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(54) FLUID CIRCULATION DEVICE

(57) Provided is a fluid circulation device capable of preventing that efficiency of a treatment by a fluid circulation is significantly lowered, even in a case where a blockage has occurred in a micro-channel, to prevent lowering of an operating rate. The fluid circulation device 1 is provided with a structure body 2 comprising: a plural number of second flow passages 22 extended in a direction, and at the same time, arranged so as to be lined up in a direction intersecting the direction, each for circulating a second fluid; and introduction part-communicating parts 75, first to third communicating parts 78, 79 and 80 for linking second flow passages 22 adjacent to each other in the arrangement direction of the plural number of second flow passages 22 to allow communicating with each other; formed therein.

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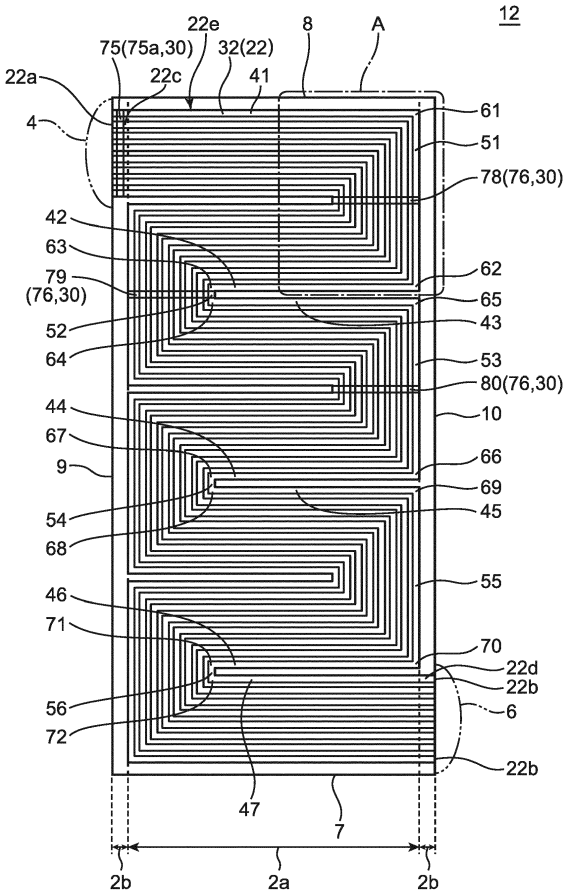

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Description

BACKGROUND OF THE INVENTION

(FIELD OF THE INVENTION)

[0001] The present invention relates to a fluid circulation device.

[0002] Hitherto, there are known fluid circulation devices for circulating a fluid inside, provided inside with a large number of micro-channels for circulating a fluid. For example, JP 2010-286229 A discloses an example of such fluid circulation devices.

[0003] Specifically, JP 2010-286229 A discloses a micro-channel heat exchanger as an example of the fluid circulation devices. This micro-channel heat exchanger comprises a layered body, in which: hot side layers having a plural number of micro-channels for circulating a high temperature fluid arranged thereon; and cold side layers having a plural number of micro-channels for circulating a low temperature fluid arranged thereon; are layered inside the layered body, with interposing a separating plate therebetween. In the layered body, heat exchange is to be performed between the high temperature fluid flowing in the micro-channels of the hot side layers and the low temperature fluid flowing in the micro-channels of the cold side layers.

SUMMARY OF THE INVENTION

Technical Problem

[0004] In a conventional fluid circulation device, there has been a concern that an occurrence of a blockage in a micro-channel inhibits a fluid from flowing in a flow passage downward from a blocked portion, to cause a significant lowering of operating rate of the fluid circulation device.

[0005] Specifically, for example, in a case where a foreign substance such as a machine oil having a high viscosity or a rust is mixed in a fluid, the foreign substance causes a blockage inside a micro-channel, in some cases. In a case where a temperature of a fluid is lowered to a significantly low temperature due to a heat exchange, a freezing of the fluid also causes a blockage in a micro-channel, in some cases. When a blockage has occurred in a micro-channel, the micro-channel is disabled to circulate a fluid, and as a result, lowers an efficiency of a treatment which is performed with circulating a fluid. Since a fluid circulation device is expected to continuously conduct a treatment with circulating a fluid for a certain period of time, in such a case where an efficiency of a treatment by a fluid circulation is lowered due to an occurrence of blockage, it is necessary to perform a maintenance work for removing the blockage. In this case, it is impossible to avoid stopping fluid circulation, and as a result, operating rate of the fluid circulation device is significant lowered.

[0006] An object of the present invention is to provide a fluid circulation device capable of preventing that efficiency of a treatment by a fluid circulation is significantly lowered, even in a case where a blockage has occurred in a micro-channel, to prevent lowering of operating rate.

Solution to Problem

[0007] Provided by the present invention is a fluid circulation device for circulating a fluid which comprises a structure body, in which: a plural number of micro-channels extended in a direction, and at the same time, arranged so as to be lined up in a direction intersecting the direction, each for circulating the fluid; and at least one communicating part for linking micro-channels adjacent to each other in the arrangement direction of the plural number of micro-channels to each other to allow communicating with each other: are formed inside.

[0008] In this fluid circulation device, in a case where a blockage has occurred in one micro-channel of two adjacent micro-channels which communicate through the communicating part, in a position upstream from the communicating part, it is possible to introduce a fluid from the other micro-channel to the micro-channel through the communicating part. Thus, the part downstream from the connected spot of the communicating part in the one of the micro-channels in which the blockage has occurred can contribute to a treatment by a fluid circulation. Thus, it is possible to prevent that an efficiency of a treatment by a fluid circulation is significantly lowered, and as a result, it is possible to continuously conduct a treatment by a fluid circulation for a certain period of time, without stopping the fluid circulation. Thus, it is possible to prevent lowering of operating rate of a fluid circulation device.

[0009] In the fluid circulation device, it is preferred that the plural number of micro-channels comprise a plural number of first micro-channels extended in a direction, and at the same time, arranged so as to be lined up in a direction intersecting the direction in the structure body, each for circulating the first fluid, and a plural number of second micro-channels disposed in a parallel direction vertical both to the extended direction of the first fluid passages and the arrangement direction of the first fluid passages in the structure body, with being spaced from the row of the plural number of first micro-channels, and at the same time, arranged in parallel with the row of the first micro-channels, each circulating the second fluid; it is preferred that the structure body has an arrangement area in which the plural number of first micro-channels are arranged, and a non-arrangement area positioned outside the arrangement area, in which the first micro-channels are not arranged, when the structure body is viewed from the parallel direction; and it is preferred that the at least one communicating part comprises a non-arrangement area-communicating part which is provided to the non-arrangement area, allowing adjacent second micro-channels to communicate with each other.

[0010] According to this configuration, since the non-arrangement area-communicating part does not overlap with the first micro-channels in the parallel direction, a thickness of the structure body in the parallel direction is not locally decreased due to the non-arrangement area-communicating part in addition to the first micro-channels. Thus, it is possible to prevent strength of the structure body from being locally lowered.

[0011] In this case, it is preferred that each of the second micro-channels comprises an introduction part which is a part disposed in the non-arrangement area, and is a part extending over a predetermined area in the side downstream from an inlet of the second micro-channels; and it is preferred that the non-arrangement area-communicating part allows the introduction parts of the second micro-channels adjacent to each other to communicate with each other.

[0012] According to this configuration, it is possible to introduce the second fluid to an introduction part of a second micro-channel where a blockage easily occurs, which is a part in the vicinity downstream of the inlet, from the introduction part of an adjacent second micro-channel, through a non-arrangement area-communicating part. Thus, it is possible to allow the region of the second micro-channel in the side downstream from the inlet, where a blockage easily occurs, to contribute to a treatment by a circulation of the second fluid.

[0013] In the fluid circulation device, it is preferred that each of the micro-channels has a curving part and a downstream part which follows the curving part downstream, and that the at least one communicating part comprises a downstream part-communicating part for allowing downstream parts of adjacent micro-channels to communicate with each other.

[0014] According to this configuration, it is possible to introduce a fluid into the downstream part of a micro-channel which follows the curving part downstream where a blockage easily occurs, from a downstream part of an adjacent micro-channel, through a downstream part-communicating part. Thus, it is possible to allow the region of a micro-channel in the side downstream from a curving part, where a blockage easily occurs, to contribute to a treatment by a fluid circulation.

[0015] In the fluid circulation device, it is preferred that the plural number of micro-channels comprise a plural number of first micro-channels extended in a direction, and at the same time, arranged so as to be lined up in a direction intersecting the direction in the structure body, each for circulating the first fluid, and a plural number of second micro-channels disposed in a parallel direction vertical both to the extended direction of the first fluid passages and the arrangement direction of the first fluid passages in the structure body, with being spaced from the row of the plural number of first micro-channels, and at the same time, arranged in parallel with the row of the first micro-channels, each circulating the second fluid; it is preferred that the structure body has an arrangement area in which the plural number of first micro-channels are arranged, and a non-arrangement area positioned outside the arrangement area, in which the first micro-channels are not arranged, when the structure body is viewed from the parallel direction; it is preferred that the at least one communicating part comprises a plural number of arrangement area-communicating parts which are provided to the arrangement area, allowing parts of adjacent second micro-channels disposed in the arrangement area to communicate with each other; and it is preferred that the plural number of arrangement area-communicating parts are lined up in a direction intersecting the first flow passages which overlap with the arrangement area-communicating part, when the structure body is viewed from the parallel direction.

[0016] According to this configuration, it is possible to prevent formation of a spot with a locally lowered strength in the structure body due to the plural number of arrangement area-communicating parts and the first flow passages, as in a case where the plural number of arrangement area-communicating parts are lined up in a direction which agrees with the extended direction of the first flow passages which overlap therewith.

[0017] In the fluid circulation device, it is preferred that the communicating part has a width equal to or less than a flow passage width of the micro-channels.

[0018] According to this configuration, it is possible to prevent lowering of a pressure-resistance property of the structure body of the fluid circulation device at the spots of the communicating part.

Advantageous Effect of the Invention

[0019] As described above, according to the present invention, it is possible to provide a fluid circulation device capable of preventing that efficiency of a treatment by a fluid circulation is significantly lowered, even in a case where a blockage has occurred in a micro-channel, to prevent lowering of operating rate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

FIG. 1 is a schematic perspective view of the fluid circulation device according to an embodiment of the present invention.

FIG. 2 is a plan view of a first substrate which constitutes the structure body of the fluid circulation device shown in FIG. 1.

FIG. 3 is a plan view of a second substrate which constitutes the structure body of the fluid circulation device shown in FIG. 1.

FIG. 4 is a partial cross-sectional view of a stacked part of the first substrate in which the first passages are formed and the second substrate in which the second flow passages are formed, in the structure body.

FIG. 5 is a view showing a configuration in the vicinity

of the inlet and the introduction part of the second flow passage of the structure body in an embodiment of the present invention, and how the second fluid flows when a blockage has occurred at the inlet.

FIG. 6 is a view showing a configuration of the second flow passage in region A of FIG. 3, and how the second fluid flows when a blockage has occurred in the first curving part.

FIG. 7 is a view of inlets and introduction parts of the second flow passages of the structure body according to the comparative example without provided with the communicating part, corresponding to FIG. 5.

FIG. 8 is a view of the second flow passages of the structure body according to the comparative example without provided with the communicating part, corresponding to FIG. 6.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] Hereinafter, an embodiment of the present invention will be described with referring to the drawings.

[0022] FIG. 1 shows an entire configuration of the fluid circulation device 1 according to an embodiment of the present invention. The fluid circulation device 1 according to the present embodiment is a heat exchanger which performs a treatment of heat-exchanging between a first fluid and a second fluid, with circulating the fluids inside. The fluid circulation device 1 is provided with a structure body 2, a first supply header 3, a second supply header 4, a first discharge header 5, and a second discharge header 6.

[0023] The structure body 2 is a block-shaped object in which a large number of first flow passages 21 (see FIG. 2) which are micro-channels for circulating the first fluid, a large number of second flow passages 22 (see FIG. 3) which are micro-channels for circulating the second fluid, and a plural number of communicating parts 30 for linking adjacent second flow passages 22 to each other to allow communicating with each other are formed inside, and exhibit a rectangular parallelepiped shape. The first flow passages 21 are an example of the first micro-channels of the present invention, and the second flow passages 22 are an example of the second micro-channels of the present invention. The structure body 2 has a plural number of first substrates 11 each provided with a plural number of first flow passages 21, and a plural number of second substrates 12 each provided with a plural number of second flow passages 22 and a plural number of communicating parts 30.

[0024] The first substrate 11 and the second substrate 12 are flat plates having identical rectangular outer shapes when viewed from one side in a thickness direction. These first substrate 11 and the second substrate 12 are made of a stainless steel plate, for example. The structure body 2 is a stacked body formed by stacking the first substrates 11 and the second substrates 12 alternately so as to be adhered to one another. Thereby, in the structure body 2, the plural number of first flow passages 21 arranged in the first substrates 11 and the plural number of second flow passages 22 arranged in the second substrates 12 are lined up alternately in the stacked direction of the substrate thereof. The structure body 2 has four side surfaces which are vertical to plate surfaces of each of the stacked substrates 11 and 12. These four side surfaces are formed with individual end surfaces corresponding to four sides of each of the substrates 11 and 12.

[0025] Specifically, each of the substrates 11 and 12 individually has a pair of short end surfaces constituting a pair of short sides of the outer shape of the rectangular shape thereof, and a pair of long end surfaces constituting a pair of long sides of the outer shape of the rectangular shape, which is vertical to the short end surfaces thereof. The four side surfaces of the structure body 2 comprise a pair of short side surfaces 7, 8 and a pair of long side surfaces 9 and 10. One of the short side surfaces 7 is formed with a succession of one of the short side surfaces of each of the stacked substrates 11 and 12, and the other short side surface 8 is formed with a succession of the other short side surface of each of the stacked substrates 11 and 12. One of the short side surfaces 7 and the other short side surface 8 are side surfaces in the opposite side from each other. One of the long side surfaces 9 is formed with a succession of one of the long side surfaces of each of the stacked substrates 11 and 12, and the other long side surface 10 is formed with a succession of the other long side surface of each of the stacked substrates 11 and 12. One of the long side surfaces 9 and the other long side surface 10 are side surfaces in the opposite side from each other. The short side surfaces 7, 8 and the long side surfaces 9, 10 are disposed vertically to each other. A length of the long side surfaces 9, 10 in the extended direction of the long sides of each of the substrates 11, 12 is longer than a length of the short side surfaces 7, 8 in the extended direction of the short sides of each of the substrates 11, 12.

[0026] On one of the plate surfaces of each of the first substrates 11, a plural number of first grooves 23 constituting the plural number of first flow passages 21 are formed, as shown in FIG. 2. Each first groove 23 is formed, for example, by etching. In one of the plate surfaces of each first substrate 11, each first groove 23 is arranged in the extended direction of the short sides of the first substrate 11, so as to be lined up at intervals. Each first groove 23 also extends linearly over from one of the short end surfaces of the first substrate 11 to the other short end surface, in parallel with long sides of the first substrate 11. Each first groove 23 exhibits a circular arc-shaped cross-section as shown in FIG. 4, in a cross-section vertical to the extended direction thereof. Opening of each first groove 23 in one of the plate surfaces of a first substrate 11 is sealed with a second substrate 12 stacked on the plate surface, to thereby form a plural number of first flow passages 21 arranged on the one of the plate surfaces.

[0027] Each first flow passage 21 is arranged in the structure body 2, so as to be extended linearly in a direction parallel to the long side surfaces 9, 10, and at the same time, so as to be lined up at intervals in a direction orthogonal to the extended direction thereof. Each first flow passage 21 exhibits a semicircular cross-section, in a cross-section vertical to the extended direction thereof. Each first flow passage 21 has an inlet 21a (see FIG. 2) for receiving the first fluid at one end, and an outlet 21b for discharging the first fluid which has flowed in the first flow passage 21, at an end in the opposite side from the inlet 21a. The inlet 21a opens in one of the short side surfaces 7 of the structure body 2, and the outlet 21b opens in the other short side surface 8 of the structure body 2.

[0028] On one of the plate surfaces of each second substrate 12 (see FIG. 3), a plural number of second grooves 32 which constitute the plural number of second flow passages 22 are formed. Each second groove 32 is formed, for example, by etching. Each second groove 32 has a circular arc-shaped cross-section similar to the cross-section of the first groove 23, as shown in FIG. 4. Opening of each second groove 32 in one of the plate surfaces of a second substrate 12 are sealed with a first substrate 11 which is stacked on the plate surface, to thereby form the plural number of second flow passages 22 arranged on the one of the plate surfaces.

[0029] Each second flow passage 22 is formed into a largely-meander shape as a whole, in the present embodiment. Each second flow passage 22 has an inlet 22a for receiving the second fluid in one end, and an outlet 22b for discharging the second fluid which has flowed in the second flow passage 22, in an end in the opposite side from the inlet 22a. The inlets 22a open in one of the long side surfaces 9 of the structure body 2 in a region close to the other short side surface 8. That is to say, the inlets 22a are disposed in one of the long side surfaces 9 of the structure body 2, in a position close to the outlets 21b of the first flow passages 21. The outlets 22b open in the other long side surface 10 of the structure body 2, in a region close to the one of the short side surfaces 7. That is to say, the outlets 22b are disposed in the other long side surface 10 of the structure body 2 in a position close to the inlets 21a of the first flow passages 21.

[0030] The plural number of second flow passages 22 are disposed in the structure body 2 in a parallel direction vertical both to the extended direction of the first fluid passages 21 and the arrangement direction of the plural number of first fluid passages 21 on the first substrate 11, with being spaced from the row of the plural number of first flow passages 21 on the first substrate 11. The parallel direction is a direction which agree with the stacked direction of the substrates 11, 12. The plural number of second flow passages 22 on the second substrate 12 are arranged in parallel with the row of the plural number of first flow passages 21 on the first substrate 11, allowing a heat exchange between the second fluid flowing in the second flow passages 22 and the first fluid flowing in the first flow passages 21.

[0031] Each second flow passage 22 has first to seventh horizontally linear parts 41, 42, 43, 44, 45, 46, 47, first to sixth vertically linear parts 51, 52, 53, 54, 55, 56, and first to twelfth curving parts 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, as shown in FIG. 3.

[0032] The first horizontally linear part 41 is a part extended linearly from the inlet 22a toward the other long side surface 10, in parallel with the short side surfaces 7, 8. That is, an end of the first horizontally linear part 41 is provided to the one of the long side surfaces 9, and an inlet 22a is provided to the end.

[0033] The first curving part 61 is connected to the first horizontally linear part 41, to an end part closer to the other long side surface 10. The first curving part 61 is a part where the second flow passages 22 change orientation from the extended direction of the first horizontally linear part 41, so as to be directed to one of the short side surfaces 7, along a direction in parallel with the long side surface 10.

[0034] The first vertically linear part 51 is a part which is connected downstream to the first curving part 61, and extends linearly in parallel with the long side surfaces 9, 10.

[0035] The second curving part 62 is connected to the first vertically linear part 51, to an end part closer to the one of the short side surfaces 7. The second curving part 62 is a part where the second flow passages 22 change orientation, from the extended direction of the first vertically linear part 51, so as to be directed to one of the long side surfaces 9, along a direction in parallel with the short side surface 8.

[0036] The second horizontally linear part 42 is a part which is connected downstream to the second curving part 62, and extends linearly in parallel with the short side surfaces 7, 8.

[0037] The third curving part 63 is connected to the second horizontally linear part 42, to an end part closer to one of the long side surfaces 9. The third curving part 63 is a part where the second flow passages 22 change orientation, from the extended direction of the second horizontally linear part 42, so as to be directed to one of the short side surfaces 7, along a direction in parallel with the long side surface 9.

[0038] The second vertically linear part 52 is a part which is connected downstream to the third curving part 63, and extends linearly in parallel with the long side surfaces 9, 10.

[0039] The fourth curving part 64 is connected to the second vertically linear part 52, to an end part closer to the one of the short side surfaces 7. The fourth curving part 64 is a part where the second flow passages 22 change orientation, from the extended direction of the second vertically linear part 52, so as to be directed to the other long side surface 10, along a direction in parallel with the short side surface 8.

[0040] The third horizontally linear part 43 is a part which is connected downstream to the fourth curving part

64, and extends linearly in parallel with the short side surfaces 7, 8.

[0041] Then, to an end part of the third horizontally linear part 43 closer to the other long side surface 10, a fifth curving part 65 is linked. From the fifth curving part 65, a third vertically linear part 53, a sixth curving part 66, a fourth horizontally linear part 44, a seventh curving part 67, a fourth vertically linear part 54, an eighth curving part 68, a fifth horizontally linear part 45, a ninth curving part 69, a fifth vertically linear part 55, a tenth curving part 70, a sixth horizontally linear part 46, an eleventh curving part 71, a sixth vertically linear part 56, a twelfth curving part 72, and a seventh horizontally linear part 47 are linked downstream in this order.

[0042] Configuration of a region consisting of the fifth curving part 65, the third vertically linear part 53, the sixth curving part 66, the fourth horizontally linear part 44, the seventh curving part 67, the fourth vertically linear part 54, the eighth curving part 68 and the fifth horizontally linear part 45 is identical to the configuration of the region consisting of the first curving part 61, the first vertically linear part 51, the second curving part 62, the second horizontally linear part 42, the third curving part 63, the second vertically linear part 52, the fourth curving part 64 and the third horizontally linear part 43. Configuration of a region consisting of the ninth curving part 69, the fifth vertically linear part 55, the tenth curving part 70, the sixth horizontally linear part 46, the eleventh curving part 71, the sixth vertically linear part 56, and the twelfth curving part 72 is identical to the configuration of the region consisting of the first curving part 61, the first vertically linear part 51, the second curving part 62, the second horizontally linear part 42, the third curving part 63, the second vertically linear part 52 and the fourth curving part 64.

[0043] The seventh horizontally linear part 47 extends to the other long side surface 10, and an end thereof in the long side surface 10 is provided with an outlet 22b of the second flow passage 22.

[0044] The structure body 2 has an arrangement area 2a which is an area in which the plural number of first flow passages 21 are arranged when the structure body 2 is viewed from the parallel direction (the stacked direction), and a pair of non-arrangement areas 2b which are positioned to the both outsides of the arrangement area 2a, in which the first flow passages 21 are not arranged, when the structure body is viewed from the parallel direction. When viewed from the parallel direction, the arrangement area 2a occupies the most part of the structure body 2, and is disposed in the center of the structure body 2 in the arrangement direction of the first flow passages 21. One of the non-arrangement areas 2b is an area from one of the long side surfaces 9 to an end of the arrangement area 2a in the side of the one of the long side surfaces 9, in the structure body 2. The other non-arrangement area 2b is an area from the other long side surface 10 to an end of the arrangement area 2a in the side of the other long side surface 10, in the structure body 2.

[0045] The inlet 22a of each second flow passage 22 is disposed in one of the non-arrangement areas 2b. Each second flow passage 22 has an introduction part 22c, a lead out part 22d and an effective region 22e.

[0046] The introduction part 22c is a part disposed in one of the non-arrangement areas 2b of a second flow passage 22. That is, the introduction part 22c is a part over a predetermined small area in the side downstream from the inlet 22a, in a second flow passage 22. In other words, the introduction part 22c is a part in the vicinity of the upstream end of the first horizontally linear part 41, and is a part in the vicinity of the inlet 22a. Specifically, the introduction part 22c is a part from the inlet 22a to the boundary between one of the non-arrangement areas 2b and the arrangement area 2a, in a second flow passage 22.

[0047] The lead out part 22d is a part which is joined upstream to the outlet 22b, and is a part disposed in the other non-arrangement area 2b. That is to say, this lead out part 22d is a part in the vicinity of the downstream end of the seventh horizontally linear part 47, and is a part in the vicinity of the outlet 22b. Specifically, the lead out part 22d is a part from the outlet 22b to the boundary between the other non-arrangement area 2b and the arrangement area 2a, in a second flow passage 22.

[0048] The effective region 22e is a part for circulating the second fluid so that the second fluid is allowed to exchange heat with the first fluid which flows in the first flow passages 21 provided to the arrangement area 2a. This effective region 22e is a part other than the introduction part 22c and the lead out part 22d of a second flow passage 22, namely, a part between the introduction part 22c and the lead out part 22d. Specifically, the effective region 22e is a part disposed in the arrangement area 2a of a second flow passage 22.

[0049] Each communicating part 30 (see FIG. 3, FIG. 5 and FIG. 6) is for linking second flow passages 22 adjacent to each other in the arrangement direction of the second flow passages 22 in the second substrate 12, to allow communicating with each other. The plural number of communicating parts 30 comprise a plural number of introduction part-communicating parts 75 and a plural number of effective region-communicating parts 76.

[0050] The introduction part-communicating part 75 is for linking introduction parts 22c of adjacent second flow passages 22 in the second substrate 12 to each other to allow communicating with each other. This introduction part-communicating part 75 is provided to the non-arrangement area 2b in its entirety. That is, the introduction part-communicating part 75 is an example of the non-arrangement area-communicating part of the present invention. The introduction part-communicating part 75 is individually provided each between adjacent introduction parts 22c. The plural number of introduction part-communicating parts 75 provided on the second substrate 12 are lined up in a line in a direction orthogonal to the extended direction of the introduction parts 22c. Through

these plural number of introduction part-communicating parts 75, the introduction parts 22c of all the second flow passages 22 provided on the second substrate 12 communicate with one another.

[0051] The plural number of introduction part-communicating parts 75 are formed with introduction part-communicating grooves 75a which are formed in the non-arrangement area 2b of the second substrate 12, so as to open in one of the plate surfaces of the second substrate 12. Specifically, in the non-arrangement area 2b, an introduction part-communicating groove 75a is formed orthogonally to each second grove 32. The introduction part-communicating groove 75a exhibits a circular arc-shaped cross-section in a cross-section vertical to the extended direction of the introduction part-communicating groove 75a. An introduction part-communicating groove 75a has a maximum depth equal to a maximum depth of a second groove 32. Openings of the introduction part-communicating grooves 75a formed in the one of the plate surfaces of the second substrate 12 are sealed with a first substrate 11 which is stacked on the plate surface, to thereby form introduction part-communicating parts 75 between adjacent introduction parts 22c. An introduction part-communicating part 75 has a width Wi equal to or less than a flow passage width Wa of a second flow passage 22 (flow passage width of the introduction part 22c). The width Wi of an introduction part-communicating part 75 is a distance between both ends of the introduction part-communicating part 75 in a direction orthogonal both to the arrangement direction of the portion of the plural number of the second flow passages 22 where communication is allowed by the introduction part-communicating parts 75 (the introduction part 22c) and the parallel direction. A distance between an inlet 22a and an introduction part-communicating part 75 in a direction orthogonal to the arrangement direction and the parallel direction, namely, the extended direction of the introduction part 22c is configured to be larger than the flow passage width Wa of a second flow passage 22.

[0052] The plural number of effective region-communicating parts 76 are for linking effective regions 22e of second flow passages 22 adjacent to each other in the arrangement direction of the second flow passages 22 to each other to allow communicating with each other. The effective region-communicating part 76 is an example of the arrangement area-communicating part of the present invention. The effective region-communicating parts 76 are provided to the arrangement area 2a. In the present embodiment, the plural number of effective region-communicating parts 76 comprise a plural number of first communicating parts 78, a plural number of second communicating parts 79 and a plural number of third communicating parts 80. The first communicating parts 78 allow spots in the most upstream side in the effective region 22e to communicate, among the first, second and third communicating parts 78, 79 and 80. The second communicating parts 79 allow a spot in the side downstream from the first communicating parts 78 to communicate, in the effective region 22e. The third communicating parts 80 allow a spot in the side further downstream from the second communicating parts 79 to communicate, in the effective region 22e.

[0053] Specifically, the first communicating parts 78 link first vertically linear parts 51 of adjacent second flow passages 22, which follow the first curving parts 61 downstream, to each other, to communicating with each other. The first vertically linear part 51 is an example of the downstream part of the present invention, and the first communicating part 78 is an example of the downstream part-communicating part of the present invention. The first communicating part 78 is individually provided each between adjacent first vertically linear parts 51. The plural number of first communicating parts 78 provided on the second substrate 12 are lined up in a line in a direction orthogonal to the extended direction of the first vertically linear parts 51, when viewed from the parallel direction. The plural number of first communicating parts 78 are lined up in a line also in a direction orthogonal to the extended direction of the first flow passages 21 to which the first communicating parts 78 overlap, when viewed from the stacking direction. Through these plural number of first communicating parts 78, the first vertically linear parts 51 of all the second flow passages 22 provided on the second substrate 12 communicate with one another.

[0054] The plural number of first communicating parts 78 are formed with first communicating grooves 78a formed on the second substrate 12, so as to open in one of the plate surfaces of the second substrate 12. Specifically, on the second substrate 12, a first communicating groove 78a is formed orthogonally to the part constituting the first vertically linear part 51 of each second grove 32. The first communicating groove 78a exhibits a circular arc-shaped cross-section in a cross-section vertical to the extended direction thereof. The first communicating grooves 78a exhibit a shape as shown in FIG. 4 in a cross-section along the extended direction thereof. A first communicating groove 78a has a maximum depth equal to a maximum depth of a second groove 32. Openings of the first communicating groove 78a formed on the one of the plate surfaces of the second substrate 12 are sealed with a first substrate 11 which is stacked on the plate surface, to thereby form first communicating grooves 78a between adjacent first vertically linear parts 51. A first communicating part 78 has a width W1 equal to or less than a flow passage width Wa of a second flow passage 22 (flow passage width of the first vertically linear part 51). The width W1 of the first communicating part 78 is a distance from one end to the other end of the first communicating part 78 in a direction orthogonal both to the arrangement direction of the portion of the plural number of the second flow passages 22 where communication is allowed by the first communicating parts 78 (the first vertically linear part 51) and the parallel direction.

[0055] The second communicating parts 79 link the second vertically linear parts 52 of second flow passages 22 adjacent to each other, which follow the third curving

parts 63 downstream, to allow communicating with each other. The plural number of second communicating parts 79 provided on the second substrate 12 are configured similarly to the plural number of first communicating parts 78. The second vertically linear part 52 is an example of the downstream part of the present invention, and the second communicating part 79 is an example of the downstream part-communicating part of the present invention.

[0056] The third communicating parts 80 link the third vertically linear parts 53 of second flow passages 22 adjacent to each other, which follow the fifth curving parts 65 downstream, to allow communicating with each other. The plural number of third communicating parts 80 provided on the second substrate 12 are configured similarly to the plural number of first communicating parts 78. The third vertically linear part 53 is an example of the downstream part of the present invention, and the third communicating part 80 is an example of the downstream part-communicating part of the present invention.

[0057] The first supply header 3 (see FIG. 1 and FIG. 2) is attached to the structure body 2 to distribute and supply the first fluid to each inlet 21a of all the first flow passages 21 provided inside the structure body 2. The first fluid is, for example, a fluid having a low temperature. The first supply header 3 is attached to one of the short side surfaces 7 in which the inlets 21a of the first flow passages 21 open. The first supply header 3 entirely covers all the inlets 21a which open in the one of the short side surfaces 7. Thereby, the space inside the first supply header 3 communicates with each inlet 21a. To the first supply header 3, a supply pipe which is not illustrated is connected, and the first fluid supplied through the supply pipe to the first supply header 3 is to be distributed from the space inside the first supply header 3 to each inlet 21a.

[0058] The first discharge header 5 (see FIG. 1 and FIG. 2) is attached to the structure body 2 to receive the first fluid outflowed from the outlets 21b of all the first flow passages 21 provided inside the structure body 2. The first discharge header 5 is attached to the other short side surface 8 in which the outlets 21b of the first flow passages 21 open. The first discharge header 5 entirely covers all the outlets 21b which open in the other short side surface 8. Thereby, the space inside the first discharge header 5 communicates with each outlet 21b. To the first discharge header 5, a discharge pipe which is not illustrated is connected, and the first fluid outflowed from each outlet 21b to the space inside the first discharge header 5 is to be discharged through this discharge pipe.

[0059] The second supply header 4 (see FIG. 1 and FIG. 3) is attached to the structure body 2 to distribute and supply the second fluid to each inlet 22a of all the second flow passages 22 provided inside the structure body 2. The second fluid is, for example, a fluid having a higher temperature than that of the first fluid. The second supply header 4 is attached to one of the long side surfaces 9 in which the inlets 22a of the second flow passages 22 open. The second supply header 4 entirely covers all the inlets 22a which open in the one of the long side surfaces 9. Thereby, the space inside the second supply header 4 communicates with each inlet 22a. To the second supply header 4, a supply pipe which is not illustrated is connected, and the second fluid supplied through the supply pipe to the second supply header 4 is to be distributed from the space inside the second supply header 4 to each inlet 22a.

[0060] The second discharge header 6 (see FIG. 1 and FIG. 3) is attached to the structure body 2 to receive the second fluid outflowed from the outlets 22b of all the second flow passages 22 provided inside the structure body 2. The second discharge header 6 is attached to the other long side surface 10 in which the outlets 22b of the second flow passages 22 open. The second discharge header 6 entirely covers all the outlets 22b which open in the other long side surface 10. Thereby, the space inside the second discharge header 6 communicates with each outlet 22b. To the second discharge header 6, a discharge pipe which is not illustrated is connected, and the second fluid outflowed from each outlet 22b to the space inside the second discharge header 6 is to be discharged through this discharge pipe.

[0061] In the fluid circulation device 1 according to the present embodiment, since introduction parts 22c of adjacent second flow passages 22 communicate with each other through an introduction part-communicating part 75, when a blockage has occurred in an introduction part 22c, in a position upstream from the introduction part-communicating part 75, it is possible to introduce the second fluid from an introduction part 22c adjacent to the introduction part 22c in which the blockage has occurred, through the introduction part-communicating part 75 to the side downstream from the blocked spot of the introduction part 22c.

[0062] Specifically, for example, in some cases, the second fluid is a high pressure gas, and an oil having a high viscosity is mixed in the gas as a foreign substance. In some cases, the second fluid is a liquid, and a rust produced in an external pipe is mixed in the liquid as a foreign substance. In these cases, when the second fluid is distributed from the second supply header 4 to an inlet 22a of each second flow passage 22, a blockage 100 (see FIG. 5) sometimes occurs in the inlet 22a of an introduction part 22c of a second flow passage 22, due to the foreign substance included in the second fluid. In some cases, the second fluid is cooled to freeze due to a heat exchange with the first fluid, and a blockage 100 due to the freeze occurs in an inlet 22a. In these cases, the second fluid is stopped to be introduced from the inlet 22a where the blockage 100 has occurred, to an introduction part 22c which follows the inlet 22a downstream. However, in the present embodiment, since the introduction part 22c where the blockage 100 has occurred communicates with an adjacent introduction part 22c through the introduction part-communicating part 75, the second

fluid is introduced from the adjacent introduction part 22c to the introduction part 22c where the blockage 100 has occurred, through the introduction part-communicating part 75.

[0063] On the other hand, in a configuration in which introduction parts 22c of adjacent second flow passages 22 do not communicate with each other as in the comparative example shown in FIG. 7, when a blockage 100 occurs in an inlet 22a of an introduction part 22c, the second fluid is stopped to flow into the introduction part 22c. In this case, it becomes impossible to circulate the second fluid in the second flow passage 22 in which the blockage 100 has occurred at the inlet 22a thereof, this second flow passage 22 becomes not able to contribute at all to a heat exchanging treatment in the fluid circulation device 1. As a result, efficiency of the heat exchanging treatment in the fluid circulation device is significantly lowered, and thus, it is necessary to stop the circulation of the fluid to perform a maintenance work to remove the blockage 100, causing a lowering of operating rate of the fluid circulation device 1.

[0064] To the contrary, in the present embodiment, since the second fluid is introduced through an introduction part-communicating part 75 from an adjacent introduction part 22c to an introduction part 22c in the side downstream from a blockage 100 as described above, it is possible to circulate the second fluid in the second flow passage 22 in which a blockage 100 has occurred at the inlet 22a, to allow the second flow passage 22 to contribute to the treatment of heat exchanging with the first fluid flowing in a first flow passage 21. Therefore, it is possible to prevent that efficiency of a heat exchanging treatment in the fluid circulation device 1 is significantly lowered, and to conduct the heat exchanging treatment continuously for a certain period of time, without performing a maintenance work for removing a blockage 100. Thus, it is possible to prevent lowering of operating rate of the fluid circulation device 1.

[0065] In addition, since the introduction part-communicating parts 75 are provided to the non-arrangement area 2b, it is possible to prevent that a first flow passage 21 provided to the arrangement area 2a and an introduction part-communicating part 75 overlap with each other in the parallel direction to locally lower strength of the structure body 2 of the fluid circulation device 1 at the overlapping portion.

[0066] In the present embodiment, since first vertically linear parts 51 of adjacent second flow passages 22 are allowed to communicate with each other through a first communicating part 78, when a blockage has occurred in a second flow passage 22 in a position upstream from the first communicating part 78, it is possible to introduce the second fluid from a second flow passage 22 adjacent to the second flow passage 22 in which the blockage has occurred, through a first communicating part 78 to the side downstream from the blocked spot of the second flow passage 22.

[0067] Specifically, for example, a blockage 101 sometimes occurs in a first curving part 61 of a second flow passage 22, as shown in FIG. 6. In a curving part of a flow passage, since a flow of a fluid changes the orientation, a foreign object such as oil having a high viscosity is hard to flow downstream, and a blockage easily occurs. When a blockage 101 has thus occurred in a first curving part 61 of a second flow passage 22, the second fluid is stopped to flow from the upper stream to the lower stream of the second flow passage 22. However, in the present embodiment, in a first vertically linear part 51 which follows a first curving part 61 downstream, the second fluid is introduced from a first vertically linear part 51 of an adjacent second flow passage 22 through a first communicating part 78.

[0068] On the other hand, in a configuration in which first vertically linear parts 51 of adjacent second flow passages 22 do not communicate with each other as in the comparative example shown in FIG. 8, it becomes impossible to circulate the second fluid in a second flow passage 22 in which a blockage 101 has occurred in the first curving part 61. Therefore, this second fluid passage 22 becomes not able to contribute at all to a heat exchanging treatment in the fluid circulation device 1. Also in this case, it is necessary to stop the circulation of the fluid to perform a maintenance work to remove the blockage 101, and operating rate of the fluid circulation device 1 is lowered, similarly as in the above described case in which a blockage 100 has occurred at the inlet 22a. To the contrary, in the present embodiment, since the second fluid is introduced through a first communicating part 78 from a first vertically linear part 51 of an adjacent second flow passage 22 to a first vertically linear part 51, in the side downstream from a blockage 101 as described above, it is possible to circulate the second fluid in a region downstream from the first communicating part 78 of the second flow passage 22 in which a blockage 101 has occurred, to allow the second flow passage 22 to contribute to the treatment of heat exchanging with a first fluid flowing in a first flow passage 21. Thus, in the present embodiment, it is possible to prevent lowering of an operating rate of the fluid circulation device 1.

[0069] In the present embodiment, second vertically linear parts 52 of adjacent second flow passages 22 communicate with each other through a second communicating part 79. Therefore, when a blockage has occurred in a second flow passage 22 in a position upstream from the second communicating part 79, for example, when a blockage has occurred in a third curving part 63, it is possible to introduce the second fluid from a second flow passage 22 adjacent to the second flow passage 22 in which the blockage has occurred, through a second communicating part 79 to the side downstream from the blocked spot (the third curving part 63) of the second flow passage 22.

[0070] Similarly, in the present embodiment, third vertically linear parts 53 of adjacent second flow passages 22 communicate with each other through a third communicating part 80. Thus, when a blockage has occurred in

a second flow passage 22 in a position upstream from the third communicating part 80, for example, when a blockage has occurred in a fifth curving part 65, it is possible to introduce the second fluid from a second flow passage 22 adjacent to the second flow passage 22 in which the blockage has occurred, through a third communicating part 80 to the side downstream from the blocked spot (the fifth curving part 65) of the second flow passage 22.

[0071] By an effect obtained by these second communicating part 79 and the third communicating part 80, it becomes possible to prevent lowering of operating rate of the fluid circulation device 1, similarly as in the case of the first communicating part 78.

[0072] In the present embodiment, the plural number of first communicating parts 78, the plural number of second communicating parts 79 and the plural number of third communicating parts 80 are all lined up in a direction orthogonal to the first flow passages 21 that overlap with the communicating parts 78, 79 and 80 in the stacked direction. Thus, it is possible to prevent formation of a portion with a lowered strength in the structure body 2 due to the communicating parts and the first flow passages, as in a case where the lined up direction of the communicating parts agrees with the extended direction of the first flow passages which overlap with the communicating parts.

[0073] In the present embodiment, since the introduction part-communicating parts 75 and the first to third communicating parts 78, 79 and 80 have a width equal to or less than a flow passage width of the second flow passages 22, it is also possible to prevent lowering of a pressure-resistance property of the structure body 2 at a spot of the introduction part-communicating parts 75 and the first to third communicating part 78, 79 or 80.

[0074] The fluid circulation device according to the present invention is not necessarily limited to those having the structure as described above. For example, the following structures are also adoptable as the fluid circulation device according to the present invention

[0075] The communicating parts according to the present invention are not necessarily limited to those as the introduction part-communicating parts or the first to third communicating parts as described above. That is, in the second substrate, it is also possible to provide a communicating part for linking adjacent second flow passages 22 to each other to allow communicating with each other in a spot other than the spots provided with the introduction part-communicating part or the first to third introduction parts. For example, it is possible to dispose a plural number of communicating parts to positions adjacent downstream to the curving parts of each second flow passage, in a line along the direction in which the curving parts of the each second flow passage are lined up.

[0076] The arrangement and shape of the first flow passages may be other than the arrangement and the shape described above, and the arrangement and shape of the second flow passages may be other than the arrangement and the shape described above. For example, it is possible that both of the first flow passages and the second flow passages have a shape extended linearly. It is also possible that both of the first flow passages and the second flow passages have a meandering shape. Further, various shapes other than linear shapes or meandering shapes are adoptable as the shapes of the first flow passages and the second flow passages.

[0077] It is also possible that the first flow passages (the first grooves) are provided to one of the plate surfaces of a substrate, and the second flow passages (the second grooves) are provided to the other plate surface of the substrate which is provided with the first flow passages (the first grooves).

[0078] The plural number of communicating parts are not necessarily lined up in a line. That is to say, it is also possible that the plural number of communicating parts are disposed with being shifted from each other in a direction along the circulating direction of the fluid in the second flow passages. In this case, it is possible to better control partial lowering of strength of the structure body of the fluid circulation device.

[0079] It is not always necessary that all the large number of second flow passages arranged in a second substrate communicate with one another. That is to say, it is only necessary that, at least a pair of adjacent second flow passages communicate with each other through a communicating part, among the large number of second flow passages arranged on a second substrate.

[0080] The maximum depth of a communicating groove constituting a communicating part may be smaller than a maximum depth of a second flow passage groove.

[0081] The fluid circulation device according to the present invention is not necessarily limited to those used as a heat exchanger. For example, the fluid circulation device of the present invention may be used in a reaction vessel for producing a chemical reaction of fluids, with circulating the fluids in flow passages. The fluid circulation device according to the present invention may also be used in an extraction device for extracting a specific component from a fluid to be subjected to the extraction to an extractant, with circulating the extractant and the fluid to be subjected to the extraction in flow passages.

[0082] Provided is a fluid circulation device capable of preventing that efficiency of a treatment by a fluid circulation is significantly lowered, even in a case where a blockage has occurred in a micro-channel, to prevent lowering of an operating rate. The fluid circulation device 1 is provided with a structure body 2 comprising: a plural number of second flow passages 22 extended in a direction, and at the same time, arranged so as to be lined up in a direction intersecting the direction, each for circulating a second fluid; and introduction part-communicating parts 75, first to third communicating parts 78, 79 and 80 for linking second flow passages 22 adjacent to each other in the arrangement direction of the plural number of second flow passages 22 to allow communicating with

each other; formed therein.

Claims

1. A fluid circulation device for circulating a fluid comprising a structure body which comprises:

   a plural number of micro-channels extended in a direction, and at the same time, arranged so as to be lined up in a direction intersecting the direction, each for circulating the fluid; and
   at least one communicating part for linking micro-channels adjacent to each other in an arrangement direction of the plural number of micro-channels to each other, to allow communicating with each other; formed inside of the structure body.

2. The fluid circulation device according to claim 1, wherein:

   the plural number of micro-channels comprises a plural number of first micro-channels extended in a direction, and at the same time, arranged so as to be lined up in a direction intersecting the direction in the structure body, each for circulating the first fluid, and a plural number of second micro-channels disposed in a parallel direction vertical both to the extended direction of the first fluid passages and the arrangement direction of the first fluid passages in the structure body, with being spaced from the row of the plural number of first micro-channels, and at the same time, arranged in parallel with the row of the first micro-channels, each for circulating the second fluid;
   the structure body comprises an arrangement area with the plural number of first micro-channels arranged therein, and a non-arrangement area positioned outside the arrangement area, with no first micro-channel arranged therein, when the structure body is viewed from the parallel direction; and
   the at least one communicating part comprises a non-arrangement area-communicating part which is provided to the non-arrangement area, allowing second micro-channels adjacent to each other to communicate with each other.

3. The fluid circulation device according to claim 2, wherein:

   each of the second micro-channels comprises an introduction part which is a part disposed in the non-arrangement area, and is a part extended over a predetermined area in a side downstream from an inlet of the second micro-channel; and
   the non-arrangement area-communicating part allows the introduction parts of the second micro-channels adjacent to each other to communicate with each other.

4. The fluid circulation device according to any one of claims 1 to 3, wherein:

   each of the micro-channels comprises a curving part and a downstream part which follows the curving part downstream; and
   the at least one communicating part comprises a downstream part-communicating part for allowing the downstream parts of the micro-channels adjacent to each other to communicate with each other.

5. The fluid circulation device according to claim 1, wherein:

   the plural number of micro-channels comprises a plural number of first micro-channels extended in a direction, and at the same time, arranged so as to be lined up in a direction intersecting the direction in the structure body, each for circulating the first fluid, and a plural number of second micro-channels disposed in a parallel direction vertical both to the extended direction of the first fluid passages and the arrangement direction of the first fluid passages in the structure body, with being spaced from the row of the plural number of first micro-channels, and at the same time, arranged in parallel with the row of the first micro-channels, each for circulating the second fluid;
   the structure body comprises an arrangement area with the plural number of first micro-channels arranged therein, and a non-arrangement area positioned outside the arrangement area, with no first micro-channel arranged therein, when the structure body is viewed from the parallel direction;
   the at least one communicating part comprises a plural number of arrangement area-communicating parts which are provided to the arrangement area, allowing parts of adjacent second micro-channels disposed in the arrangement area to communicate with each other;
   the plural number of arrangement area-communicating parts are lined up in a direction intersecting the first flow passage which overlaps with the arrangement area-communicating parts, when the structure body is viewed from the parallel direction.

6. The fluid circulation device according to claim 1, wherein the communicating part has a width equal

to or less than a flow passage width of the micro-channel.

FIG. 1

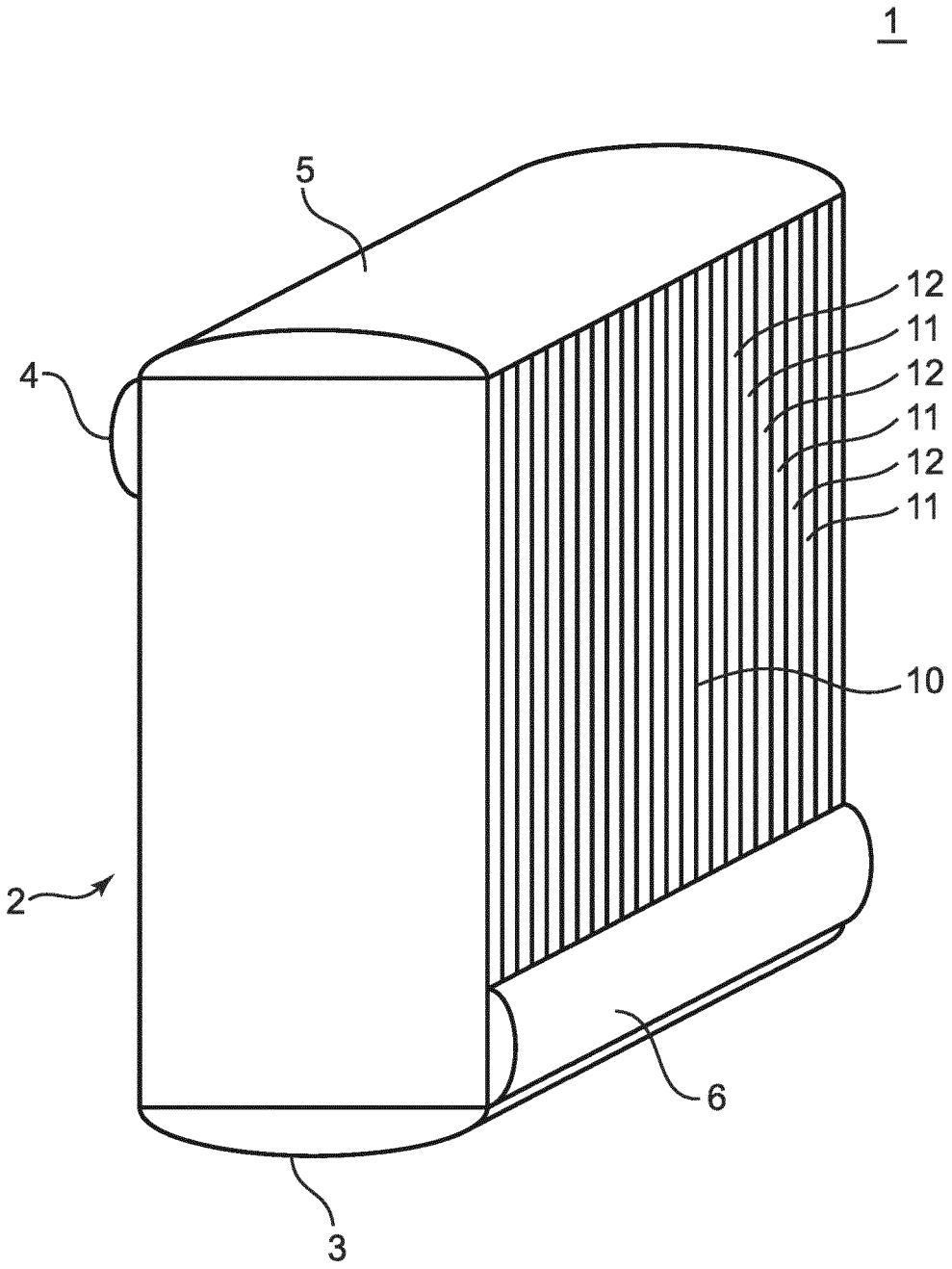


FIG. 2

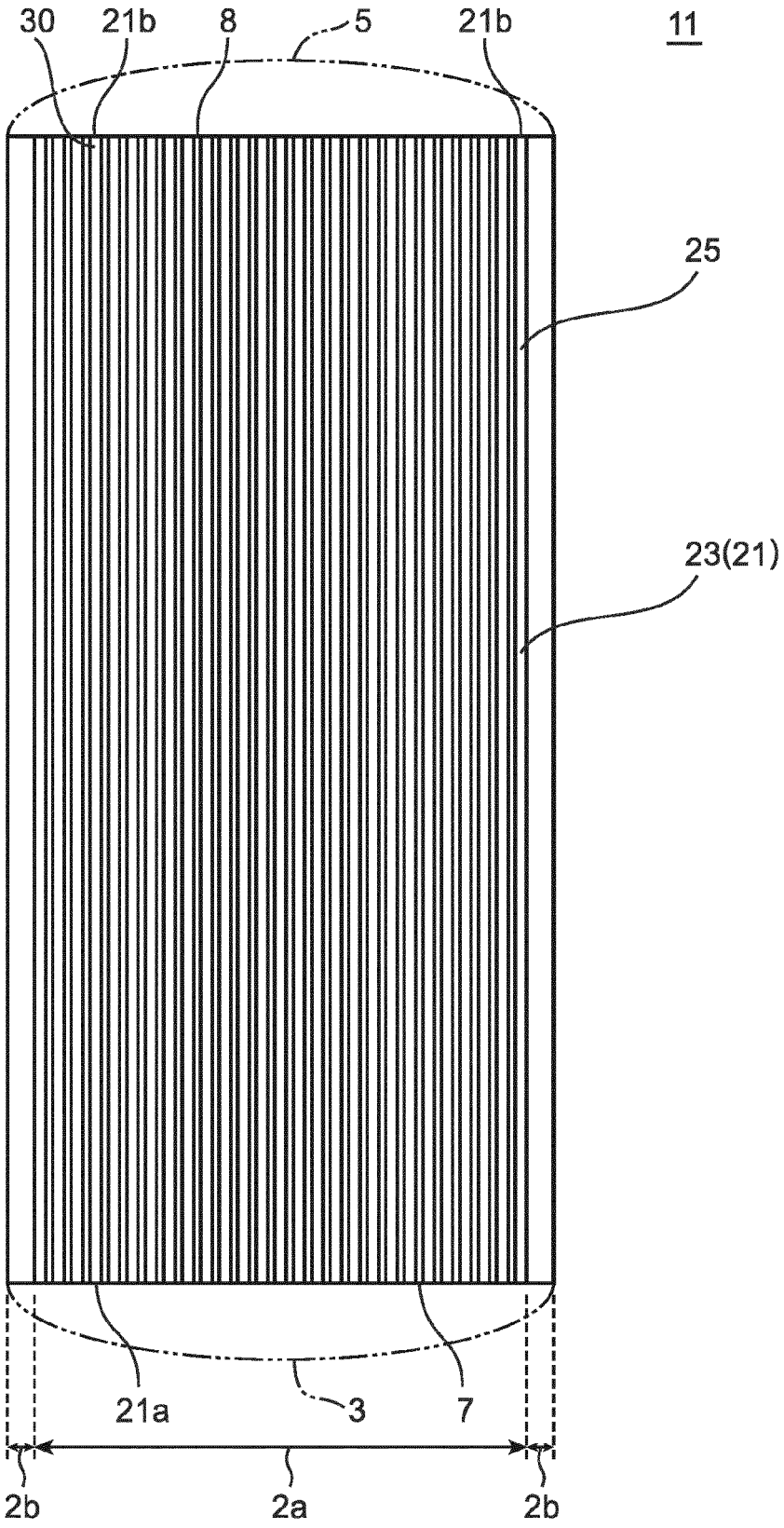


FIG. 3

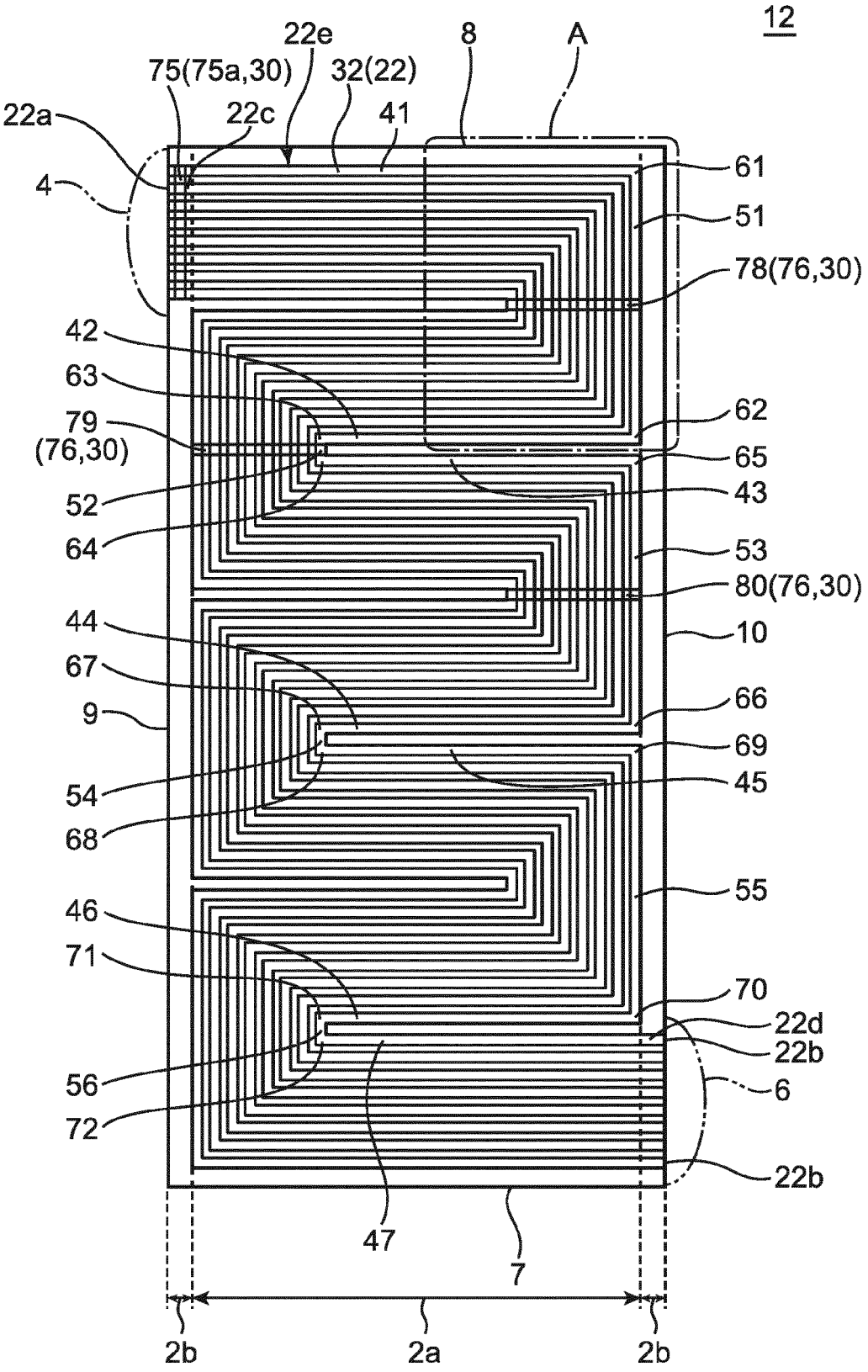

12
22e
8
A
75(75a,30)
32(22)
22a
22c
41
4
61
51
78(76,30)
42
63
79
(76,30)
62
65
52
43
64
53
80(76,30)
44
10
67
66
9
69
54
45
68
55
46
71
70
22d
22b
56
6
72
22b
47
7
2b
2a
2b

FIG. 4

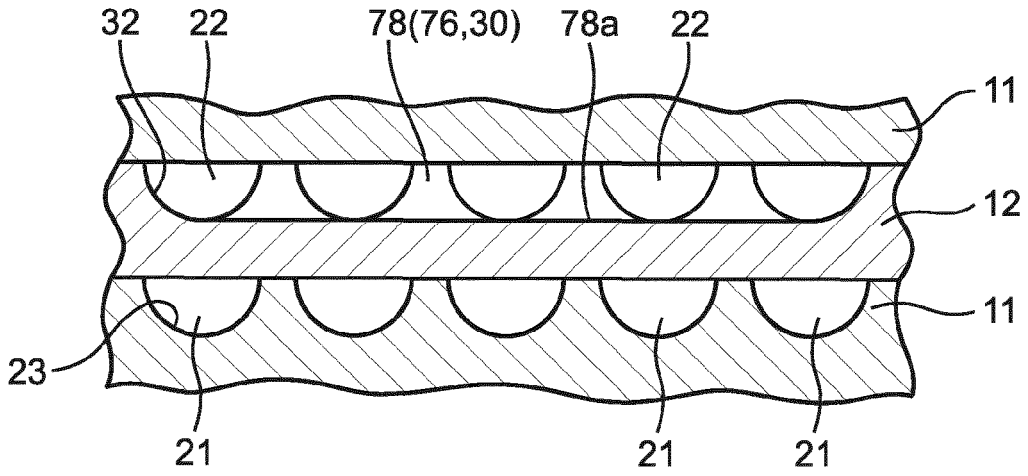

32
22
78(76,30)
78a
22
11
12
11
23
21
21
21

FIG. 5

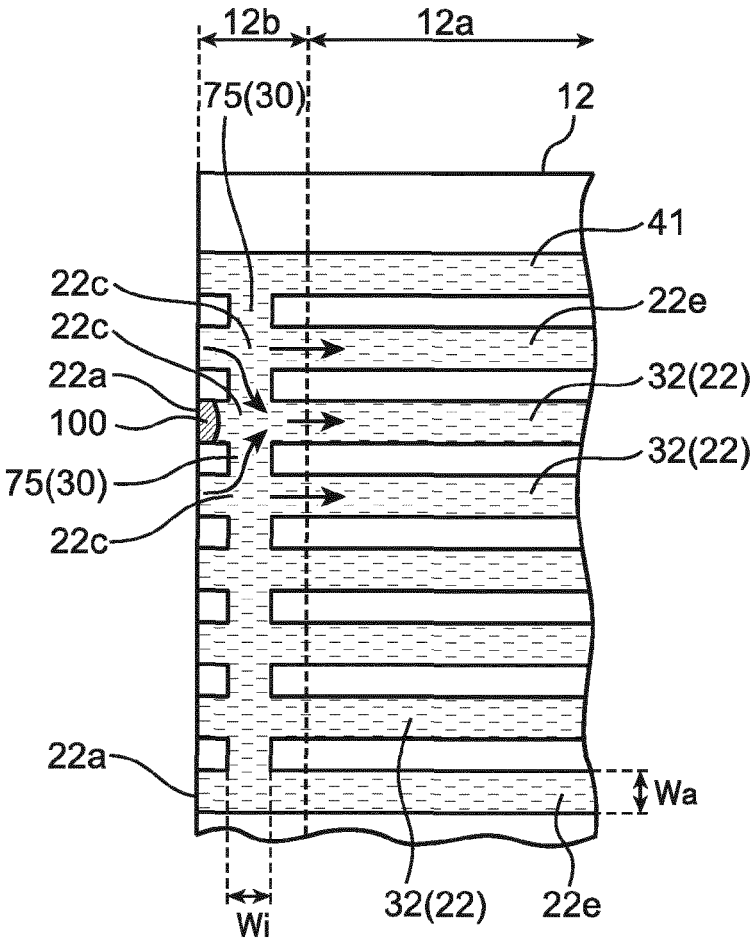

12b
12a
75(30)
12
41
22c
22e
22c
22a
32(22)
100
75(30)
32(22)
22c
22a
Wa
Wi
32(22)
22e

FIG. 6

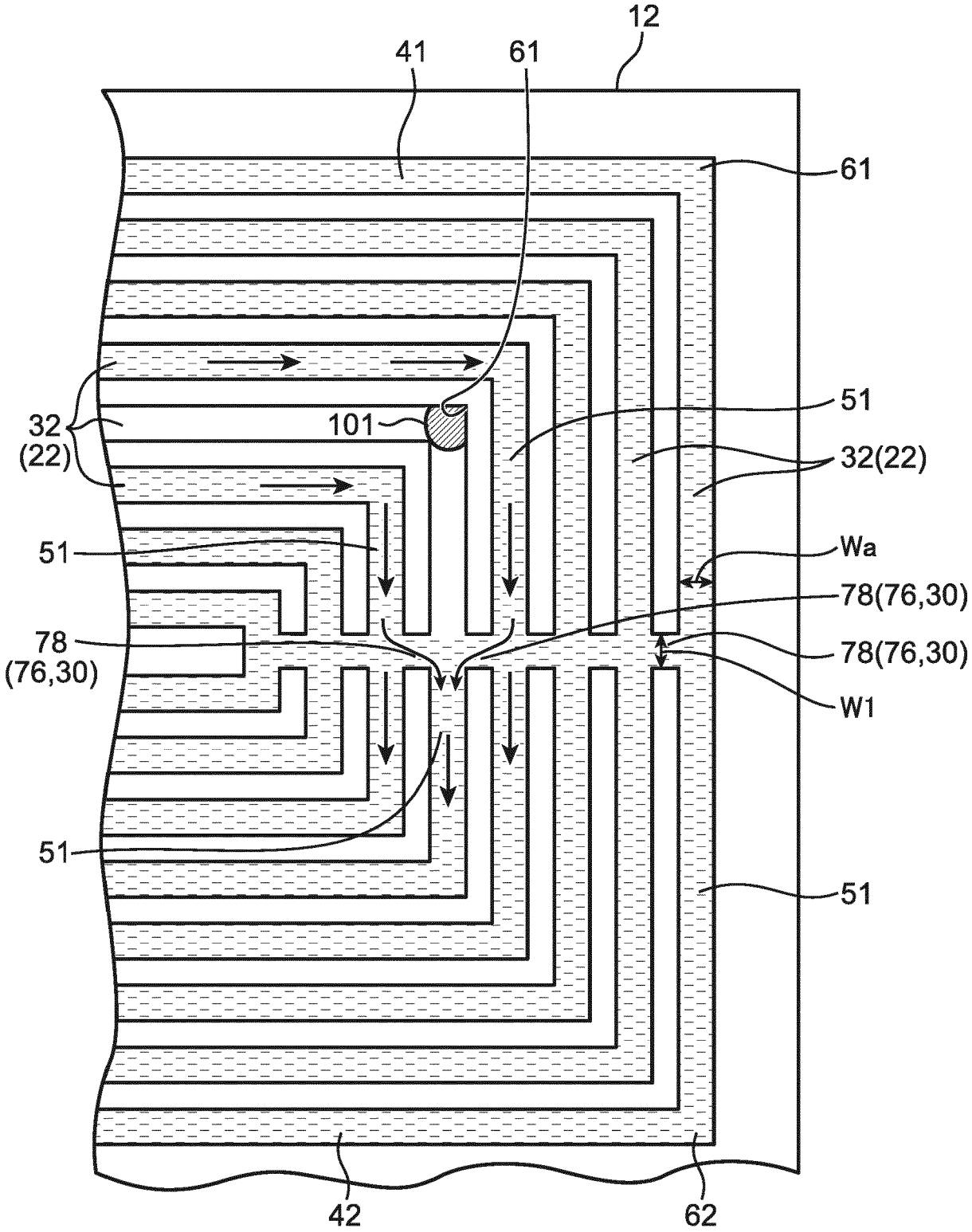

12
41
61
61
51
32
(22)
101
32(22)
51
Wa
78(76,30)
78
(76,30)
78(76,30)
W1
51
51
42
62

FIG. 7

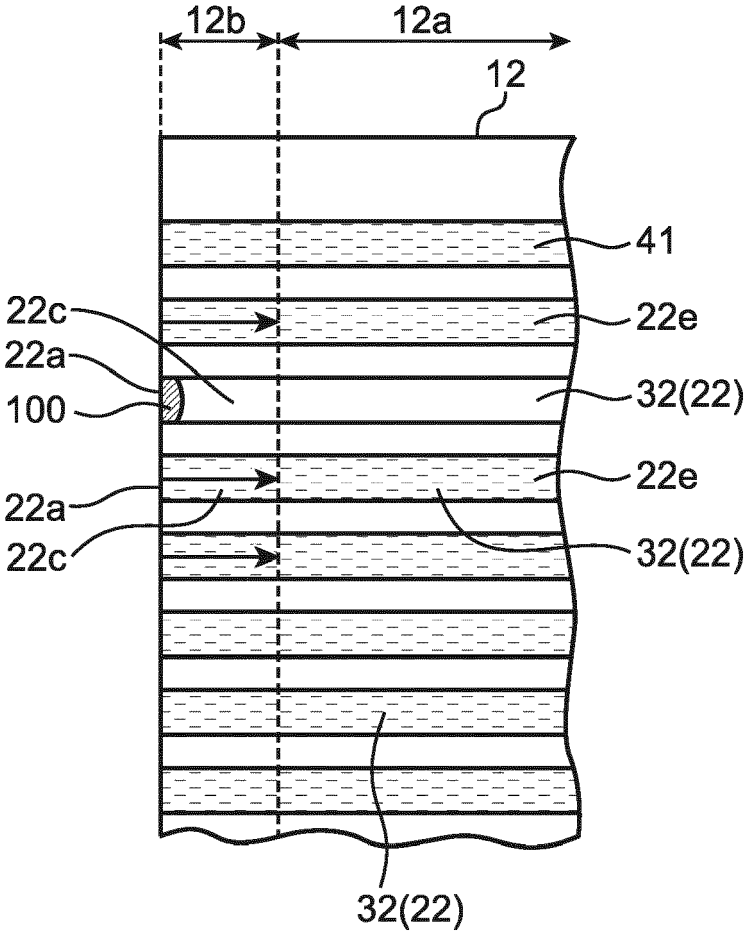
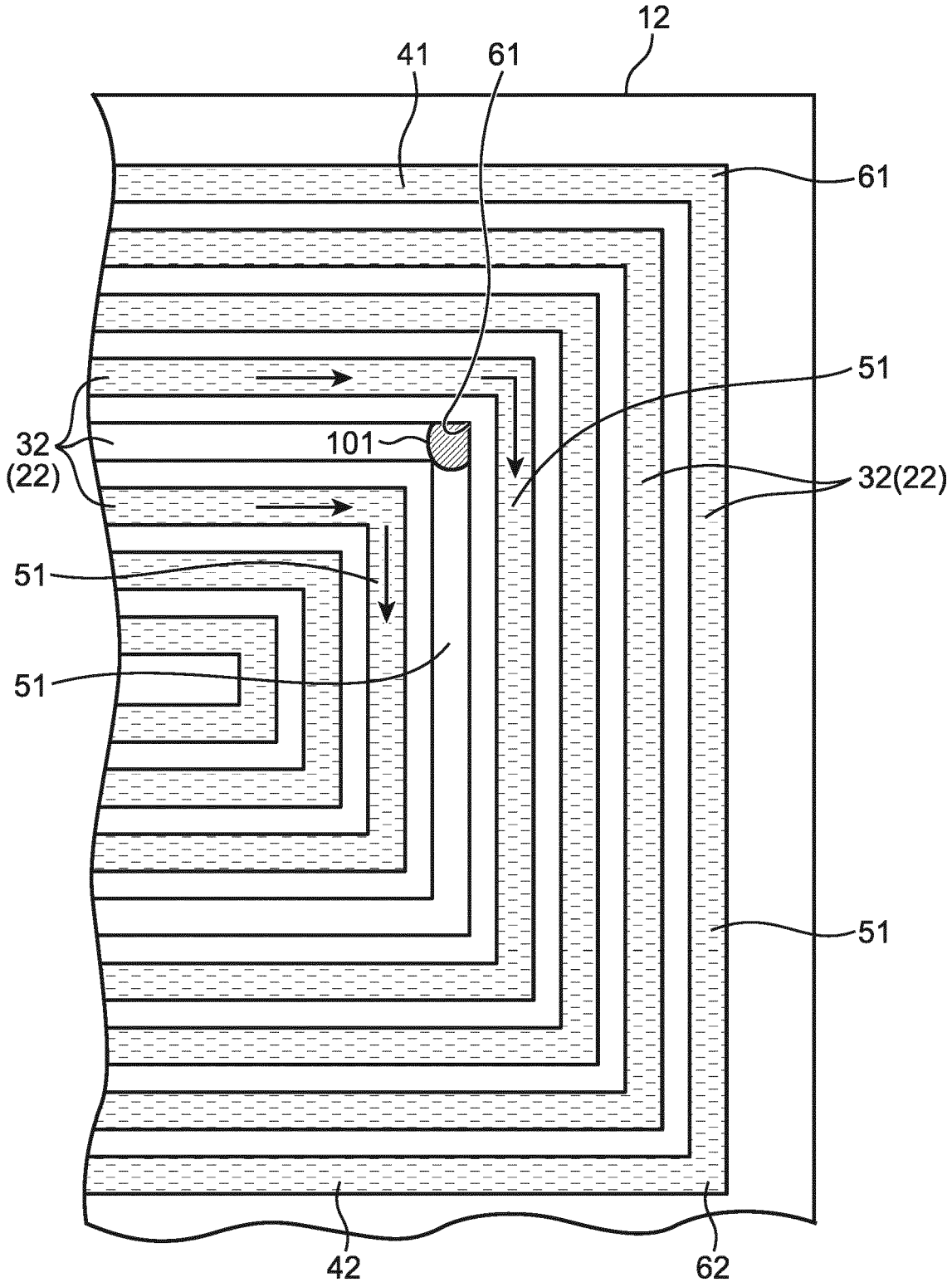


FIG. 8



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EUROPEAN SEARCH REPORT

Application Number
EP 17 20 4391

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	5 April 2018	Martínez Rico, Celia

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05-04-2018

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