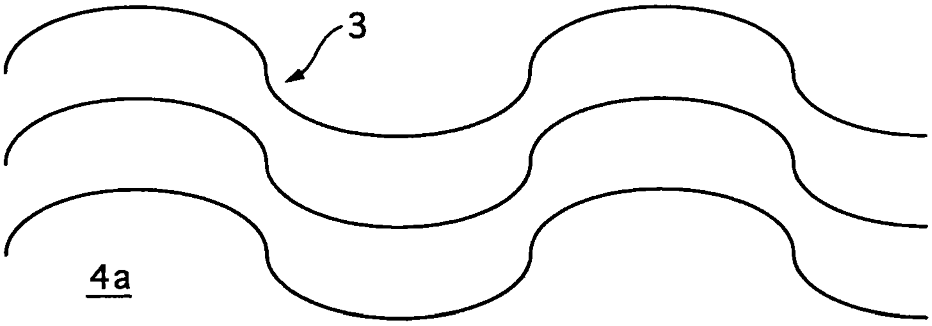


FIG. 22

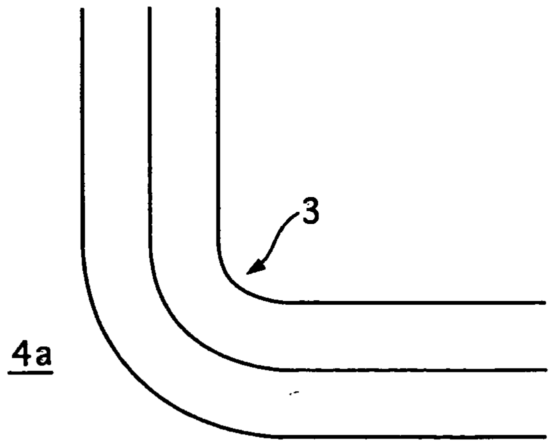
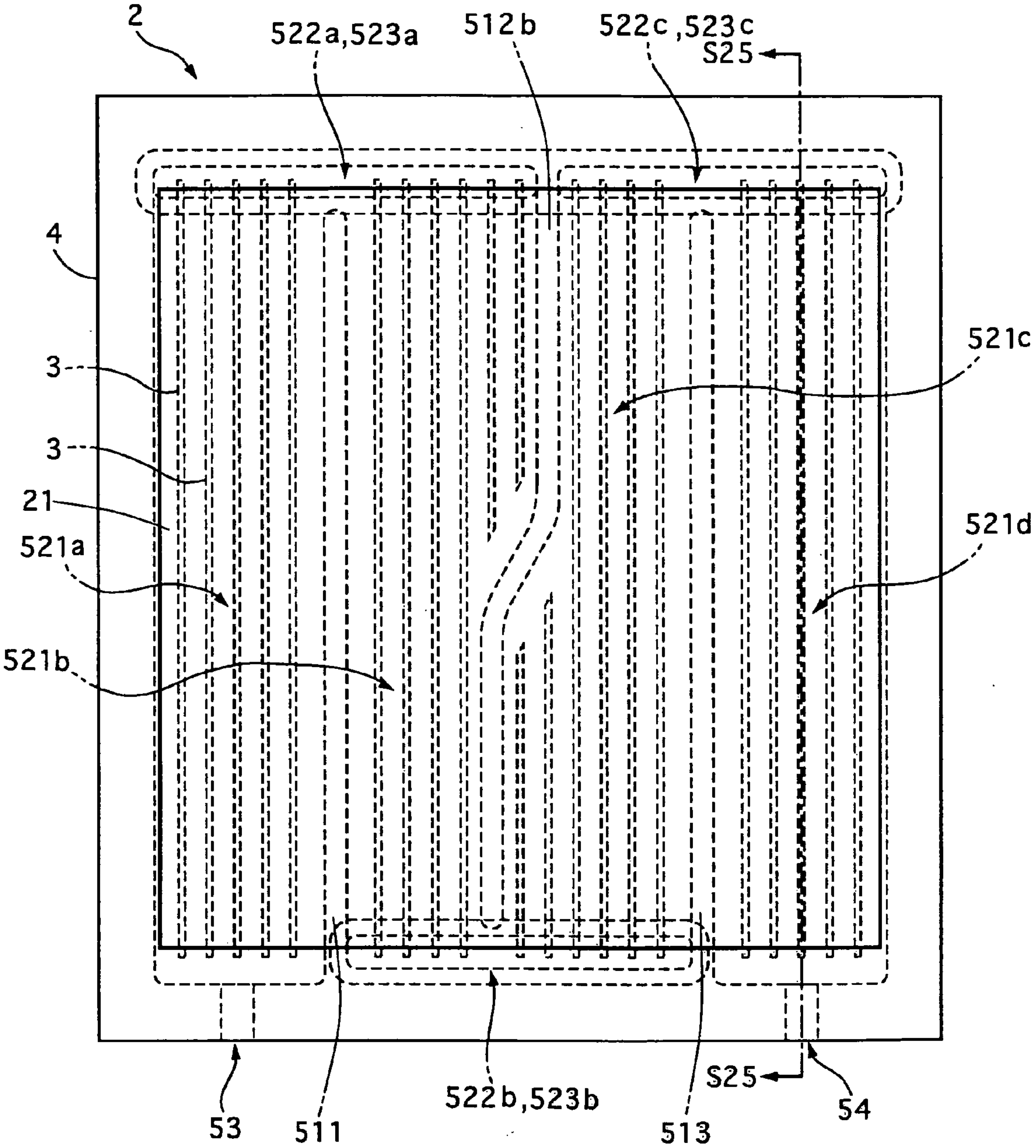
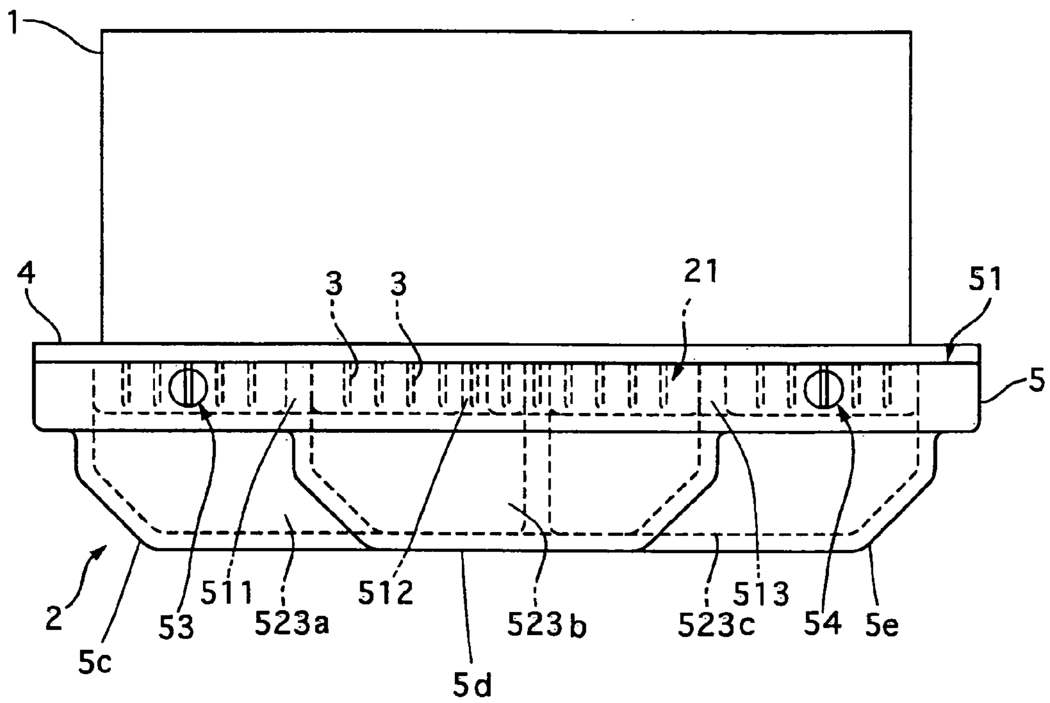


FIG. 23



2
522a,523a
512b
522c,523c
S25
4
521c
3
3
21
521d
521a
521b
S25
53
511
522b,523b
513
54

FIG. 24



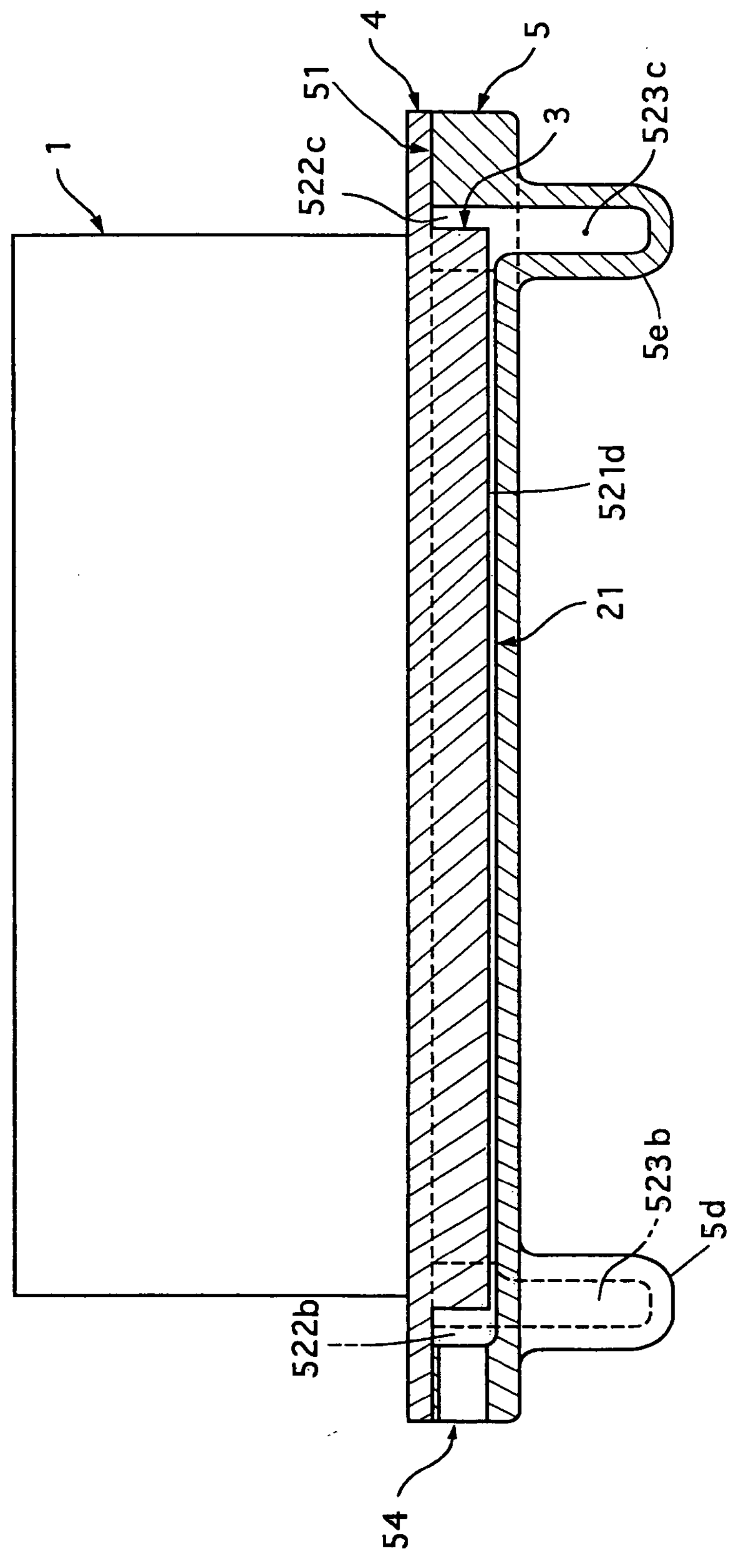


FIG. 25

FIG. 26

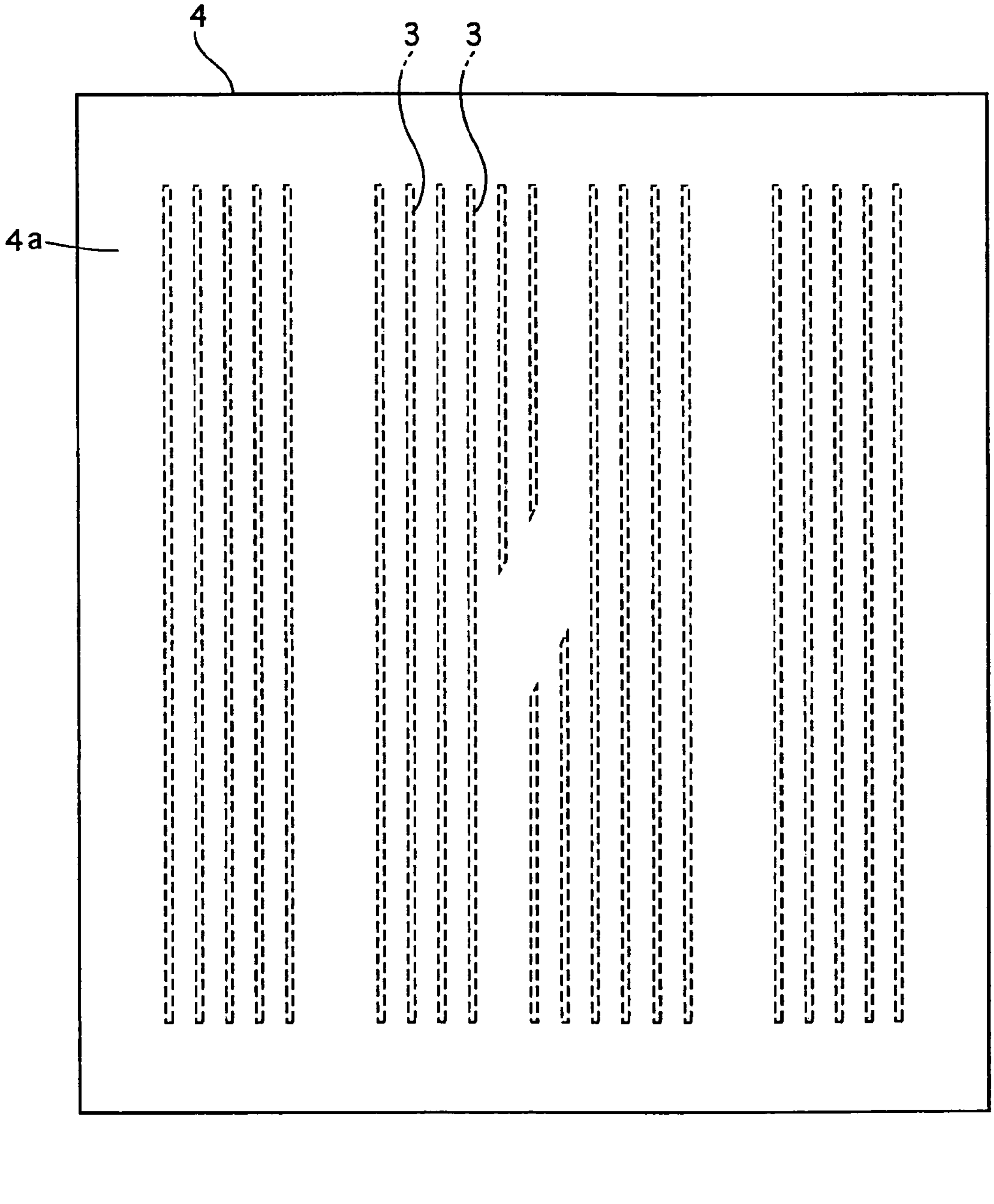


FIG. 27

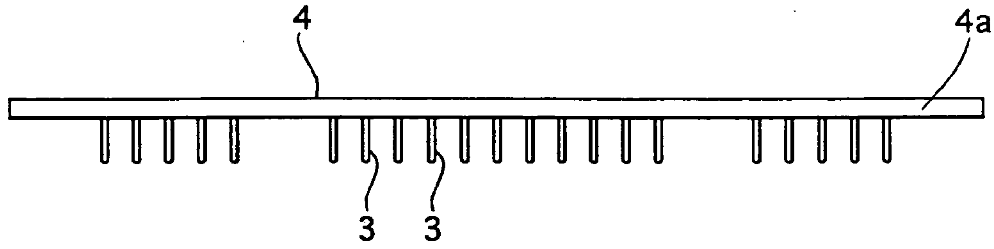

4
4a
3
3

FIG. 29

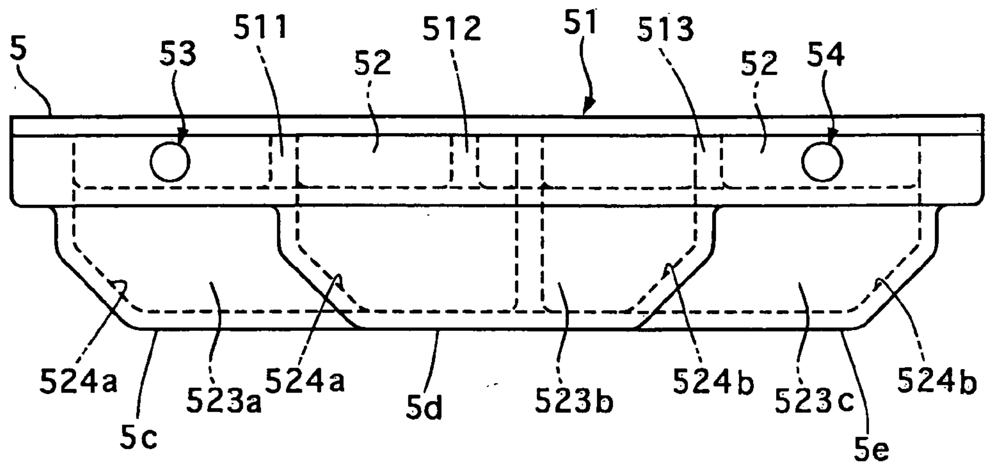

5
53
511
52
512
51
513
52
54
524a
523a
524a
5c
5d
523b
524b
523c
524b
5e

FIG. 28

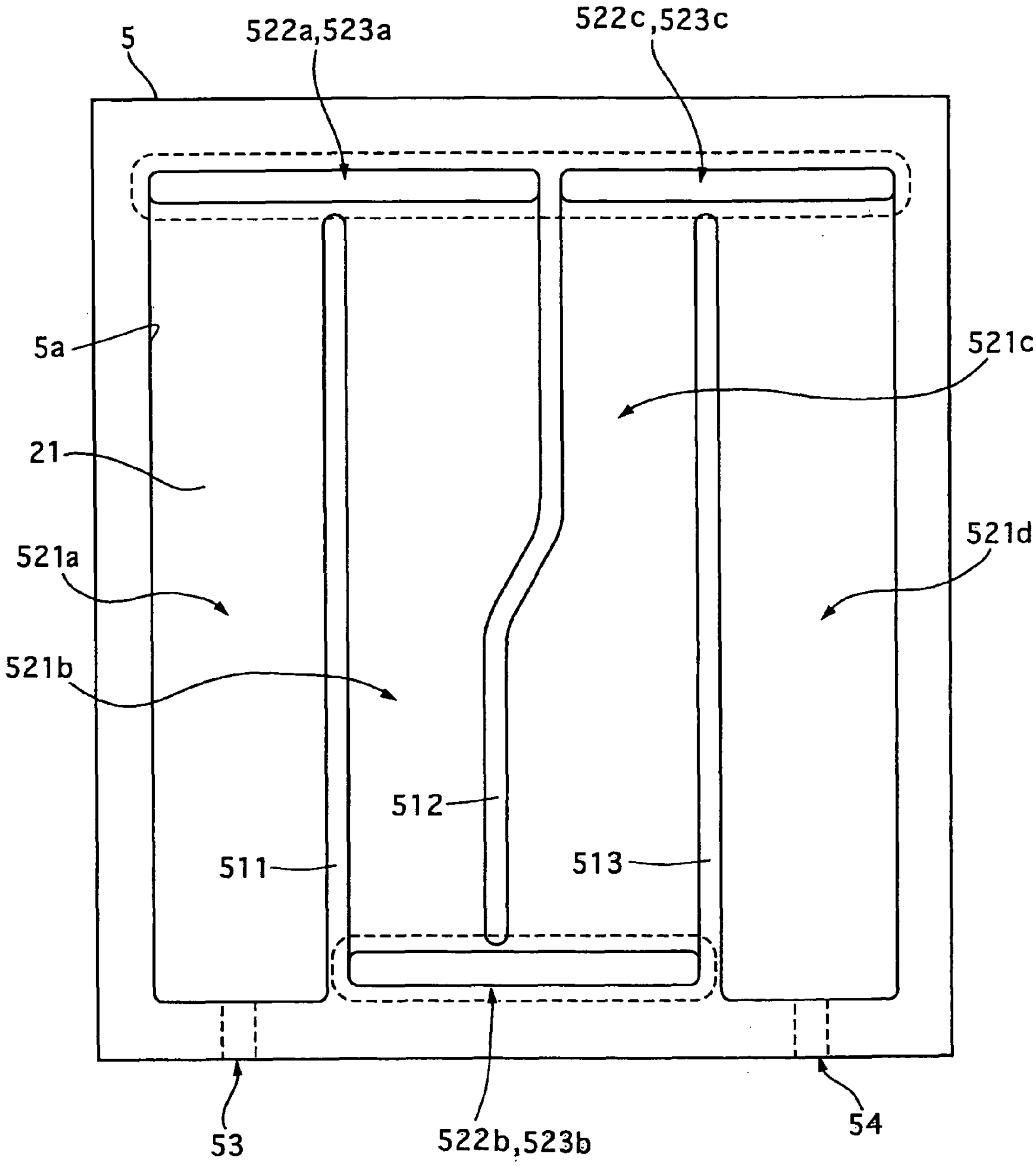

5
522a,523a
522c,523c
5a
521c
21
521a
521d
521b
512
511
513
53
522b,523b
54

FIG. 30

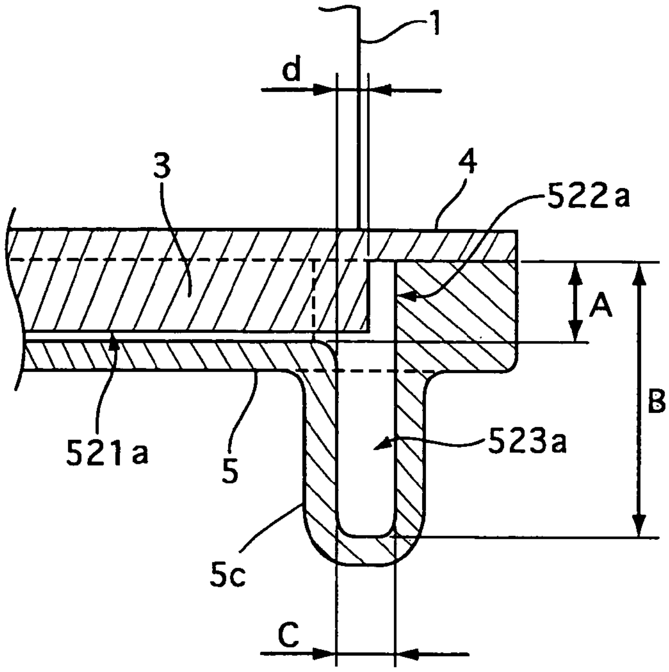

1
d
3
4
522a
A
B
521a
5
523a
5c
C

FIG. 31

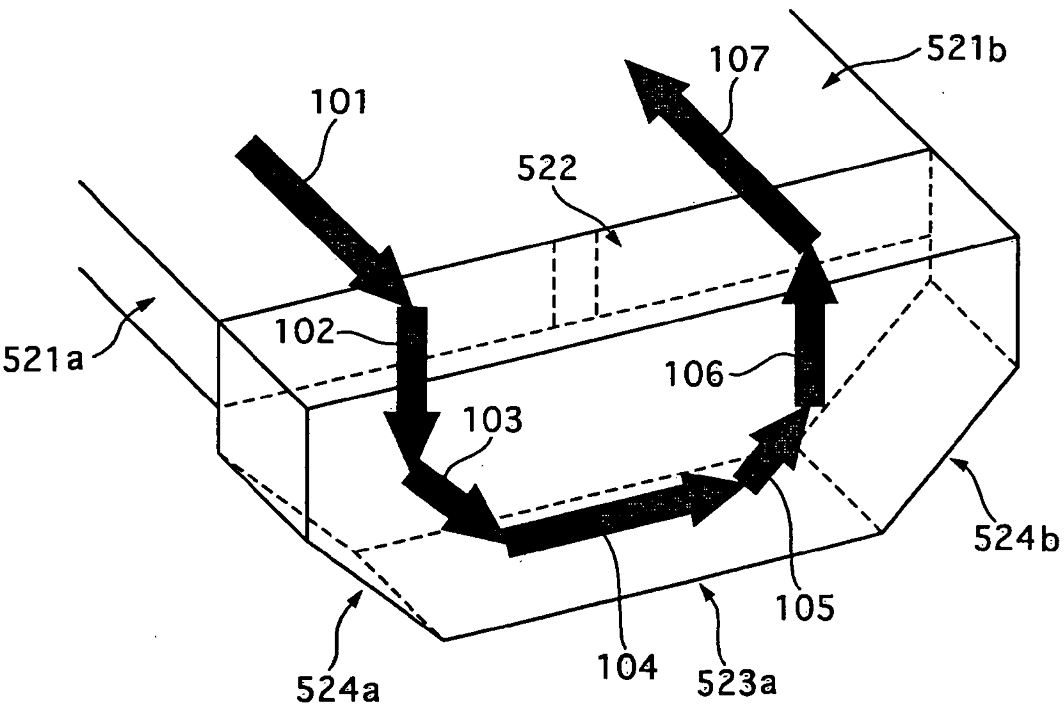

107
521b
101
522
521a
102
106
103
524b
105
104
523a
524a

FIG. 32

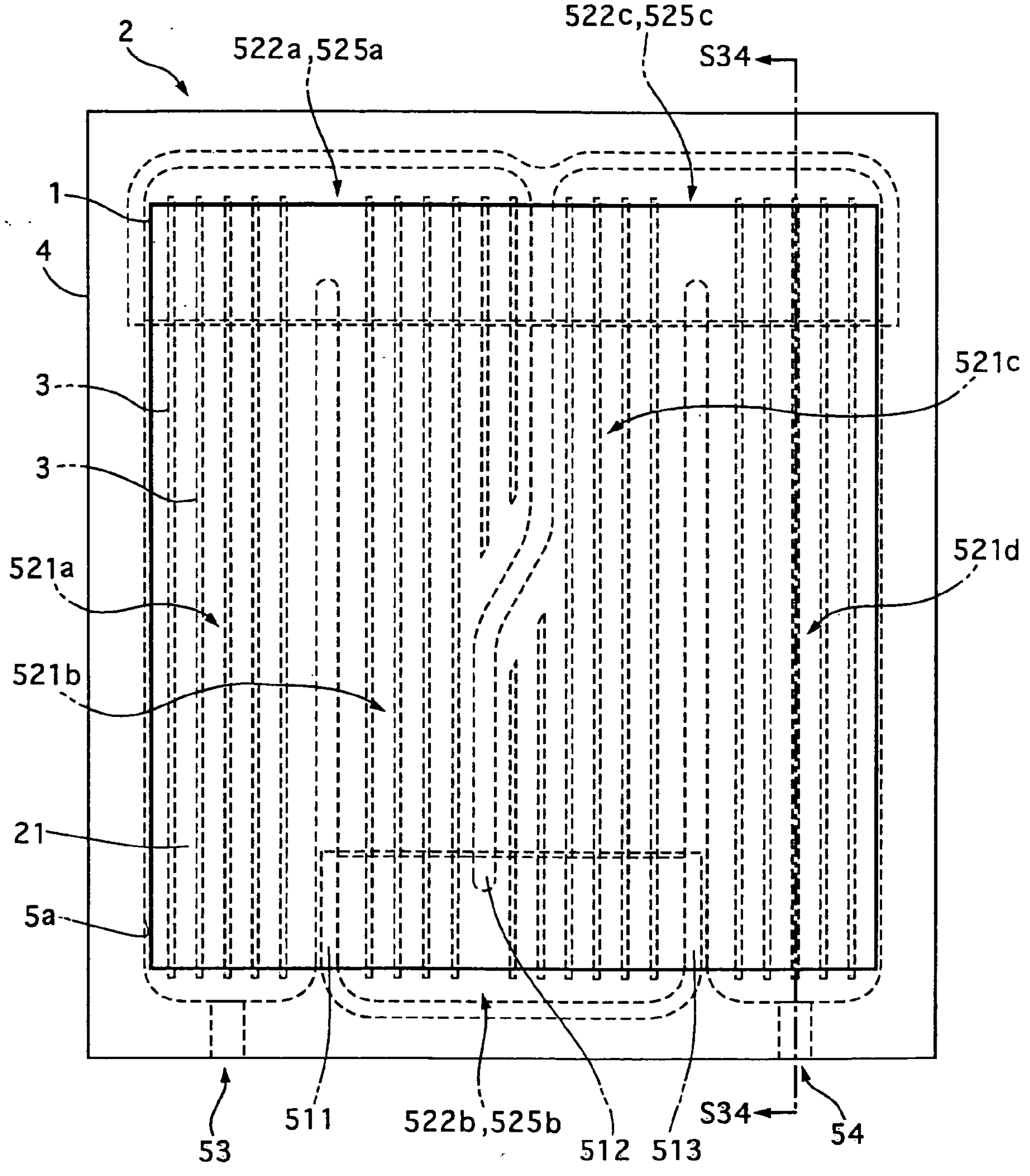

2
522a,525a
522c,525c
S34
1
4
3
3
521c
521d
521a
521b
21
5a
511
522b,525b
512
513
S34
53
54

FIG. 33

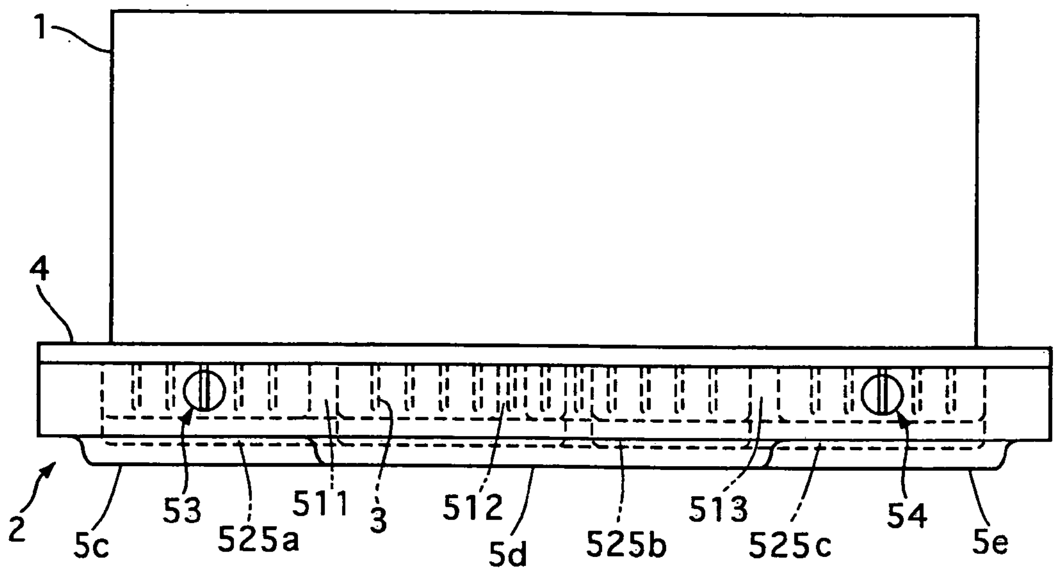


FIG. 34

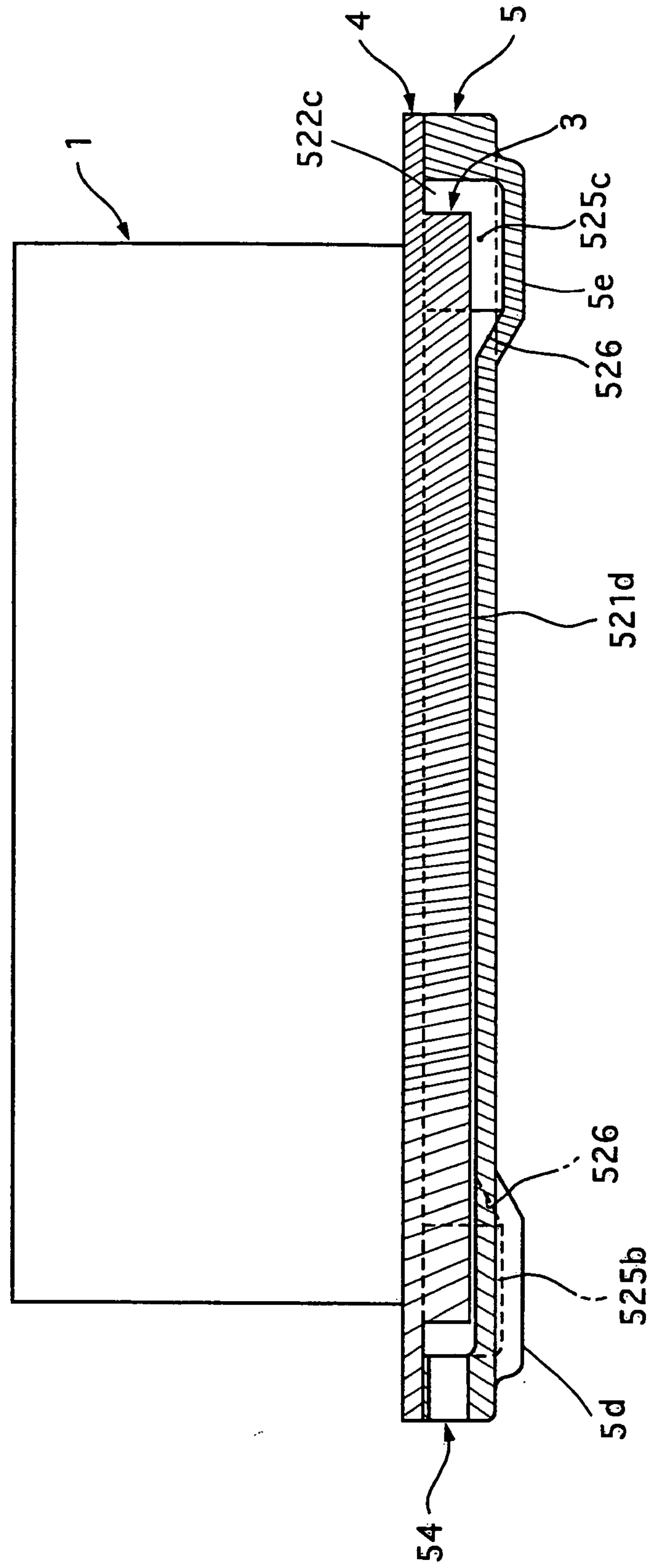


FIG. 35

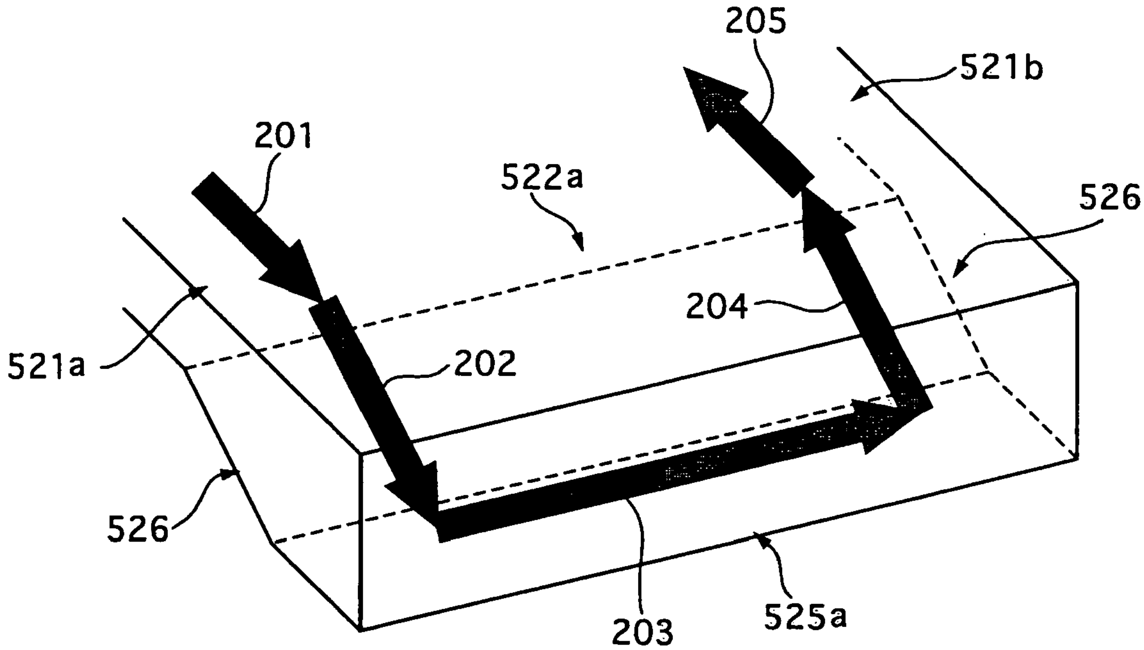
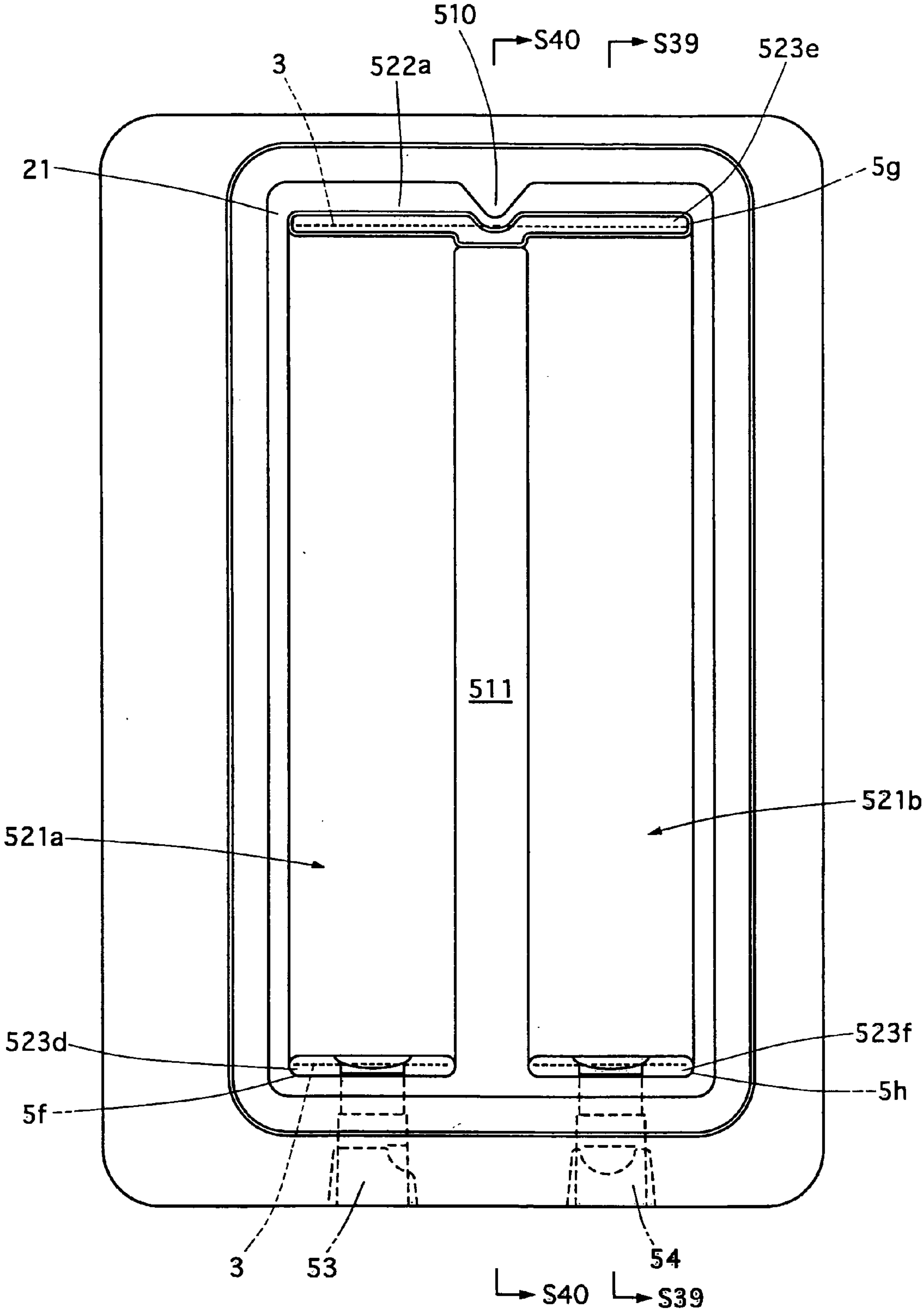


FIG. 36



510
S40
S39
3
522a
523e
21
5g
511
521b
521a
523d
523f
5h
5f
3
53
54
S40
S39

FIG. 37

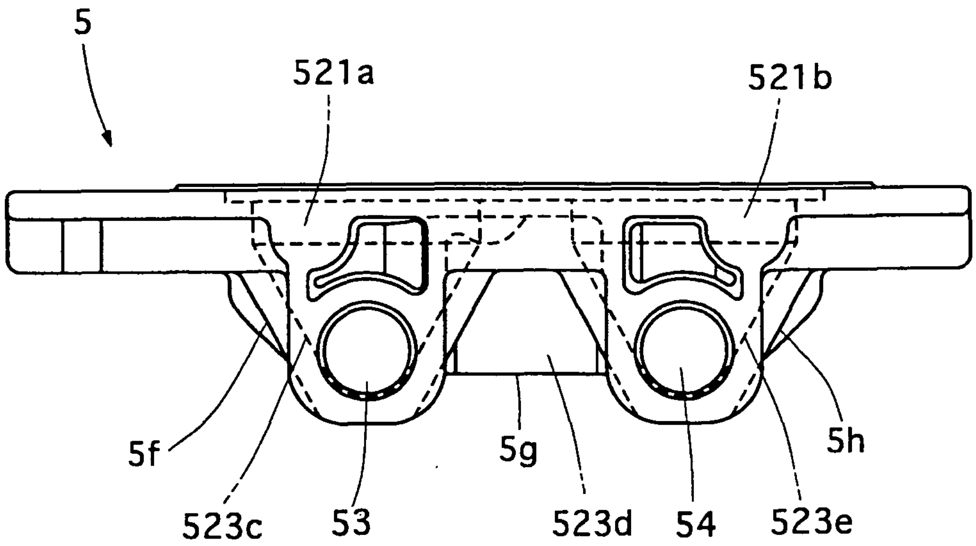


FIG. 41

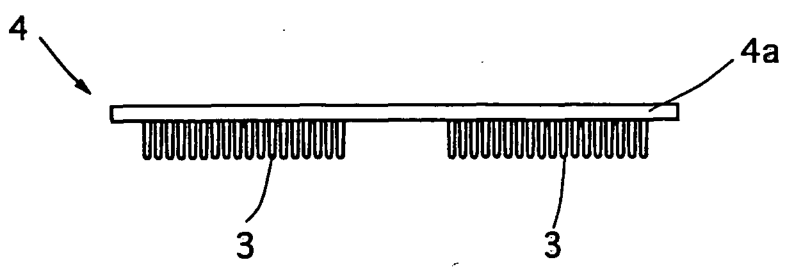


FIG. 38

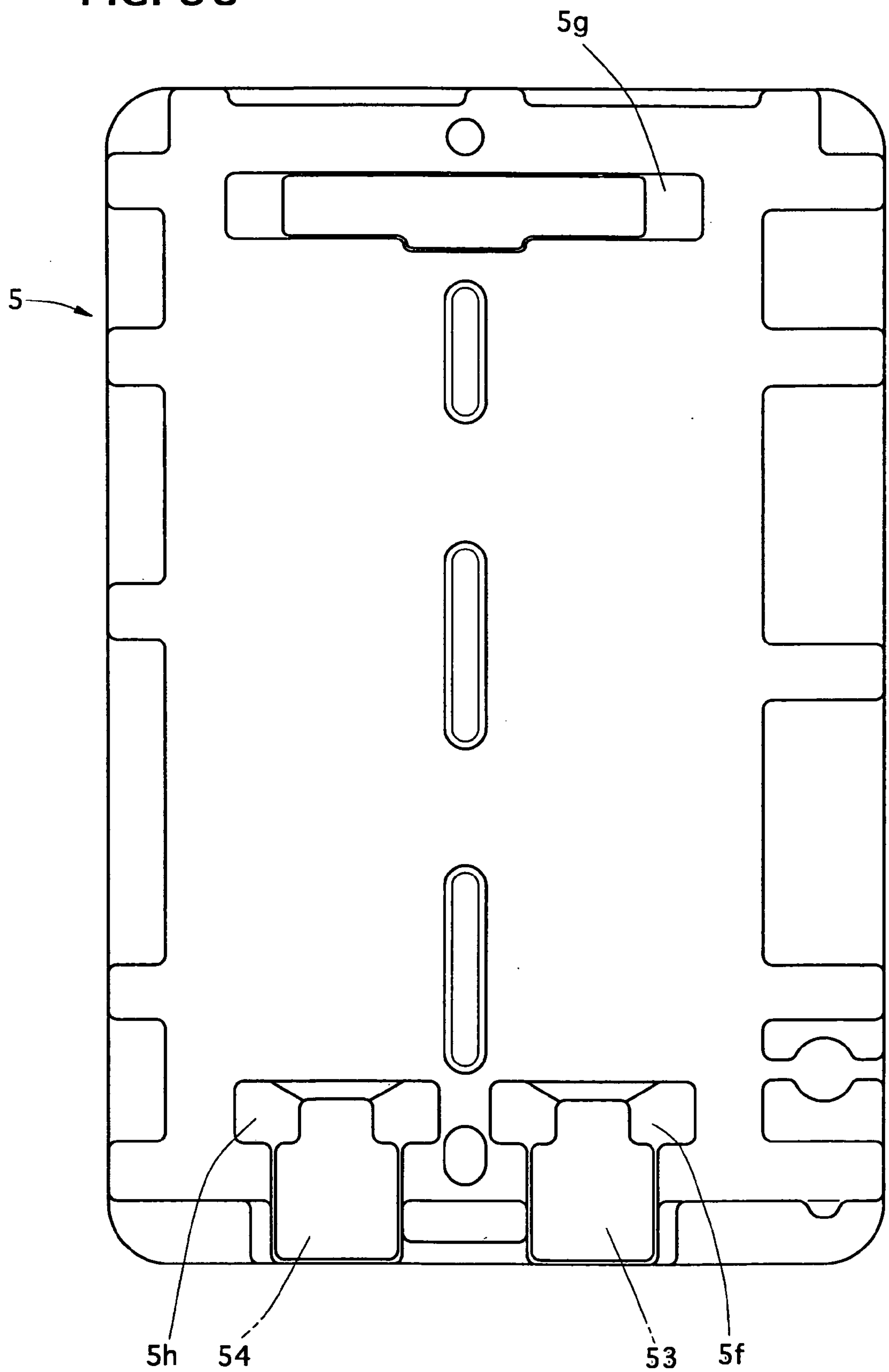


FIG. 39

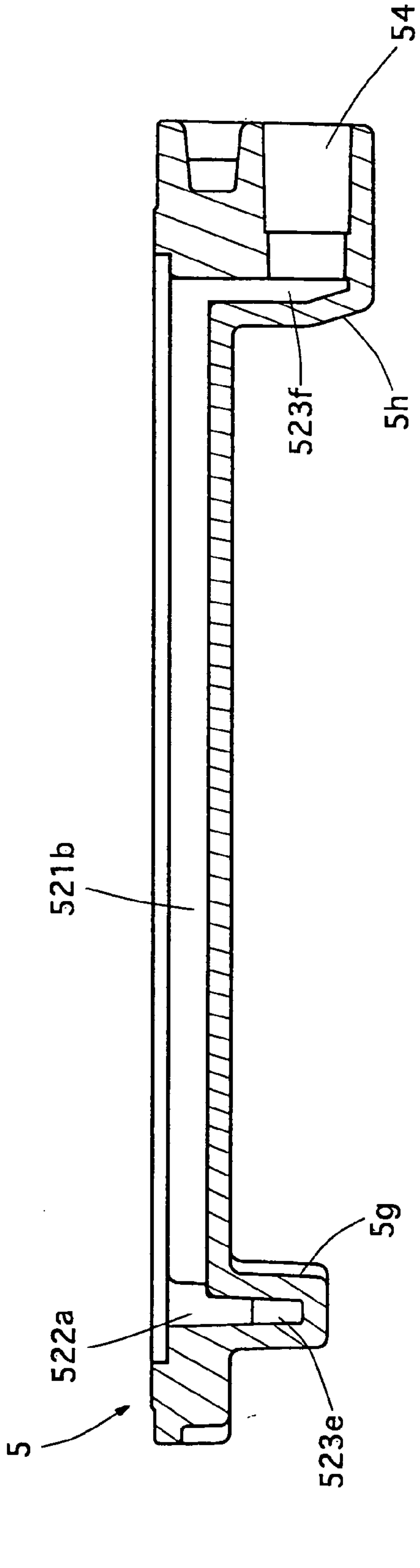


FIG. 40

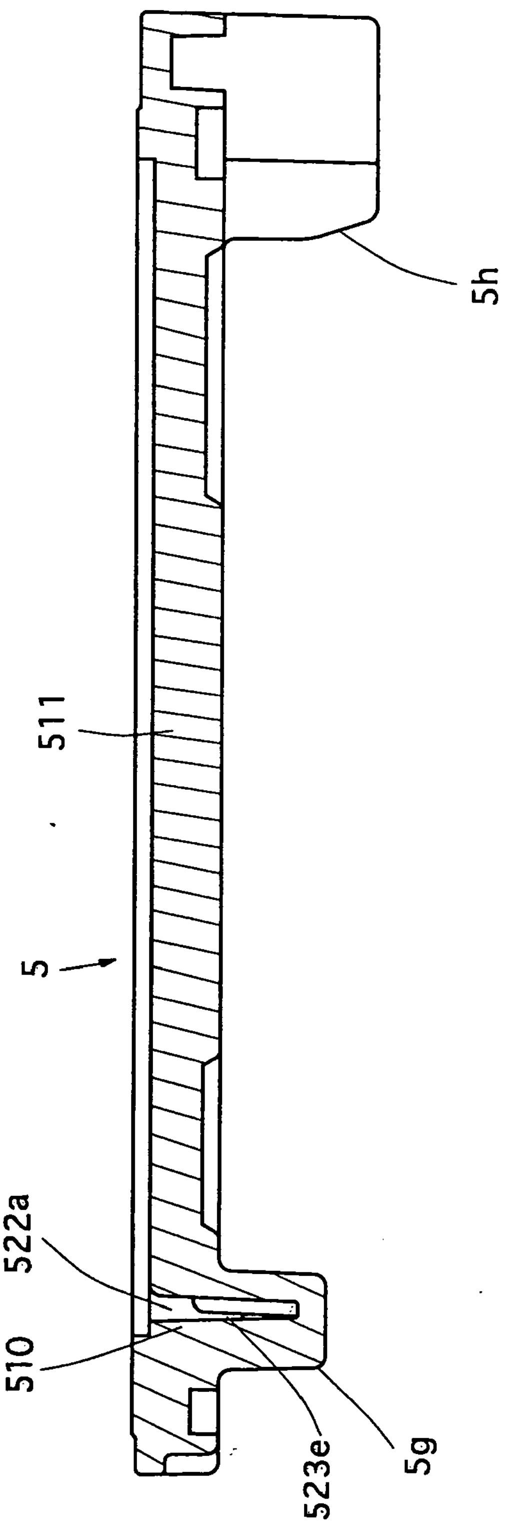


FIG. 42

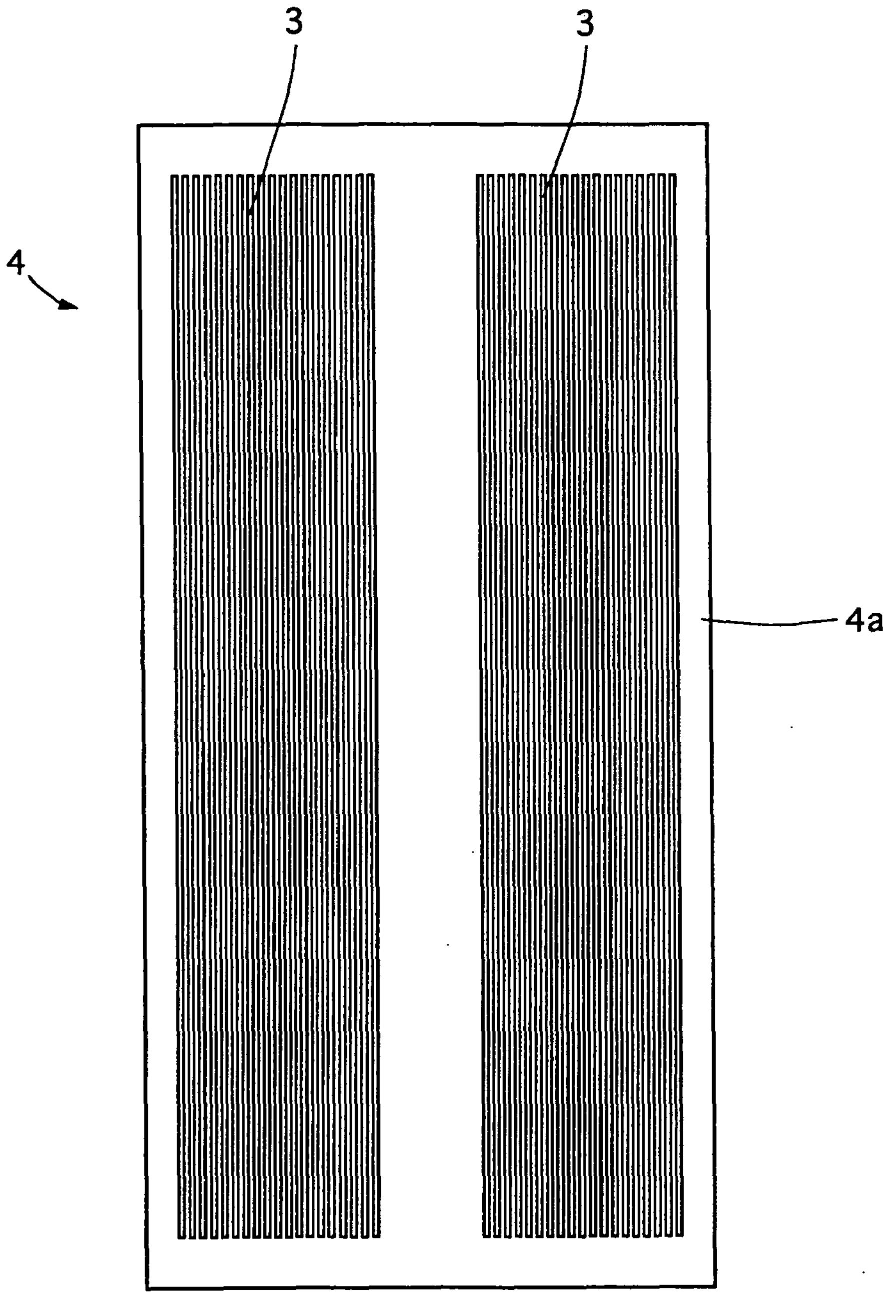
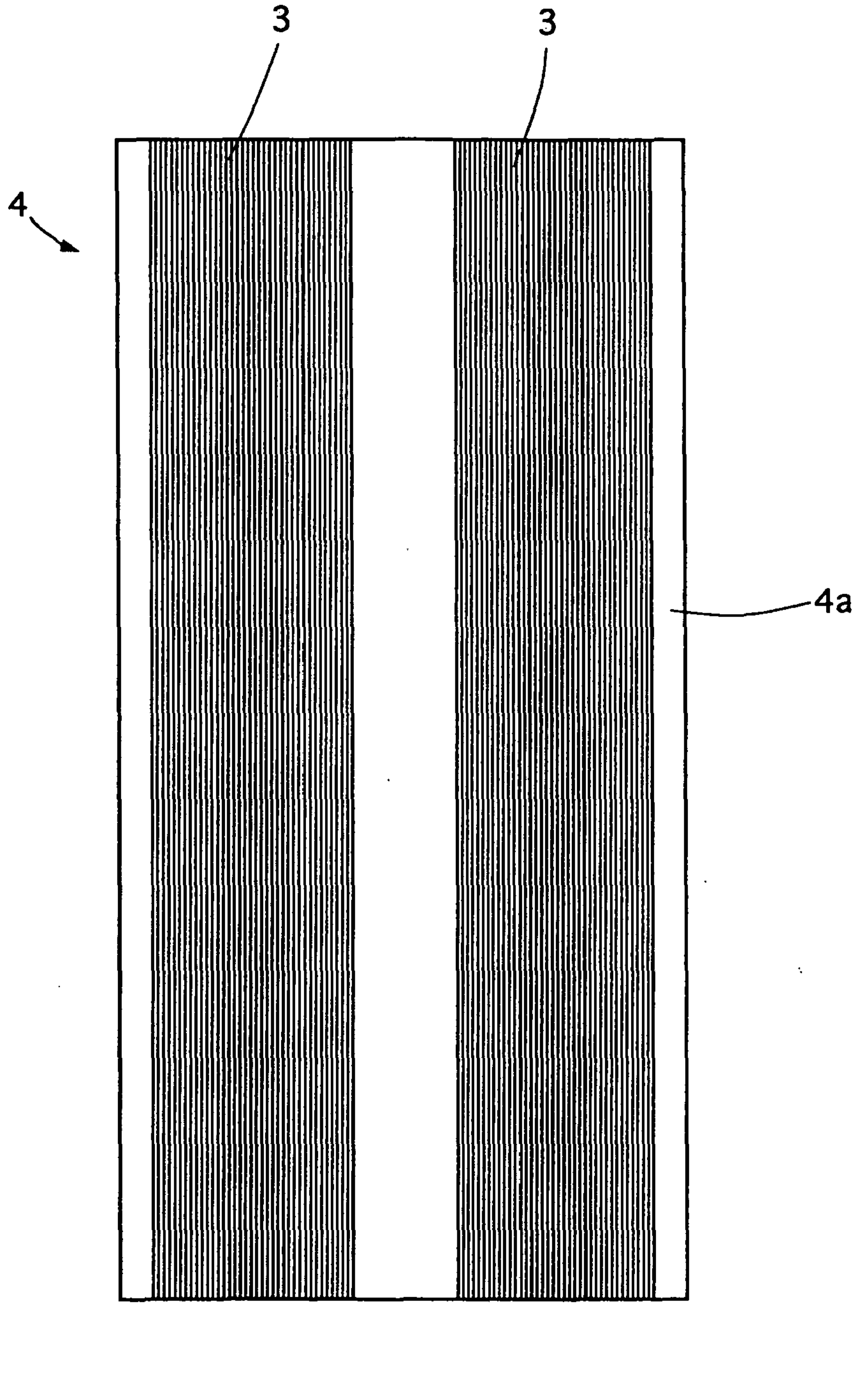


FIG. 43



REFERENCES CITED IN THE DESCRIPTION

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- JP 2002210570 A **[0024]**