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(19) **United States**(12) **Patent Application Publication****Yamamoto et al.**(10) **Pub. No.: US 2007/0029070 A1**(43) **Pub. Date: Feb. 8, 2007**(54) **SHEET TYPE FLUID CIRCULATING
APPARATUS AND ELECTRONIC DEVICE
COOLER STRUCTURE USING THE SAME**(30) **Foreign Application Priority Data**

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(76) Inventors: **Kenichi Yamamoto**, Osaka (JP); **Teruo Maruyama**, Osaka (JP); **Akio Mitsuhashi**, Osaka (JP); **Daisuke Suetsugu**, Osaka (JP); **Keizaburo Kuramasu**, Kyoto (JP)**Publication Classification**

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Correspondence Address:

WENDEROTH, LIND & PONACK L.L.P.
2033 K. STREET, NW
SUITE 800
WASHINGTON, DC 20006 (US)

(57) **ABSTRACT**

A sheet type fluid circulating apparatus includes: a fluid path having a closed structure provided in an inner space of a stacked flexible sheet; fluid filled in the fluid path; a fluid transport unit provided in at least a part of the fluid path of the flexible sheet to circulate the fluid in the fluid path; and a control circuit unit for controlling the fluid transport unit. A flexible compact light-weight sheet type fluid circulating apparatus can be provided, and a circuit board or a specimen in a biomedical process can be individually and optimally cooled.

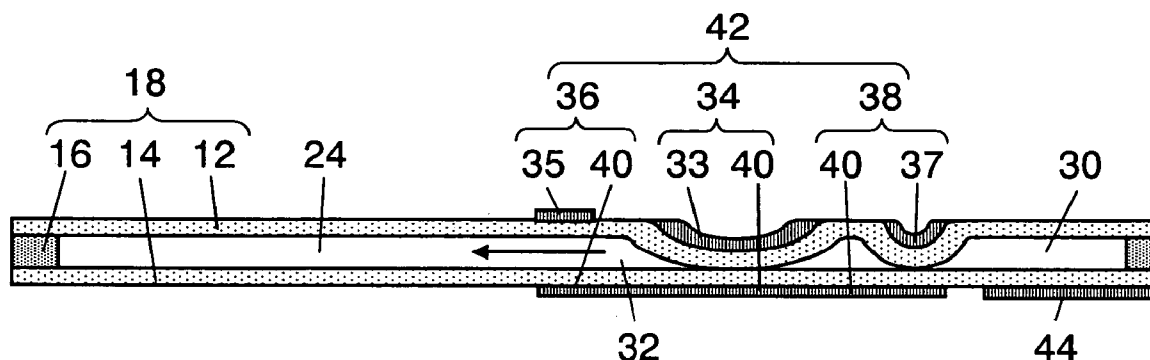
(21) Appl. No.: **11/493,486**(22) Filed: **Jul. 27, 2006**

FIG.1A

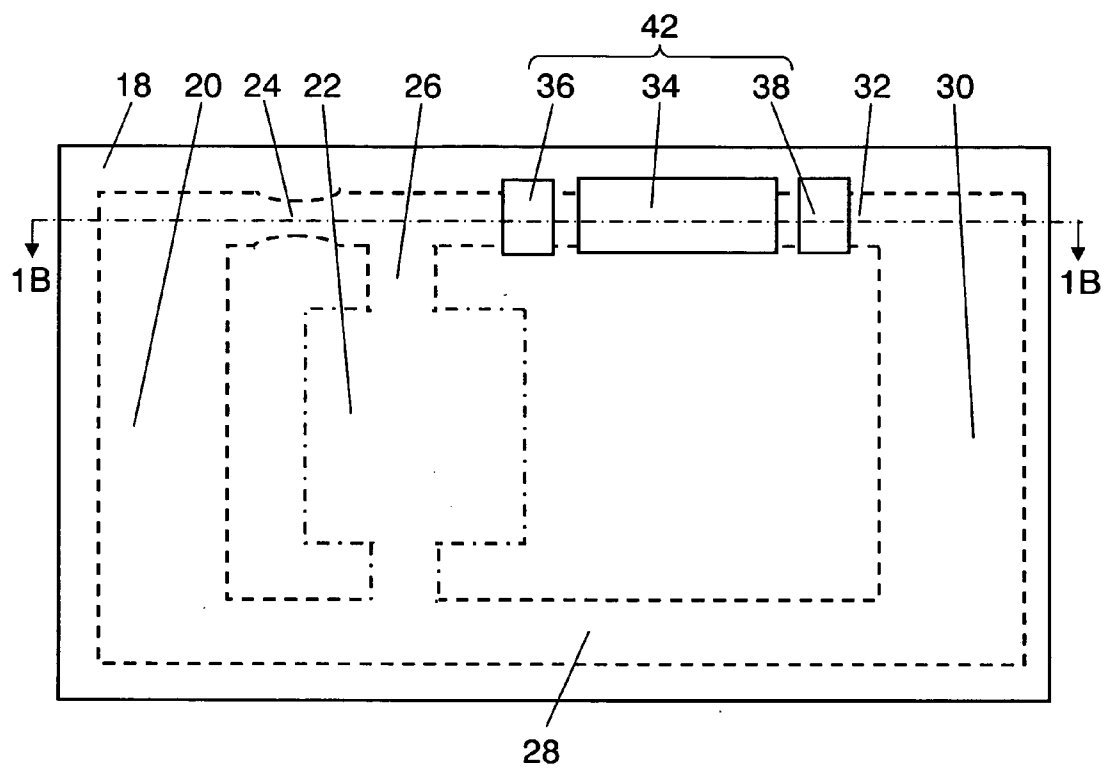


FIG.1B

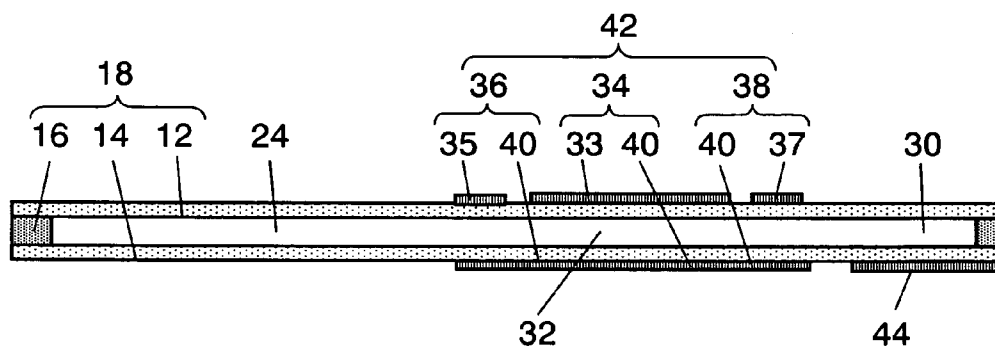


FIG.2A

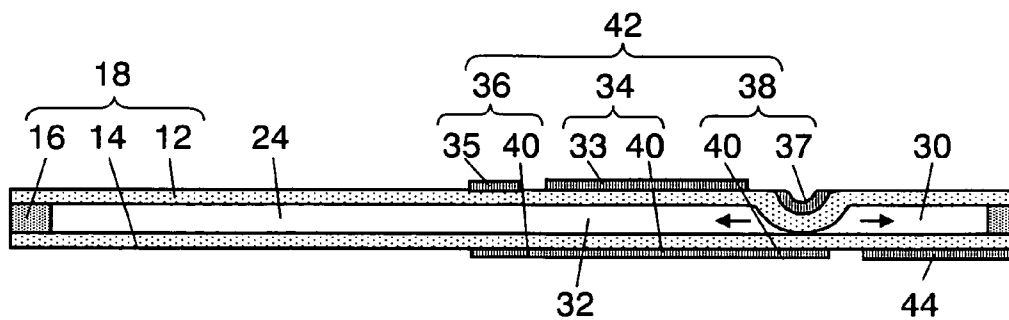


FIG.2B

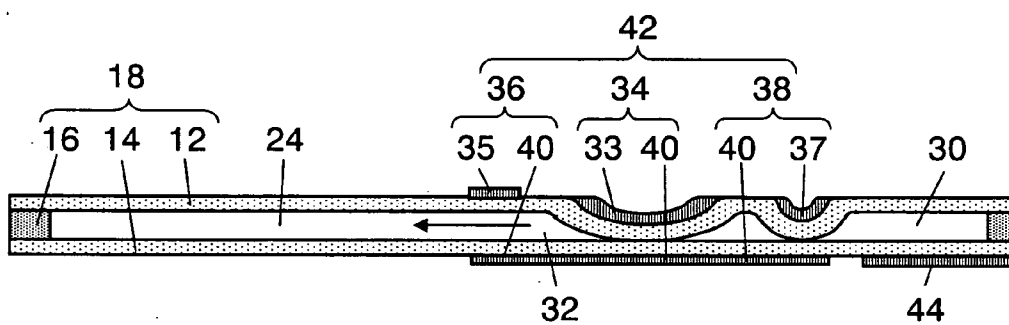


FIG.2C

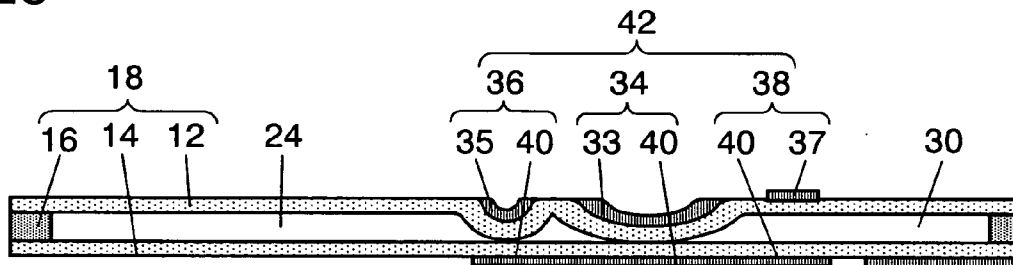


FIG.2D

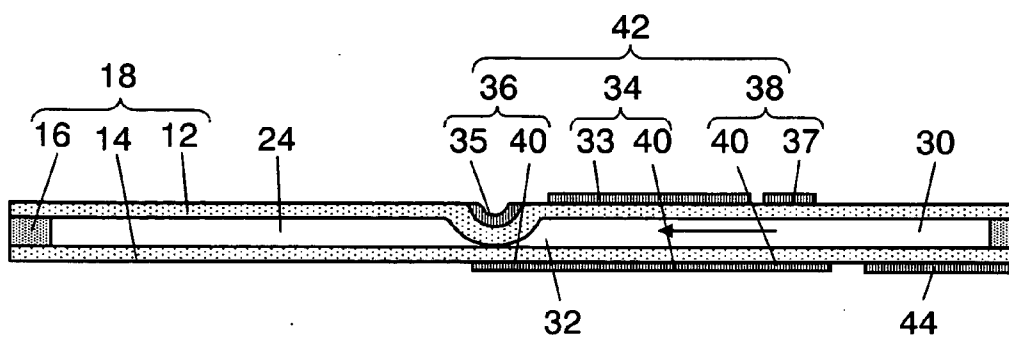


FIG.3

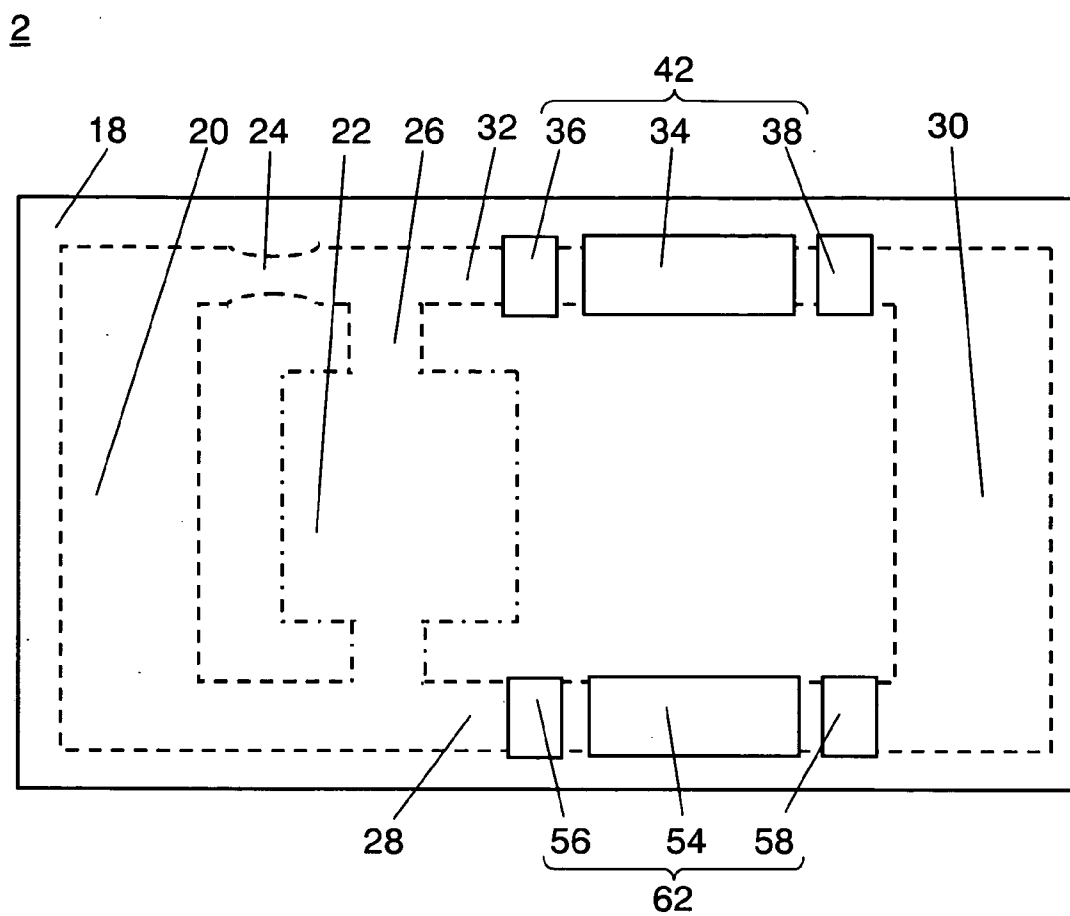


FIG.4

3

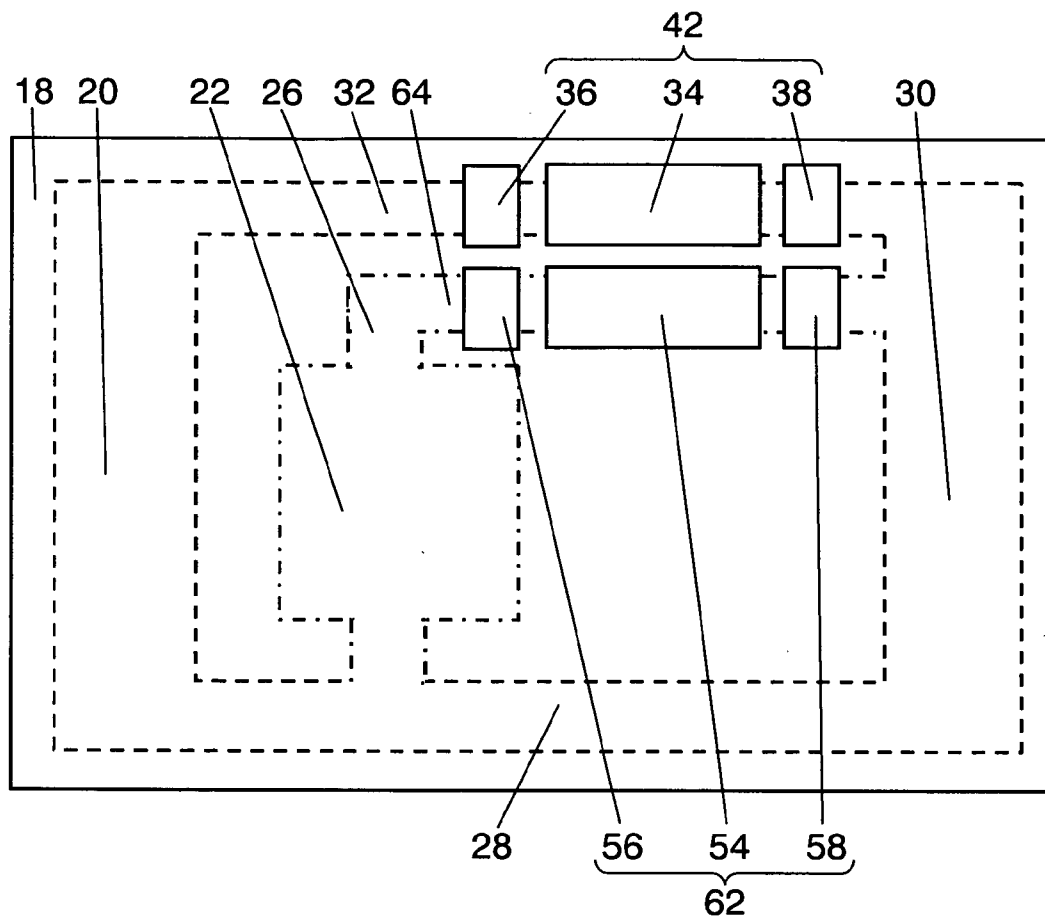


FIG.5A

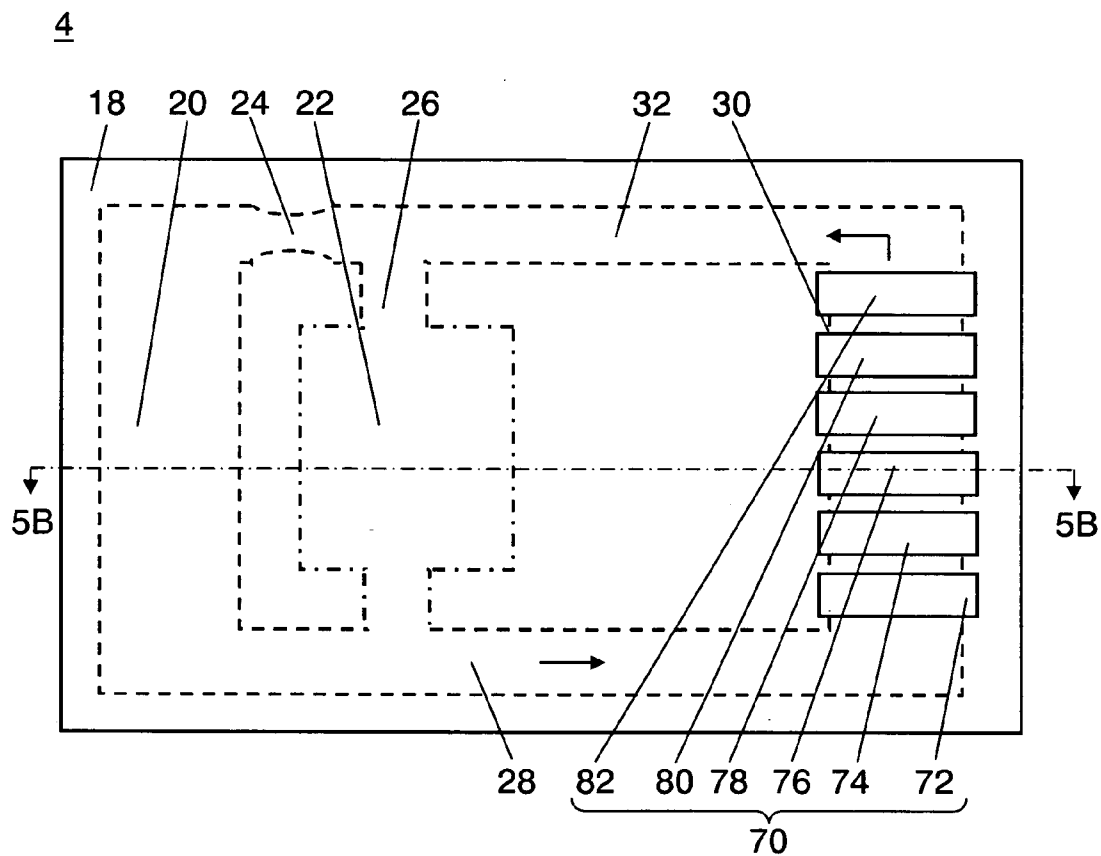


FIG.5B

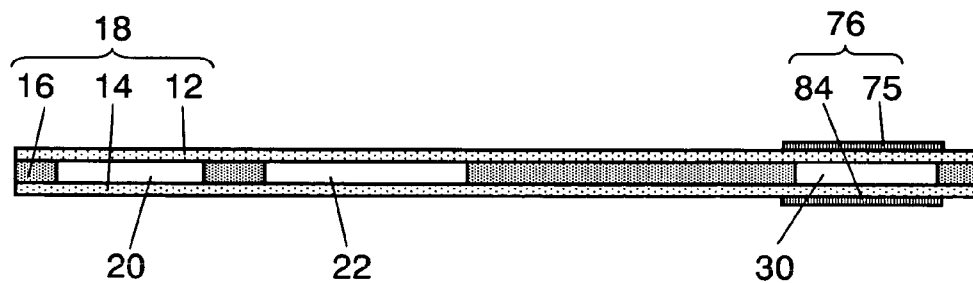


FIG.6A

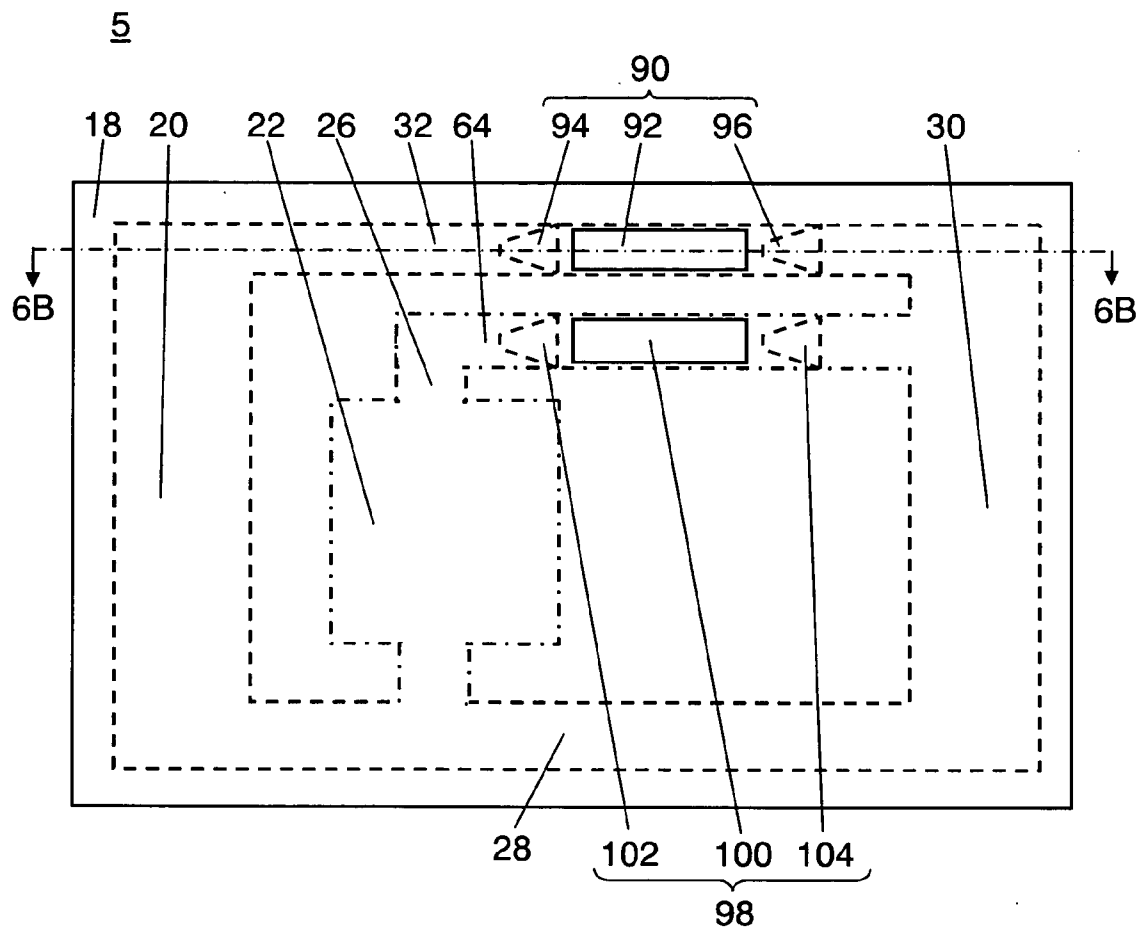


FIG.6B

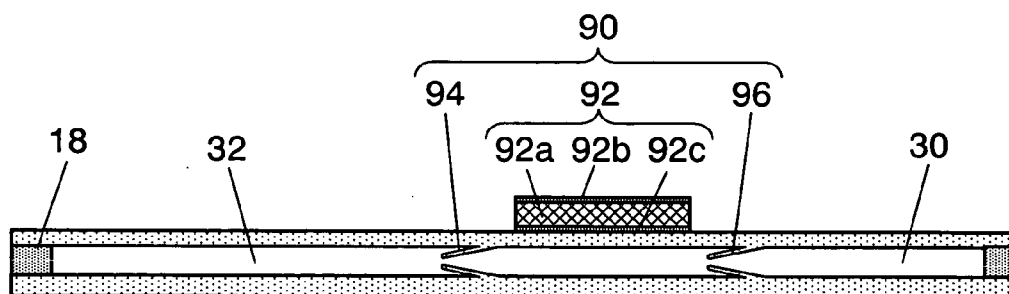


FIG.7A

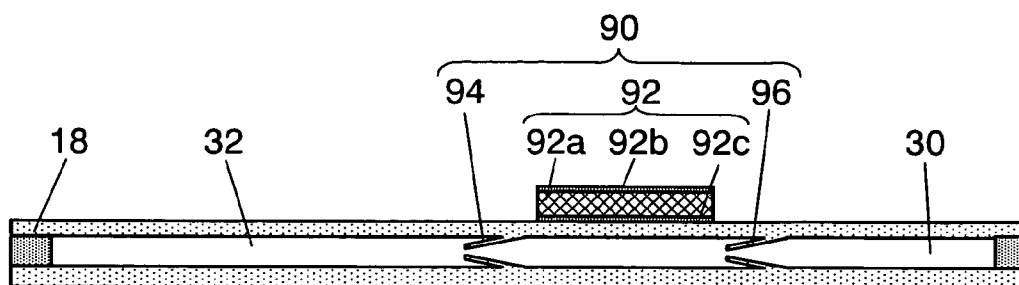


FIG.7B

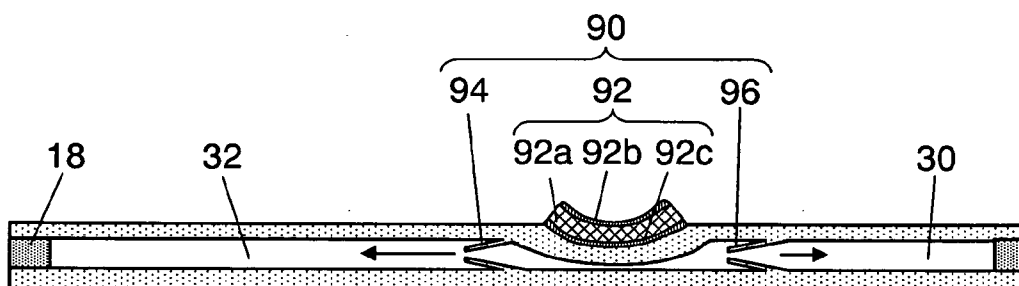


FIG.7C

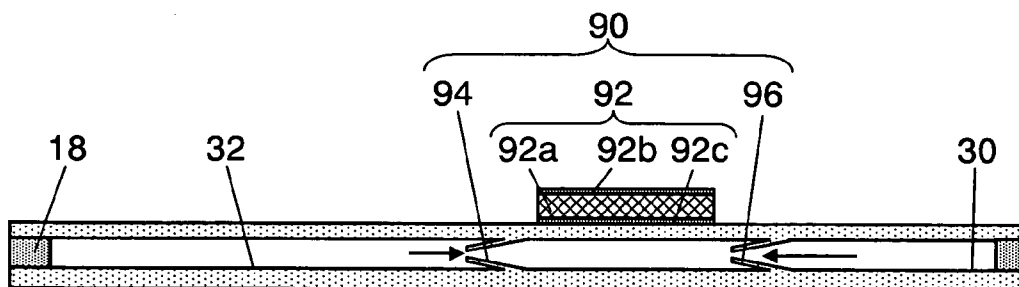


FIG.8A

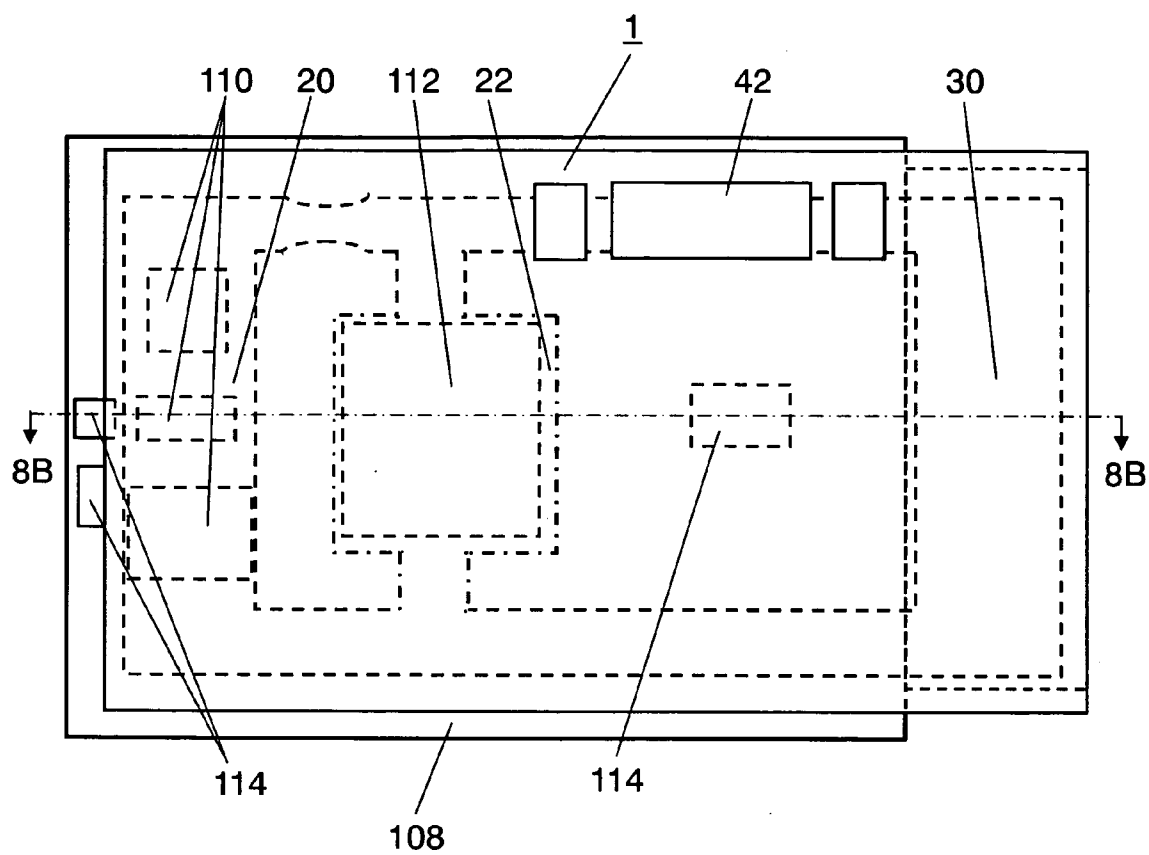


FIG.8B

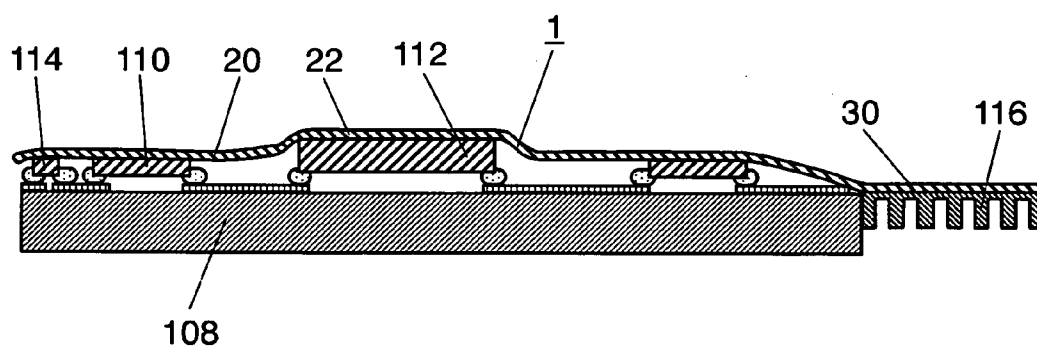


FIG.9A

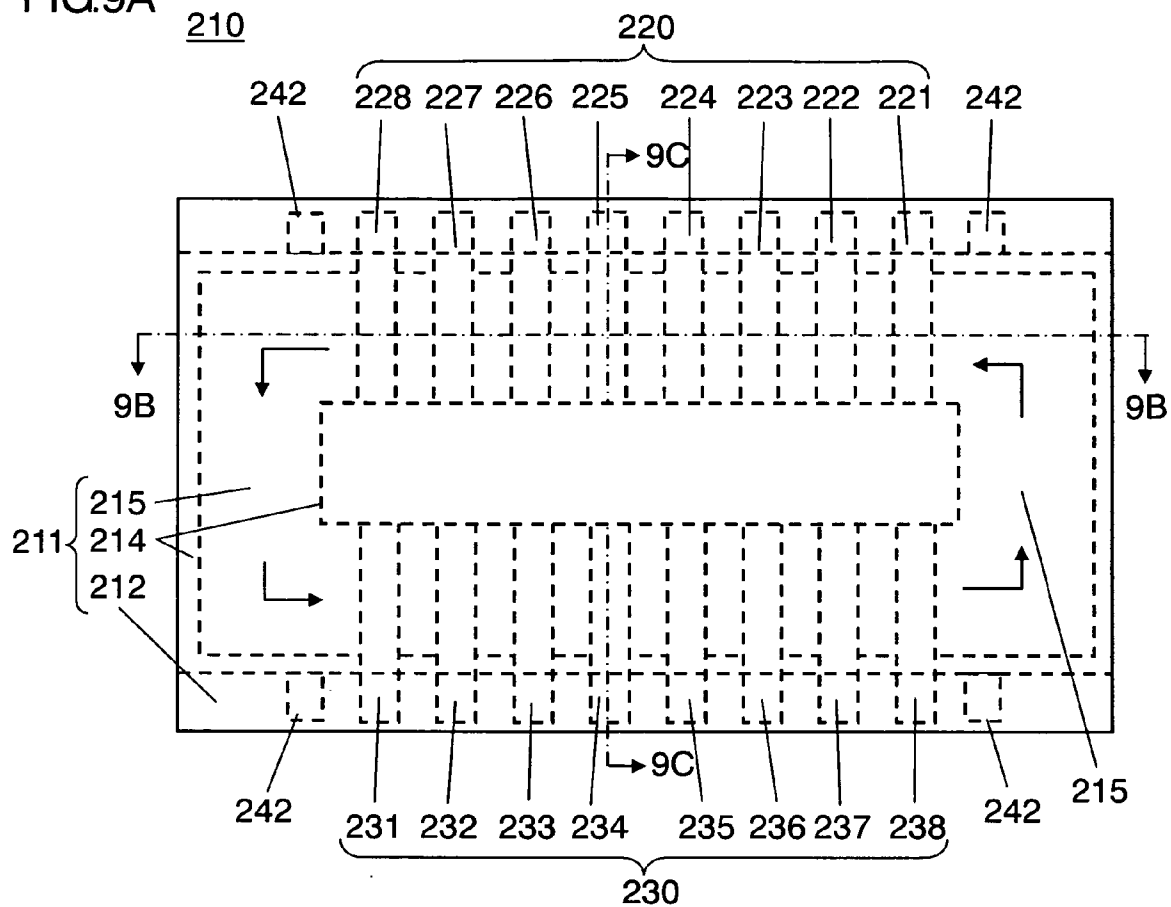


FIG.9B

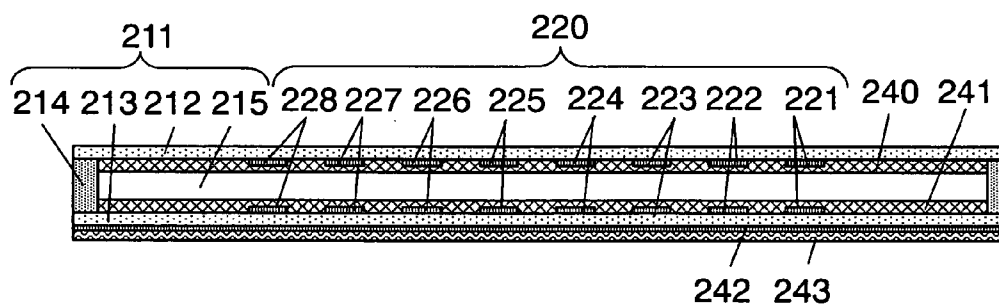


FIG.9C

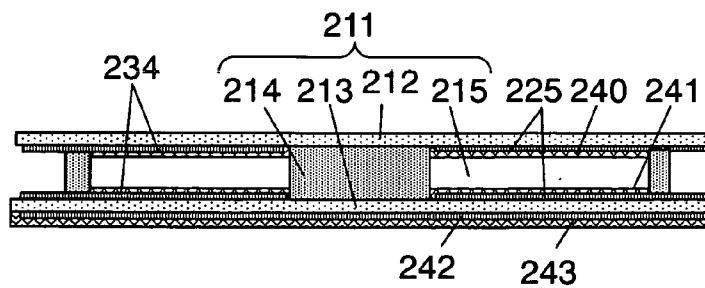


FIG.10A

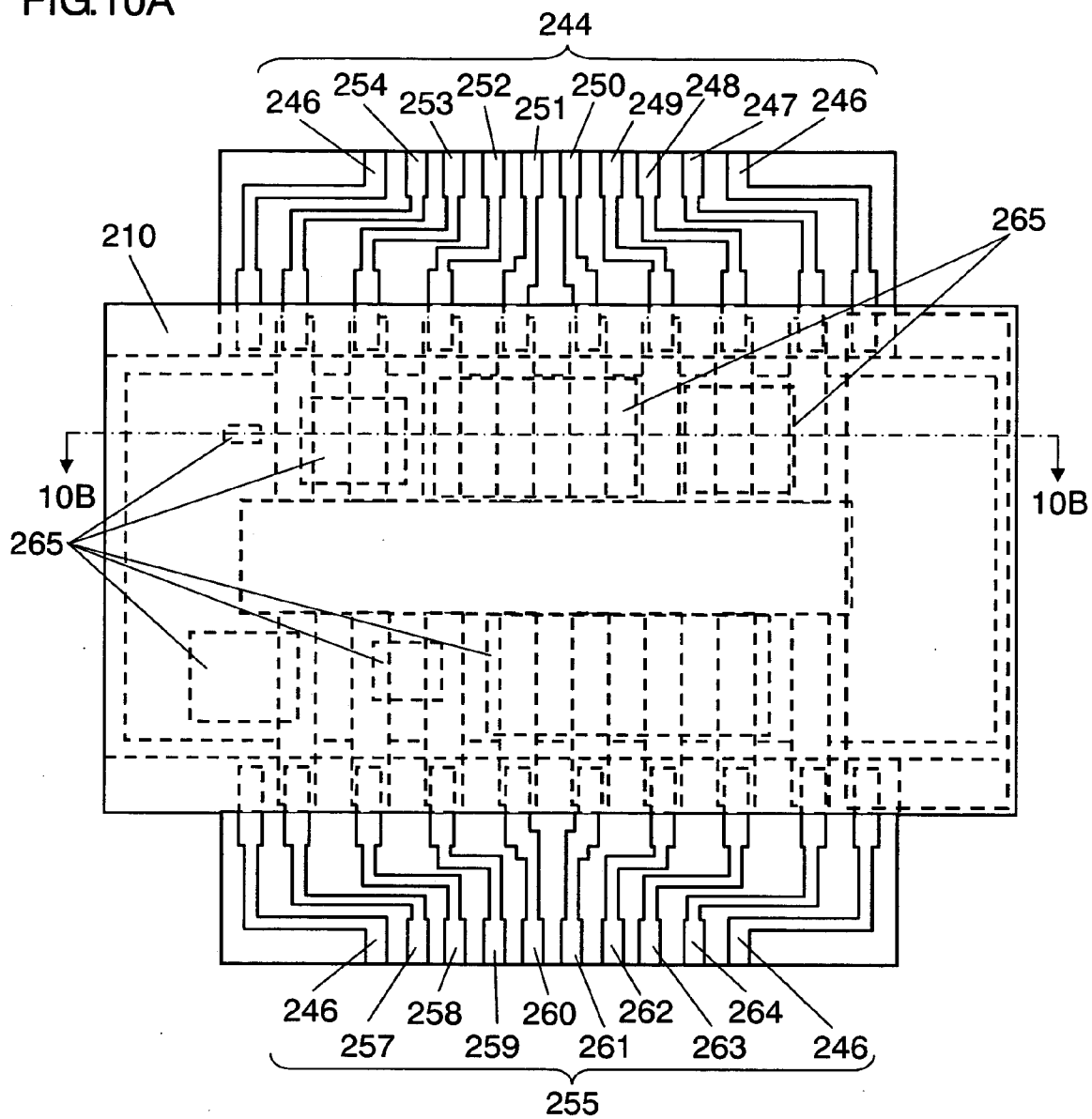


FIG.10B

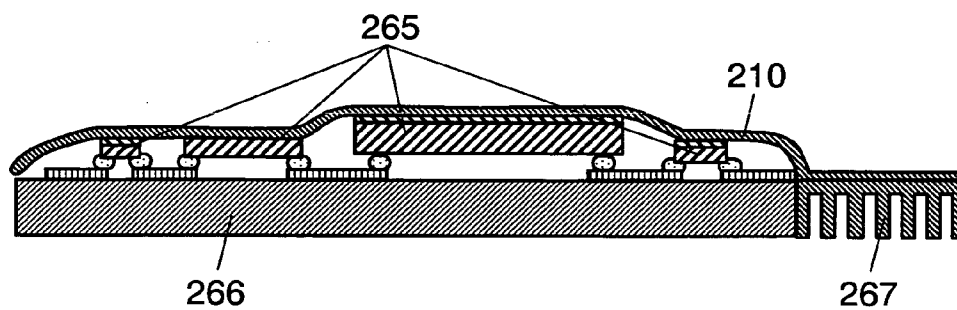


FIG.11

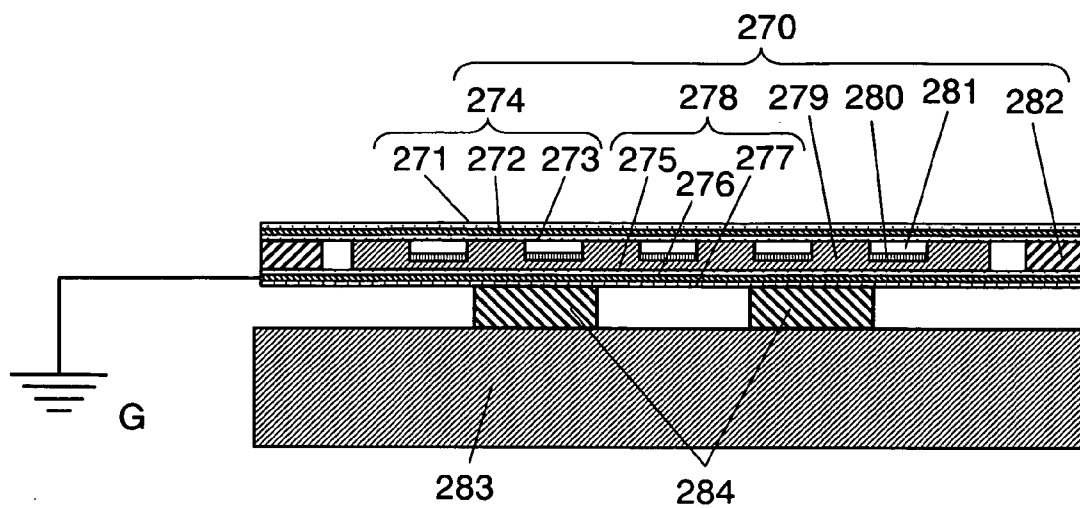


FIG.12A

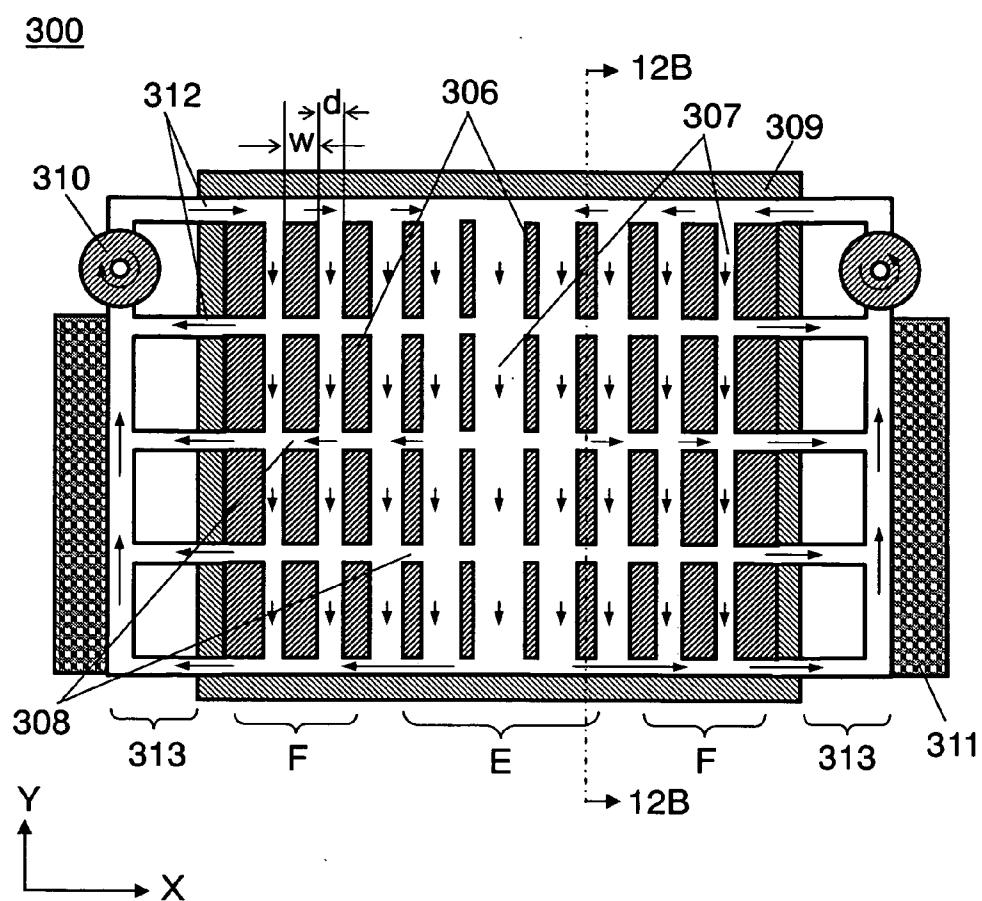


FIG.12B

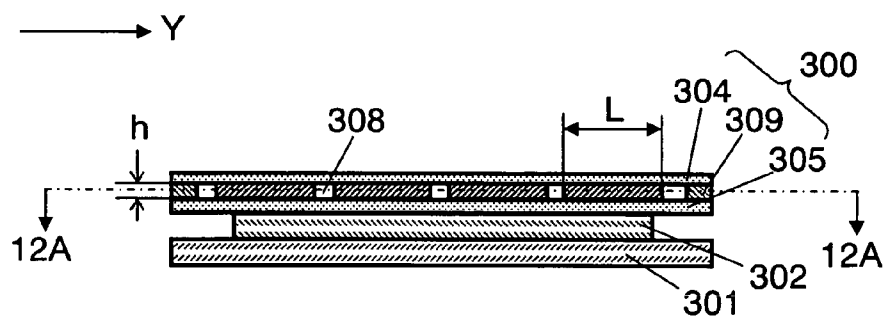


FIG.13A

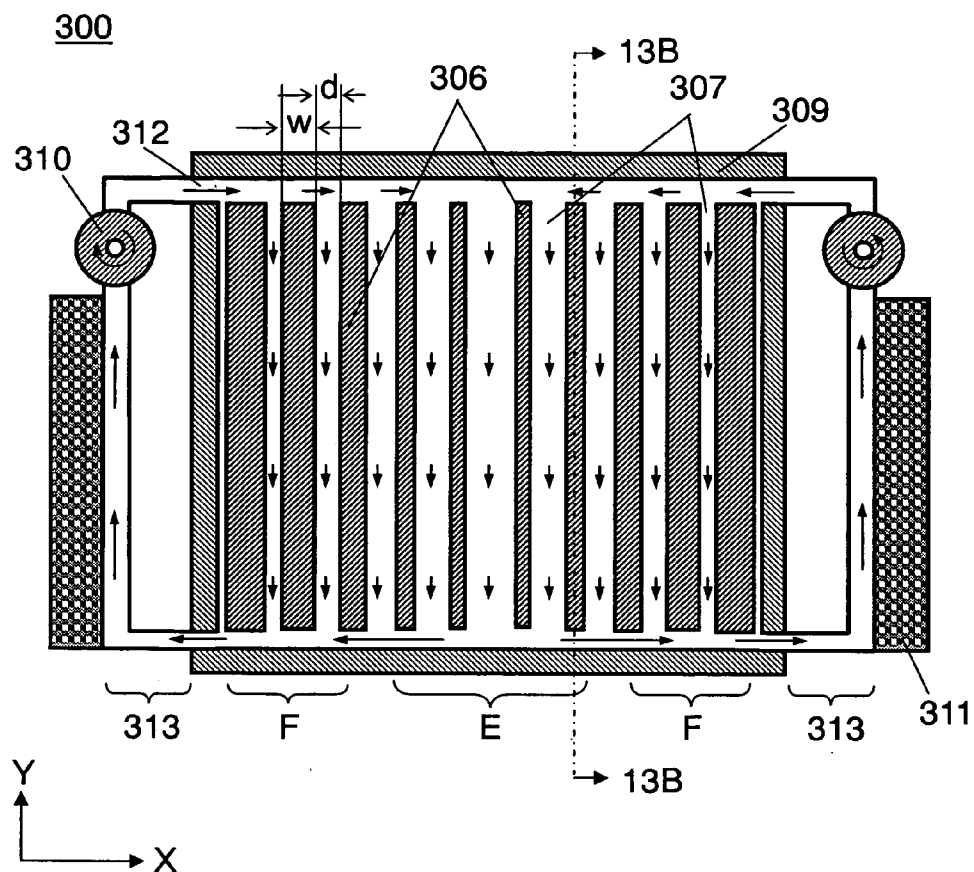


FIG.13B

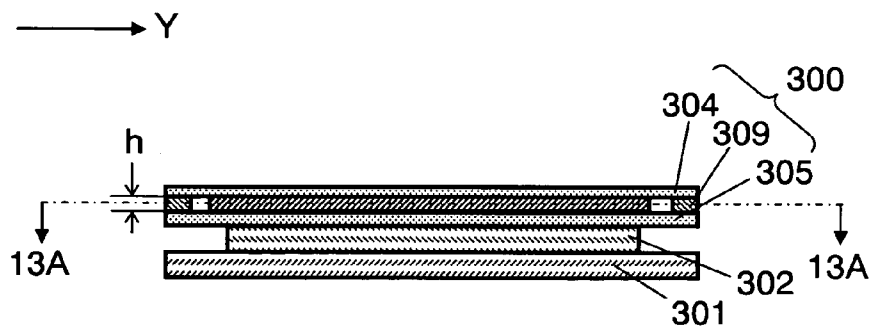


FIG.14

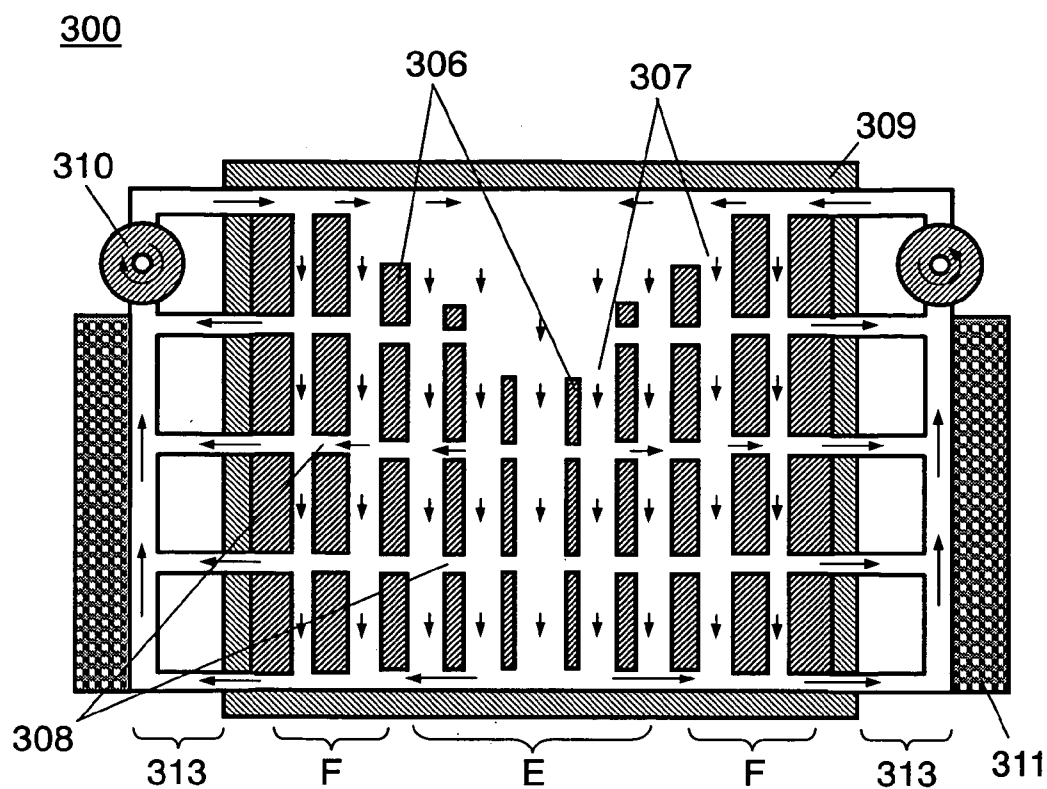


FIG.15A

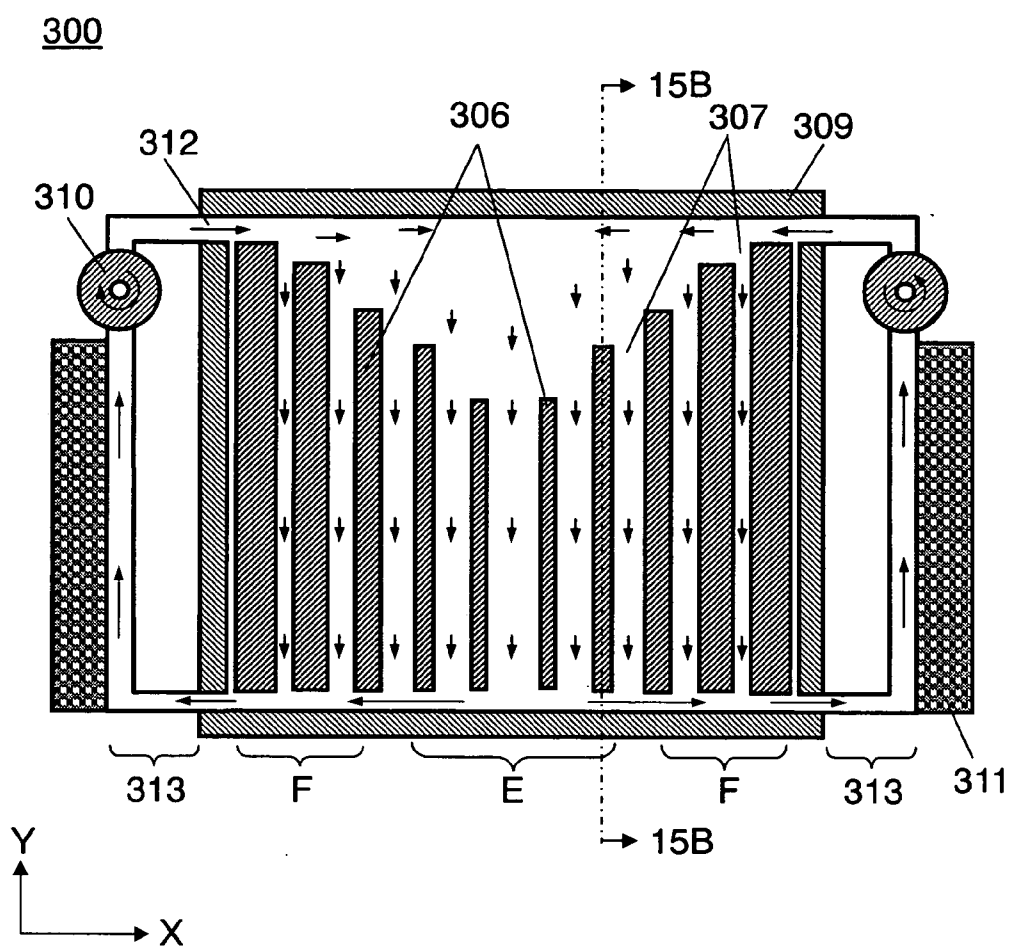


FIG.15B

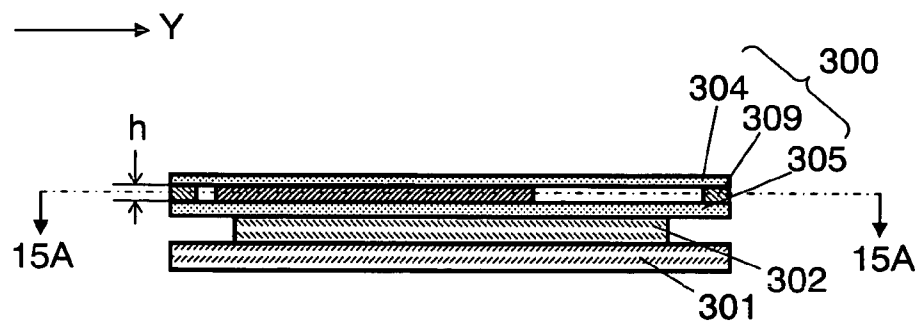


FIG.16A

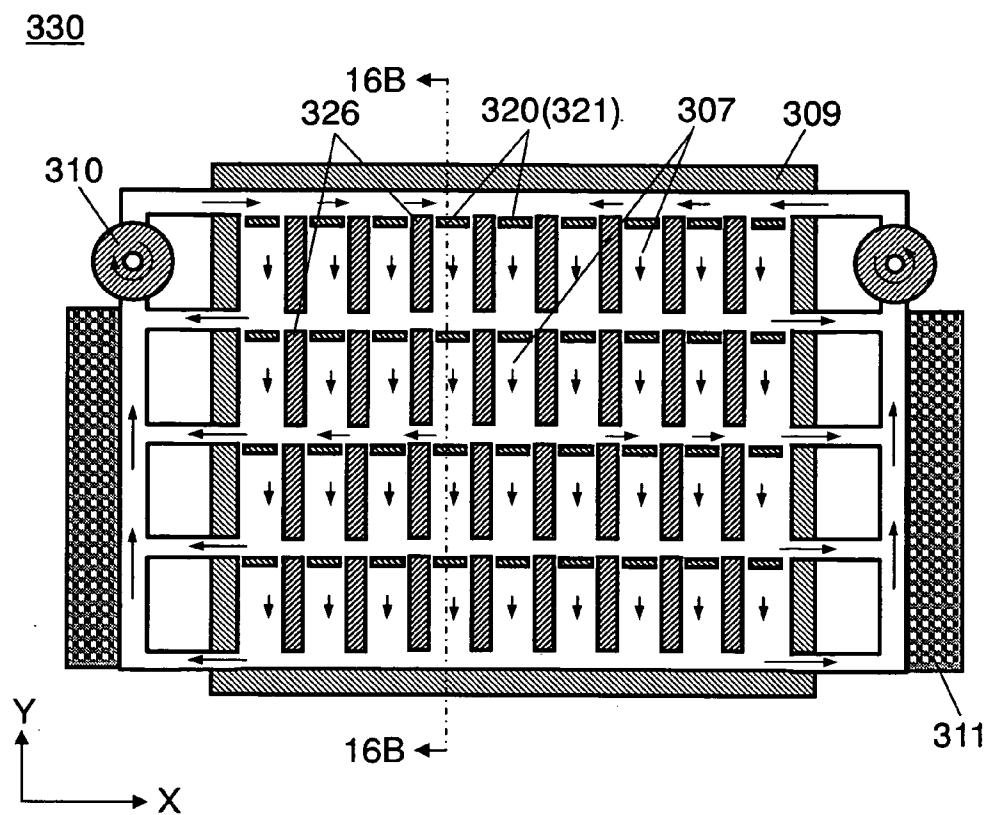


FIG.16B

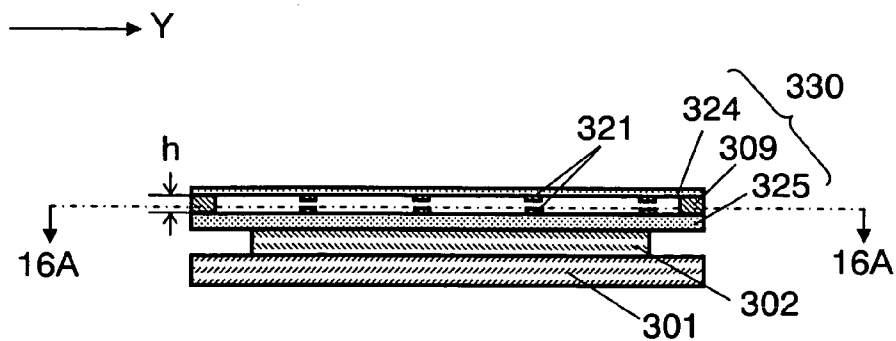


FIG.17A

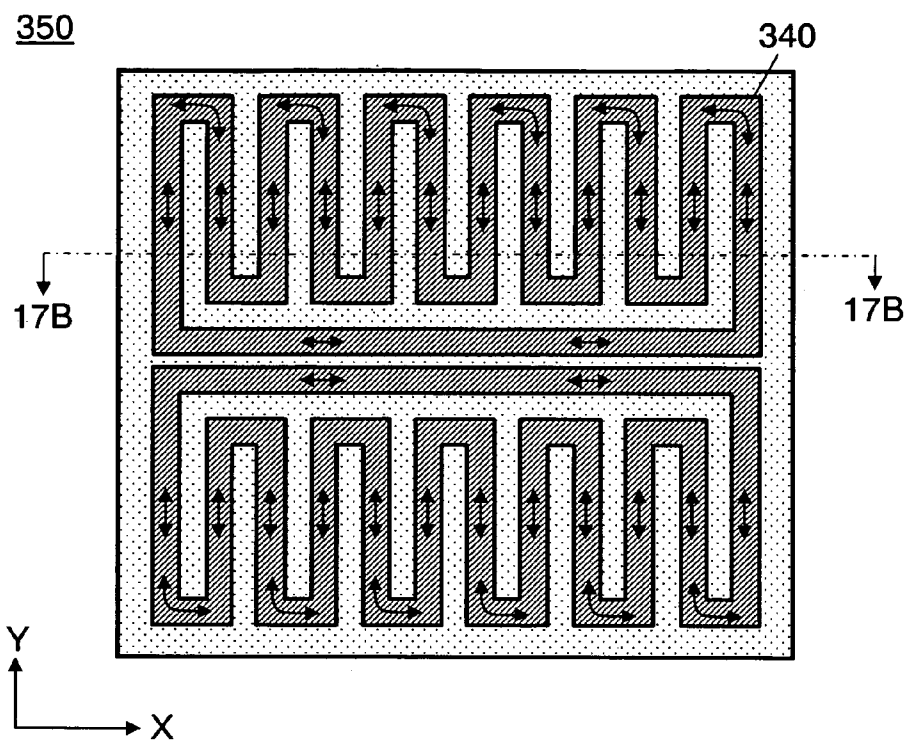


FIG.17B

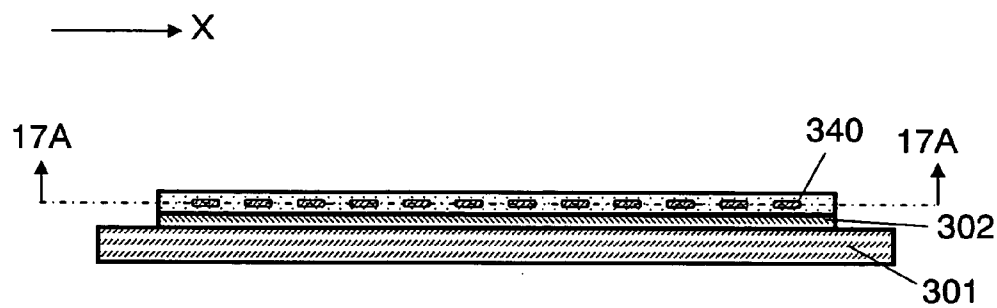


FIG.18A

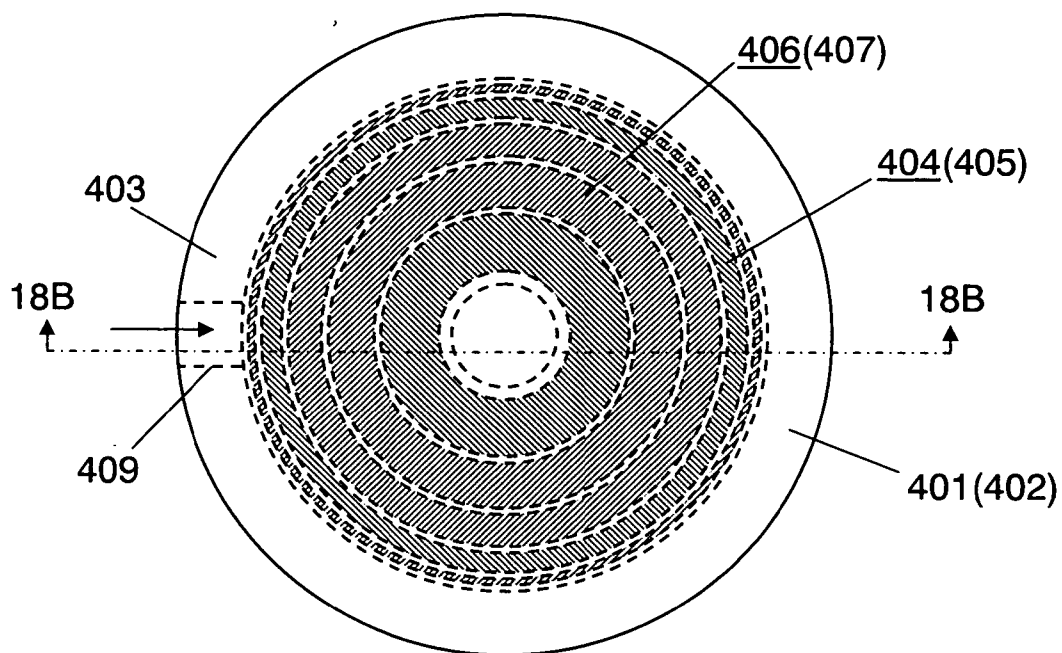


FIG.18B

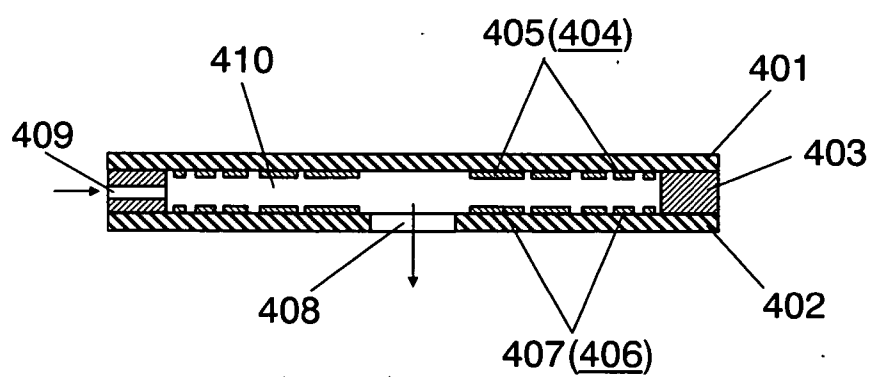


FIG.19A

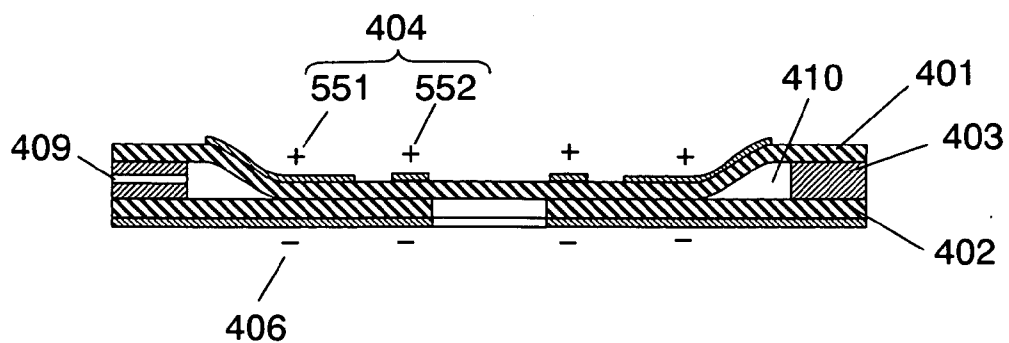


FIG.19B

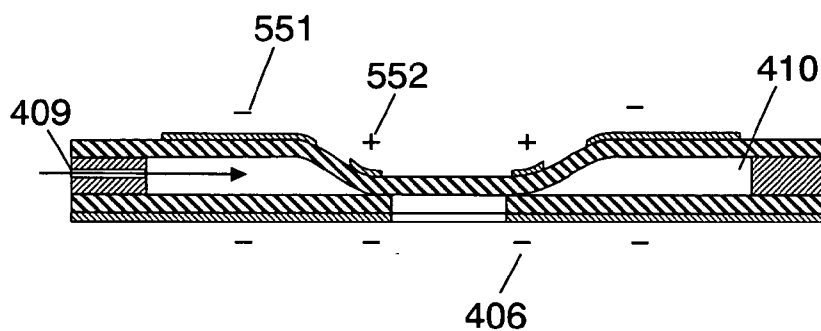


FIG.19C

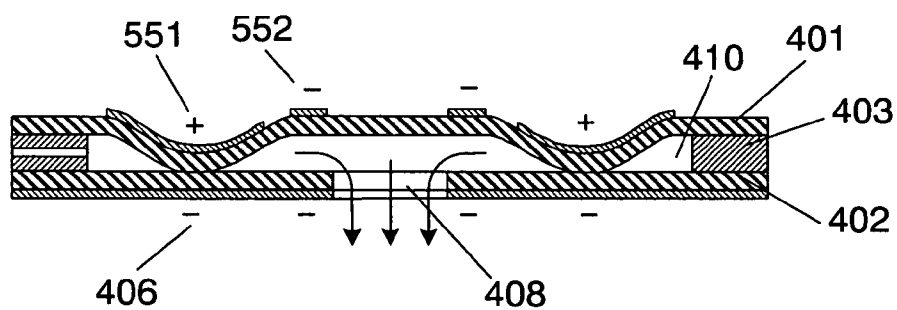


FIG.19D

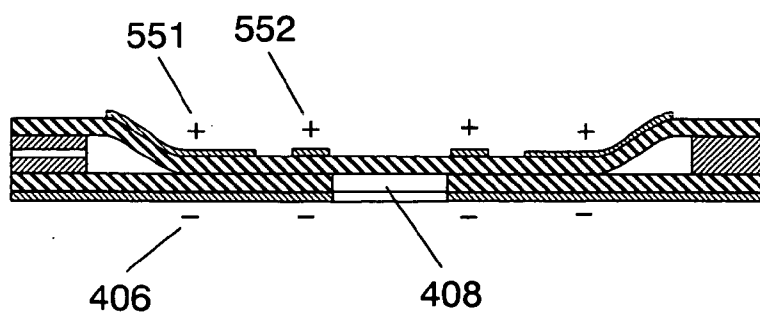


FIG.20 PRIOR ART

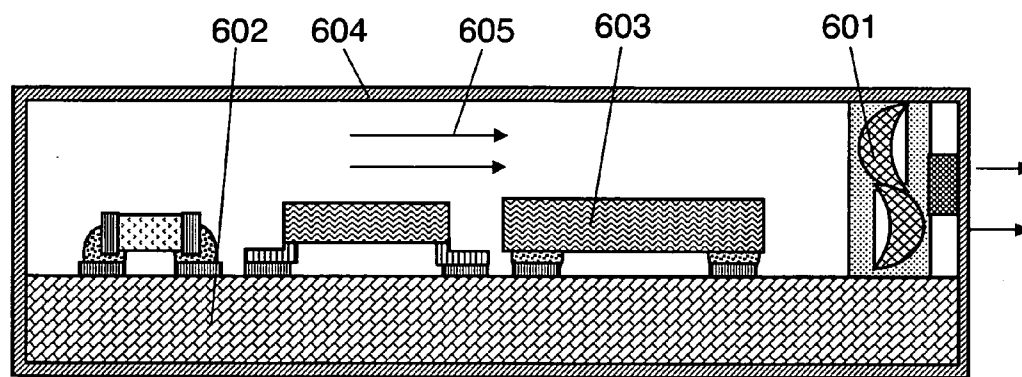


FIG.21 PRIOR ART

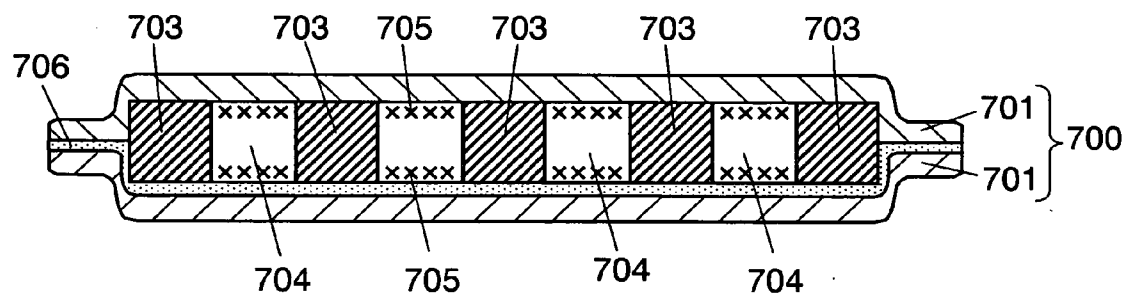
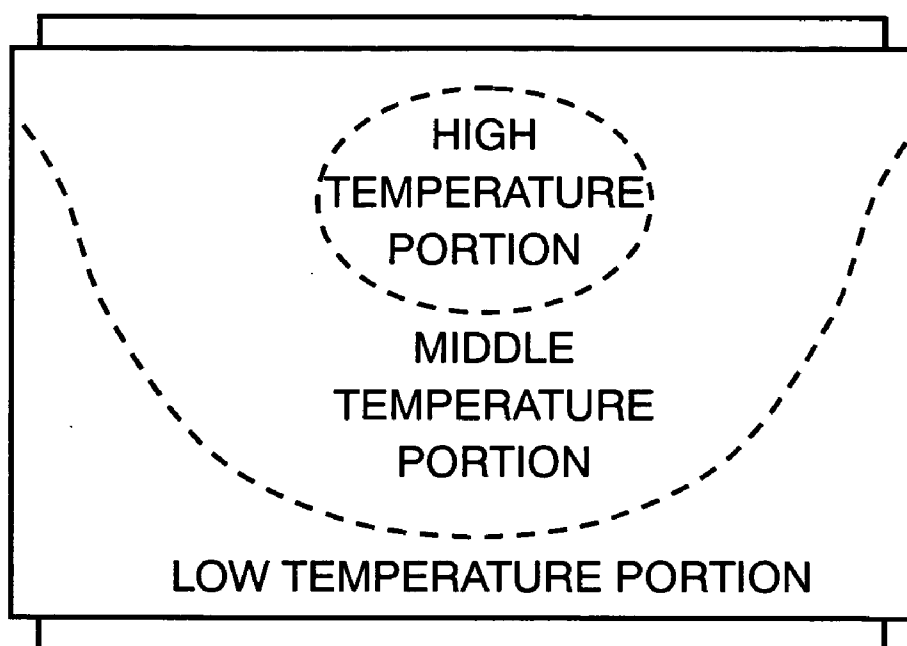


FIG.22 PRIOR ART

800



SHEET TYPE FLUID CIRCULATING APPARATUS AND ELECTRONIC DEVICE COOLER STRUCTURE USING THE SAME

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a sheet type fluid circulating apparatus for circulating and transporting fluid through a plurality of fluid paths and an electronic device cooler structure using the same.

[0003] 2. Background Art

[0004] Recently, electronic devices are being manufactured in a more compact and miniaturized size with more improved performance as recognized by a mobile phone and a laptop computer. Most of the semiconductors used in the electronic devices may suffer operation speed lowering or malfunction when they are heated to a temperature of a hundred and several tens Celsius degree. Since the heat generated from a central processing unit (CPU) particularly causes operation speed lowering and malfunction, the generated heat should be efficiently radiated.

[0005] FIG. 20 is a conceptual diagram illustrating an electronic device having an air cooler heatsink widely adopted in the art. Electronic component 603 such as a semiconductor element or a passive element is mounted in casing 604 on circuit board 602 through a soldering process. When the electronic device is operated, electronic component 603 such as a semiconductor element, a resistor, or a condenser mounted on circuit board 602 is heated. In order to cool electronic component 603, air flow 605 is generated in an inner space of casing 604 by cooling fan 601 mounted on casing 604. Using air flow 605, external cool air is forced to flow into the inside of casing 604 from the outside, while the hot air heated by electronic component 603 is forced to flow out. According to this air flow 605, electronic component 603 mounted on circuit board 602 can be cooled to a predetermined temperature or lower.

[0006] The electronic components such as a semiconductor element used in an electronic circuit have different heating conditions and characteristics. Nevertheless, since the entire circuit board was cooled as a whole according to a conventional method, it was difficult to selectively cool a particular electronic component. For this reason, the cooling fan was designed based on the heating characteristic of a thermally weakest electronic component, and thus, the conventional cooling method had bad energy efficiency from the viewpoint of the entire device. In addition, the air cooling type that uses a cooling fan has bad cooling performance because the air has a low heat transfer rate. The cooling fan also increases the weight and the volume of an electronic device, so that it functions as an obstacle for manufacturing a more compact device. Furthermore, a fast rotation of the cooling fan often generates unendurable noises.

[0007] Accordingly, another cooling method has been adopted such that the heat generated from the CPU is transferred to a lower surface of the casing or a cooling panel provided in a display side through a heat pipe. However, since the conventional heat pipe is made of metal, it has a large weight, a large thickness, and little flexibility, so that it was inappropriate to use the metal pipe in a compact light-weight electronic device.

[0008] In order to solve such problems, a Japanese Patent Unexamined Publication No. 2001-165584 (hereinafter, referred to as a patent document 1) discloses a sheet type heat pipe, in which a container of the heat pipe is made of a film material other than the metal pipe.

[0009] FIG. 21 is a schematic cross-sectional diagram illustrating sheet type heat pipe of the patent document 1. Specifically, FIG. 21 shows a cross-section perpendicularly cutaway across a longitudinal direction of the sheet type heat pipe. This sheet type heat pipe has two metal films 701 that are sealed in vacuum at both ends to form sheet type container 700 where a working fluid is enclosed. The inner space of sheet type container 700 is divided by a plurality of spacers (e.g., bulkheads) 703 to provide a plurality of vapor paths 704. In addition, wick 705 for circulating the working fluid is provided in both upper and lower sides of vapor path 704. Two metal films 701 are bonded by sealant layer 706.

[0010] In such a sheet type heat pipe, the fluid resistance increases when the interval between the vapor paths is reduced to obtain sufficient sheet flexibility. For this reason, the circulation flux of the working fluid is limited. Therefore, it is difficult to balance the tradeoff between the flexibility and the cooling performance.

[0011] In addition to a passive cooling device such as the heat pipe, an active cooling device in which a small driving pump is combined with a cooling sheet to more actively cool the circuit board having electronic components has been developed. However, since this method uses a large-sized pump, it is difficult to mount it in a space-limited device such as a laptop computer.

[0012] Accordingly, a Japanese Patent Unexamined Publication No. 06-264870 (hereinafter, referred to as a patent document 2) discloses a micro-pump integrated into a fluid path as a driving pump to move the fluid based on a principle of an electrostatic actuator.

[0013] In the micro-pump disclosed in the patent document 2, a silicon substrate is micro-fabricated, and an electrode is provided in a polyimide resin layer formed on the silicon substrate, so that a small quantity of fluid is controlled by the electrostatic force between the silicon substrate and the electrode. The micro-pump of the patent document 2 is not purposed to provide a cooling function. A method and a structure for filling the fluid in, for example, a fluid path of a flexible sheet and circulating it is not suggested as well as not disclosed. When the driving pump such as an electrostatic actuator is provided in the vicinity of an electronic component, the electronic component may be erroneously operated due to electromagnetic noises.

SUMMARY OF THE INVENTION

[0014] A fluid circulating apparatus according to the present invention includes: a fluid path having a closed structure provided in an inner space of a stacked flexible sheet; fluid filled in the fluid path; a fluid transport unit provided in at least a part of the fluid path of the flexible sheet to circulate the fluid in the fluid path; and a control circuit unit for controlling the fluid transport unit.

[0015] An electronic device cooler structure according to the present invention includes: a heat generating portion having a plurality of heat generating sources; a fluid circulating apparatus for cooling a plurality of the heat generating

sources; and a heatsink portion for cooling fluid in the fluid circulating apparatus, wherein at least a part of the fluid paths of the sheet type fluid circulating apparatus are connected to the heat generating sources, and a flux of the fluid flowing through the fluid path is changed based on the amount of heat generated in the heat generating sources.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The invention will be described with reference to the accompanying drawings, wherein like numbers reference like elements.

[0017] FIG. 1A is a plan view illustrating a sheet type fluid circulating device according to a first embodiment of the present invention.

[0018] FIG. 1B is a cross-sectional view along a line 1B-1B of FIG. 1A.

[0019] FIGS. 2A to 2D are cross-sectional views for schematically illustrating a mechanism for flowing fluid along a cooling path by a fluid transport unit in a sheet type fluid circulating apparatus according to a first embodiment of the present invention.

[0020] FIG. 3 is a plan view illustrating a sheet type fluid circulating apparatus according to a first variation of a first embodiment of the present invention.

[0021] FIG. 4 is a plan view illustrating a sheet type fluid circulating apparatus according to a second variation of a first embodiment of the present invention.

[0022] FIG. 5A is a plan view illustrating a sheet type fluid circulating apparatus according to a second embodiment of the present invention.

[0023] FIG. 5B is a cross-sectional view along a line 5B-5B of FIG. 5A.

[0024] FIG. 6A is a plan view illustrating a sheet type fluid circulating apparatus according to a third embodiment of the present invention.

[0025] FIG. 6B is a cross-sectional view along a line 6B-6B of FIG. 6A.

[0026] FIGS. 7A to 7C are cross-sectional view schematically illustrating a mechanism for flowing fluid along a cooling path by a fluid transport unit in a sheet type fluid circulating apparatus according to a third embodiment of the present invention.

[0027] FIG. 8A is a plan view illustrating an electronic device cooling structure according to a fourth embodiment of the present invention.

[0028] FIG. 8B is a cross-sectional view along a line 8B-8B of FIG. 8A.

[0029] FIG. 9A is a plan view illustrating a sheet type fluid circulating apparatus according to a fifth embodiment of the present invention.

[0030] FIG. 9B is a cross-sectional view along a line 9B-9B of FIG. 9A.

[0031] FIG. 9C is a cross-sectional view along a line 9C-9C of FIG. 9A.

[0032] FIG. 10A is a plan view illustrating an electronic device cooling structure according to a sixth embodiment of the present invention.

[0033] FIG. 10B is a cross-sectional view along a line 10B-10B of FIG. 10A.

[0034] FIG. 11 is a cross-sectional view illustrating a sheet type fluid circulating apparatus according to a seventh embodiment of the present invention.

[0035] FIG. 12A is a cross-sectional view along a line 12A-12A of FIG. 12B for describing a plasma display device according to an eighth embodiment of the present invention.

[0036] FIG. 12B is a cross-sectional view along a line 12B-12B of FIG. 12A.

[0037] FIG. 13A is a cross-sectional view along a line 13A-13A of FIG. 13B for describing a plasma display device according to a first variation of an eighth embodiment of the present invention.

[0038] FIG. 13B is a cross-sectional view along a line 13B-13B of FIG. 13A.

[0039] FIG. 14 is a cross-sectional view illustrating a plasma display device according to a second variation of an eighth embodiment of the present invention.

[0040] FIG. 15A is a cross-sectional view along a line 15A-15A of FIG. 15B for describing a plasma display device according to a third variation of an eighth embodiment of the present invention.

[0041] FIG. 15B is a cross-sectional view along a line 15B-15B of FIG. 15A.

[0042] FIG. 16A is a cross-sectional view along a line 16A-16A of FIG. 16B for describing a plasma display device according to a ninth embodiment of the present invention.

[0043] FIG. 16B is a cross-sectional view along a line 16B-16B of FIG. 16A.

[0044] FIG. 17A is a cross-sectional view along a line 17A-17A of FIG. 17B for describing a plasma display device according to a variation of eighth and ninth embodiments of the present invention.

[0045] FIG. 17B is a cross-sectional view along a line 17B-17B of FIG. 17A.

[0046] FIG. 18A is a perspective plan view illustrating a micro-pump used in a plasma display device according to eighth and ninth embodiments of the present invention.

[0047] FIG. 18B is a cross-sectional view along a line 18B-18B of FIG. 18A.

[0048] FIGS. 19A to 19D are plan views schematically illustrating operation of a micro-pump used in a plasma display device according to eighth and ninth embodiments of the present invention.

[0049] FIG. 20 is a conceptual diagram illustrating a conventional air cooling type electronic device cooler construction.

[0050] FIG. 21 is a schematic diagram illustrating a cross-section of a conventional sheet type heat pipe.

[0051] FIG. 22 is a schematic diagram illustrating a temperature distribution in a display panel of a conventional plasma display device.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0052] Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings, in which dimensions of a thickness direction, a width direction, and length direction are enlarged for convenient descriptions of a construction. In addition, like reference numerals denote like elements, and their descriptions are omitted.

First Embodiment

[0053] FIG. 1A is a plan view illustrating sheet type fluid circulating apparatus 1 according to a first embodiment of the present invention. FIG. 1B is a cross-sectional view along a line 1B-1B of FIG. 1A.

[0054] Sheet type fluid circulating apparatus 1 according to a first embodiment includes a fluid path having a closed structure provided in the inner space by stacking flexible sheets 18, fluid (not shown in the drawing) moving in the fluid path, fluid transport unit 42, and a control circuit unit (not shown in the drawing) for controlling fluid transport unit 42. The fluid path includes a plurality of cooling paths 20 and 22, heatsink path 30 provided in the inside of flexible sheet 18, inlet path 32 provided in the inside of flexible sheet 18 to connect cooling paths 20 and 22 with heatsink path 30, and outlet path 28. The fluid is filled in fluid transport unit 42, cooling paths 20 and 22, and heatsink path 30. In addition, fluid transport unit 42 has three displacement generators 34, 36, and 38 for deforming flexible sheet 18 by applying a voltage. By applying a voltage to displacement generators 34, 36, and 38 of fluid transport unit 42 using a control circuit unit, the fluid is circulated from cooling paths 20 and 22 provided in flexible sheet 18 to heatsink path 30.

[0055] In addition, fluid transport unit 42 is provided in a part of inlet path 32 connected from heatsink path 30 to cooling path 20 and 22. Cooling path 20 is provided with diaphragm 24 in a part of inlet path 32 for compressing the flow. Also, the fluid path includes outlet path 28 connected from cooling paths 20 and 22 to heatsink path 30 and branch path 26 connected from inlet path 32 to cooling path 22.

[0056] According to the above construction, the fluid output from heatsink path 30 by fluid transport unit 42 passes through inlet path 32 and diaphragm 24, and flows through cooling path 20. In this case, the fluid heated (heat absorption) in the neighboring heat generating portions flows through outlet path 28 to heatsink path 30, cooled down (heatsink) in heatsink path 30, and is output to fluid transport unit 42 again.

[0057] Similarly, the fluid output from heatsink path 30 by fluid transport unit 42 passes through inlet path 32 and branch path 26 and flows through cooling path 22. The fluid heated in cooling path 22 passes through outlet path 28 to heatsink path 30, and then cooled down there so as to be output to fluid transport unit 42, again. The fluid is circulated by repeating these operations.

[0058] As described above, sheet type fluid circulating apparatus 1 according to a first embodiment of the present

invention can efficiently cool a plurality of heat generating portions by circulating the fluid through the fluid path provided inside flexible sheet 18 using fluid transport unit 42.

[0059] In sheet type fluid circulating apparatus 1, the different flux can flow into cooling paths 20 and 22 by setting different conductance values between cooling paths 20 and 22. In the first embodiment of the present invention, a larger flux flows into cooling path 22. Therefore, the heat generating portions having different heating value can be efficiently cooled down if cooling path 22 is used for cooling a heat generating portion having a larger heating value, and cooling path 20 is used for cooling a heat generating portion having a smaller heating value.

[0060] Flexible sheet 18 is constructed by bonding sheets 12 and 14 with spacer 16. Sheets 12 and 14 and spacer 16 may be formed of resin such as polyimide resin, polyester resin, and polyethylene terephthalate resin. Spacer 16 is previously provided with the openings corresponding to cooling paths 20 and 22, heatsink path 30, inlet path 32, diaphragm 24, outlet path 28, and branch path 26, and its both surfaces are bonded with sheets 12 and 14, respectively, so that the fluid path is formed in a closed structure.

[0061] Fluid transport unit 42 uses an electrostatic force according to a first embodiment of the present invention. That is, displacement generator 34 is constructed of conductive films 33 and 40 provided in the opposite surfaces of sheets 12 and 14. Similarly, displacement generator 36 is constructed of conductive films 35 and 40 provided in the opposite surfaces of sheets 12 and 14. Similarly, displacement generator 38 is constructed of conductive films 37 and 40 provided in the opposite surfaces of sheets 12 and 14. Conductive films 33, 35, 37, 40 may be fabricated by forming an aluminum film or a copper film by, for example, a deposition method or a sputtering method.

[0062] In addition, for convenient deformation, only the areas corresponding to displacement generators 34, 36, and 38 in sheet 12 may be formed to be thinner than other areas. Similarly, sheet 14 may have thinner portions.

[0063] Although conductive film 40 provided in sheet 14 has a common connection structure by combining three displacement generators 34, 36, and 38 in this embodiment, they may be separately provided.

[0064] Water having high electric resistance is preferably used as the fluid. Alternatively, ethylene glycol can be used as the fluid. The ethylene glycol can be advantageously used even in a cold and snowy climate. In addition to water, any fluid that has low viscosity and high electric resistance can be adopted without limitation.

[0065] Although displacement generator 34 has a largest area in this embodiment, the displacement generators may have the same area.

[0066] Hereinafter, a mechanism for transporting the fluid is described with reference to FIGS. 2A to 2D.

[0067] FIGS. 2A to 2D are cross-sectional views schematically illustrating a mechanism for outputting the fluid to cooling paths 20 and 22 by fluid transport unit 42. FIGS. 2A to 2D are cross-sectional views along a line 1B-1B of FIG. 1A.

[0068] As shown in FIG. 2A, displacement generator 38 nearest to heatsink path 30 is deformed to nearly close the fluid path. This deformation allows the fluid existing in the area of displacement generator 38 of inlet path 32 to flow into both sides as shown in arrows. This deformation is generated by applying opposite polarity voltages to conductive film 37 of sheet 12 and conductive film 40 of sheet 14 using a control circuit unit. For example, when a positive voltage is applied to conductive film 40, a negative voltage is applied to conductive film 37. For example, when the interval between conductive films 37 and 40 is set to 100 μm , a voltage of 100V is preferably applied.

[0069] Then, as shown in FIG. 2B, displacement generator 34 is similarly deformed while displacement generator 38 is deformed and the fluid path is closed. Similarly, this deformation is generated by applying different polarity voltages to conductive film 33 of sheet 12 and conductive film 40 of sheet 14. In this case, since conductive film 40 is commonly connected, when the same polarity voltage is applied to conductive films 33 and 37, displacement generator 34 is deformed similarly to displacement generator 38. When displacement generator 34 is deformed, since displacement generator 38 is previously deformed and the fluid path is nearly closed, the fluid flows into the arrow direction of FIG. 2B.

[0070] Subsequently, as shown in FIG. 2C, while displacement generator 34 is deformed to nearly close the fluid path, displacement generator 36 is deformed to close the fluid path. Simultaneously, displacement generator 38 is restored to its initial state. In this case, similar to displacement generator 34, opposite polarity voltages are applied to conductive film 35 of sheet 12 and conductive film 40 of sheet 14. Since conductive film 40 is commonly connected, when the same polarity voltage is applied to conductive films 33 and 35, displacement generator 36 is deformed similarly to displacement generator 34. The same polarity voltage is applied to conductive film 37 of sheet 12 and conductive film 40 of sheet 14 in displacement generator 38. This deformation generates a repelling electrostatic force between conductive film 40 of sheet 14 and conductive film 37 of sheet 12 to be separated from each other in a predetermine distance. As a result, displacement generator 38 is restored to its initial state, so that the fluid path is opened.

[0071] Subsequently, as shown in FIG. 2D, while displacement generator 36 is deformed to nearly close the fluid path, displacement generator 34 is restored to its initial state. In this case, the same polarity voltage is applied to conductive film 33 of sheet 12 and conductive film 40 of sheet 14. This deformation generates a repelling electrostatic force between conductive film 40 of sheet 14 and conductive film 33 of sheet 12 to be separated from each other in a predetermined distance. As a result, displacement generator 34 is restored to its initial state and the fluid path is opened. Through these operations, the fluid flows from heatsink path 30 to displacement generator 34.

[0072] By repeating the cycle including the processes shown in FIGS. 2A to 2D, the fluid is circulated from heatsink path 30 to cooling paths 20 and 22.

[0073] Therefore, it is possible to externally radiate the heat generated in the heat generating portions from heatsink path 30 through the heatsink fins using the fluid if the heat

generating portions are connected to cooling paths 20 and 22, and the heatsink fins are connected to heatsink path 30 in sheet type fluid circulating apparatus 1. In this case, since the heat transportation is performed using the fluid, it is possible to effectively radiate the heat even when the heating value of the heat generating portion is relatively large.

[0074] FIG. 3 is a plan view illustrating sheet type fluid circulating apparatus 2 according to a first variation of a first embodiment of the present invention. Sheet type fluid circulating apparatus 2 has fluid transport units 42 and 62 in both sides of inlet and outlet paths 32 and 28. Specifically, while sheet type fluid circulating apparatus 1 shown in FIG. 1A only has fluid transport unit 42 provided in inlet path 32, sheet type fluid circulating apparatus 2 according to this variation has another fluid transport unit 62 in outlet path 28. In addition, the constructions of displacement generators 54, 56, and 58 of fluid transport unit 62 are similar to those of displacement generators 34, 36, and 38 of fluid transport unit 42. As a result, it is possible to increase the flux of the fluid.

[0075] FIG. 4 is a plan view illustrating sheet type fluid circulating apparatus 3 according to a second variation of a first embodiment of the present invention. In this sheet type fluid circulating apparatus 3, fluid transport units 42 and 62 are respectively provided for inlet paths 32 and 64 for transporting the fluid from heatsink path 30 to cooling paths 20 and 22. In addition, the constructions of displacement generators 54, 56, and 58 of fluid transport unit 62 are similar to those of displacement generators 34, 36, and 38 of fluid transport unit 42.

[0076] According to this construction, the flux of the fluid flowing to cooling paths 20 and 22 can be controlled by respective fluid transport units 42 and 62 without diaphragm 24 shown in FIGS. 1A and 3. In other words, since there is no diaphragm, it is possible to reduce the fluid resistance. Therefore, it is possible to obtain a relatively large flux even when the pumping power of fluid transport units 42 and 62 is small. In addition, each of the fluxes in the cooling paths can be individually and optimally controlled using a plurality of fluid transport units.

Second Embodiment

[0077] FIG. 5A is a plan view illustrating sheet type fluid circulating apparatus 4 according to a second embodiment of the present invention, and FIG. 5B is a cross-sectional view along a line 5B-5B of FIG. 5A.

[0078] Similarly to sheet type fluid circulating apparatus 1 according to a first embodiment of the present invention, sheet type fluid circulating apparatus 4 according to a second embodiment includes a fluid path having a closed structure provided in the inner space of stacked flexible sheet 18, fluid (not shown in the drawing) moving through the fluid path, fluid transport unit 70, and a control circuit unit (not shown in the drawing) for controlling fluid transport unit 70. In this embodiment, the fluid path includes a plurality of cooling paths 20 and 22, heatsink path 30 provided in the inner space of flexible sheet 18, and inlet path 32 and outlet path 28 provided in the inner space of flexible sheet 18 to connect cooling paths 20 and 22 with heatsink path 30. The fluid is filled in fluid transport unit 70, cooling paths 20 and 22, and heatsink path 30. In addition, fluid transport unit 70 has six displacement generators 72, 74, 76, 78, 80, and 82 for deforming flexible sheet 18 by applying a voltage. The fluid

is circulated from cooling paths 20 and 22 provided in flexible sheet 18 to heatsink path 30 by applying a voltage to displacement generators 72, 74, 76, 78, 80, and 82 of fluid transport unit 70 using the control circuit unit.

[0079] As shown in FIGS. 5A and 5B, sheet type fluid circulating apparatus 4 of a second embodiment is different from that of a first embodiment in that fluid transport unit 70 is incorporated into heatsink path 30, and a plurality of displacement generators are provided. Other constructions are the same as those of a first embodiment, and their detailed descriptions are omitted.

[0080] According to the above construction, the fluid output from heatsink path 30 by fluid transportation unit 70 flows through inlet path 32 and diaphragm 24 to cooling path 20. The fluid heated (heat absorption) in the neighboring heat generating portions flows through outlet path 28 and heatsink path 30, and is cooled down (heat radiation) in heatsink path 30, so as to be output to fluid transport unit 70 again.

[0081] Similarly, the fluid output from heatsink path 30 by fluid transport unit 70 flows through inlet path 32 and branch path 26 to cooling path 22. The fluid heated in cooling path 22 flows through outlet path 28 to heatsink path 30, and is cooled down in heatsink path 30, so as to be output to fluid transport unit 70 again. The fluid is circulated by repeating the above processes.

[0082] Fluid transport unit 70 according to a second embodiment is constructed of a plurality of displacement generators using an electrostatic force in comparison with a first embodiment. The constructions of the displacement generators are the same as those of a first embodiment. As shown in FIG. 5B, for example, displacement generator 76 is constructed of conductive films 75 and 84 provided in the opposite surfaces of sheets 12 and 14. Other displacement generators have a similar construction.

[0083] For convenient deformation, only the areas corresponding to displacement generators 72, 74, 76, 78, 80, and 82 of sheet 12 may have a thinner thickness than those of other areas. Alternatively, only the areas corresponding to displacement generators 72, 74, 76, 78, 80, and 82 may be formed of a material susceptible to elastic deformation. Conductive film 84 provided in sheet 14 may be commonly connected to six displacement generators 72, 74, 76, 78, 80, and 82, or individually connected to them. In a second embodiment, displacement generators 72, 74, 76, 78, 80, and 82 are commonly connected.

[0084] A mechanism for transporting the fluid of fluid transporting unit 70 in sheet type fluid circulating apparatus 4 according to a second embodiment is basically similar to that of fluid transport unit 42 in sheet type fluid circulating apparatus 1 according to a first embodiment as described with reference to FIGS. 2A to 2D.

[0085] Therefore, the mechanism of fluid transport unit 70 in sheet type fluid circulating apparatus 4 according to a second embodiment will be described shortly.

[0086] Firstly, displacement generator 72 nearest to outlet path 28 is deformed to nearly close the fluid path corresponding to displacement generator 72. This deformation allows the fluid existing in the area of displacement generator 72 of heatsink path 30 to flow to both sides of displace-

ment generator 72. Also, this deformation is generated by applying different polarity voltages to conductive films (not shown in the drawing) of sheets 12 and 14 in displacement generator 72 using the control circuit unit. For example, when a positive voltage is applied to the conductive film of sheet 14, a negative voltage is applied to the conductive film of sheet 12. For example, when the interval between the conductive films of sheets 12 and 14 is set to 100 μm , a voltage of 100V is preferably applied.

[0087] Then, while the fluid path corresponding to displacement generator 72 is closed, a fluid path corresponding to displacement generator 74 is similarly deformed. Similarly to displacement generator 72, this deformation is generated by applying different polarity voltages to the conductive films (not shown in the drawings) of sheets 12 and 14 of displacement generator 74. The different polarity voltages generate deformation of displacement generator 74 similarly to displacement generator 72. When displacement generator 74 is deformed, since the fluid path is nearly closed by the deformation in displacement generator 72 in advance, the fluid is squeezed toward inlet path 32.

[0088] Subsequently, while the fluid path corresponding to displacement generator 74 is nearly closed, displacement generator 76 is deformed to nearly close the fluid path corresponding to displacement generator 76. Simultaneously, displacement generator 72 is restored to its initial state. In this case, similarly to displacement generator 74, different polarity voltages are applied to conductive films 75 and 84 of sheets 12 and 14 of displacement generator 76. On the other hand, the same polarity voltages are applied to the conductive films of sheets 12 and 14 of displacement generator 72. This generates a repelling electrostatic force between the conductive films of sheets 12 and 14 of displacement generator 72 to separate each other. As a result, displacement generator 72 is restored to its initial state so that the fluid path is opened. This deformation allows the fluid of displacement generator 76 to be squeezed toward inlet path 32. On the other hand, the fluid flows into the area of displacement generator 72 as shown in the arrow.

[0089] Subsequently, while the fluid path corresponding to displacement generator 76 is nearly closed, displacement generator 78 is deformed to nearly close the fluid path corresponding to displacement generator 78. Simultaneously, displacement generator 74 is restored to its initial state, and the fluid path corresponding to displacement generator 72 is closed. In this case, similarly to displacement generator 76, different polarity voltages are applied to the conductive films of sheets 12 and 14 of displacement generator 78. On the other hand, the same polarity voltages are applied to the conductive films of sheets 12 and 14 of displacement generator 74. This generates a repelling electrostatic force between the conductive films of sheets 12 and 14 of displacement generator 74 to separate each other. As a result, displacement generator 74 is restored to its initial state, and the fluid path is opened. The fluid of displacement generator 78 is squeezed toward inlet path 32. On the other hand, the fluid flows into the opened displacement generator 74, and the neighboring displacement generators 72 and 76 are closed.

[0090] Subsequently, while the fluid paths corresponding to displacement generators 72 and 78 are nearly closed, displacement generator 80 is deformed to nearly close the

fluid path corresponding to displacement generator 80. Simultaneously, displacement generator 76 is restored to its initial state, and the fluid path corresponding to displacement generator 74 is closed. At this time, similarly to displacement generators 72 and 78, different polarity voltages are applied to the conductive films of sheets 12 and 14 of displacement generator 80. On the other hand, the same polarity voltages are applied to the conductive films of sheets 12 and 14 of displacement generator 76. This generates a repelling electrostatic force between the conductive films of sheets 12 and 14 of displacement generator 76 to separate each other. As a result, displacement generator 76 is restored to its initial state, and the fluid path is opened. The fluid corresponding to displacement generator 80 is squeezed toward inlet path 32. On the other hand, the fluid flows into the opened displacement generator 76.

[0091] Subsequently, while the fluid paths corresponding to displacement generators 74 and 80 are nearly closed, displacement generator 82 is deformed, and the fluid path corresponding to displacement generator 82 is nearly closed. Simultaneously, displacement generators 72 and 78 are restored to their initial states, and the fluid path corresponding to displacement generator 76 is closed. At this time, similarly to displacement generators 74 and 80, different polarity voltages are applied to the conductive films of sheets 12 and 14 of displacement generator 82. On the other hand, the same polarity voltages are applied to the conductive films of sheets 12 and 14 of displacement generators 72 and 78. This generates a repelling electrostatic force between the conductive films of sheets 12 and 14 of displacement generators 72 and 78 to separate each other. As a result, displacement generators 72 and 78 are restored to their initial states, and the fluid path is opened.

[0092] The fluid of displacement generator 82 is squeezed toward inlet path 32 as shown in the arrow. On the other hand, the fluid flows into opened displacement generators 72 and 78.

[0093] When a series of the above processes are repeated for displacement generators 72 to 82, the fluid located in heatsink path 30 is sequentially transported to inlet path 32, so that the fluid is circulated.

[0094] In addition, the voltages applied to each conductive film may have a pulse shape (e.g., a rectangular wave) or a continuously changed shape such as a sinusoidal wave.

Third Embodiment

[0095] FIG. 6A is a plan view illustrating sheet type fluid circulating apparatus 5 according to a third embodiment of the present invention, and FIG. 6B is a cross-sectional view along a line 6B-6B of FIG. 6A.

[0096] Although sheet type fluid circulating apparatus 5 according to a third embodiment is similar to sheet type fluid circulating apparatus 3 according to a second embodiment, the constructions of fluid transport units 90 and 98 are different. Other constructions are the same as those of sheet type fluid circulating apparatus 3, and their detailed descriptions will be omitted.

[0097] As shown in FIG. 6A, fluid transport units 90 and 98 are constructed of displacement generator and two check valves. Specifically, fluid transport unit 90 includes displacement generator 92 formed of a piezoelectric element and

check valves 94 and 96 provided in its both sides of the fluid path. Similarly, fluid transport unit 98 includes displacement generator 100 formed of a piezoelectric element and check valves 102 and 104 provided in its both sides of the fluid path.

[0098] In addition, as shown in FIG. 6B, displacement generator 92 formed of a piezoelectric material expands and contracts piezoelectric element 92a by applying a predetermined voltage to electrode films 92b and 92c provided in both surfaces of piezoelectric element 92a to deform sheet 12. Displacement generator 100 formed of a piezoelectric material has a similar construction. The piezoelectric material used in displacement generators 92 and 100 may include, for example, a ceramic material, and may be fabricated using a thin-film process.

[0099] Hereinafter, a mechanism for transporting the fluid will be described with reference to FIGS. 7A to 7C.

[0100] FIGS. 7A to 7C are cross-sectional views schematically illustrating a mechanism for flowing fluid into cooling paths 20 and 22 by fluid transport units 90 and 98. In addition, FIGS. 7A to 7C are also cross-sectional views along the line 6B-6B of FIG. 6A.

[0101] Firstly, as shown in FIG. 7A, any voltage is not applied to displacement generator 92, and the fluid path is opened.

[0102] Then, as shown in FIG. 7B, displacement generator 92 is deformed along the fluid path by applying a voltage. This deformation allows the fluid existing in the fluid path corresponding to displacement generator 92 to be squeezed. At this time, a larger pressure is applied to the output side of check valve 94 (toward inlet paths 32 and 64), and a smaller pressure is applied to the input side of check valve 96 (toward heatsink path 30). As a result, fluid is squeezed toward check valve 94. Although part of the fluid reversely flows from check valve 96 as shown in a short arrow, most of the fluid flows in a long arrow direction.

[0103] Subsequently, as shown in FIG. 7C, when the voltage is not applied to displacement generator 92, the shape of the fluid path corresponding to displacement generator 92 is restored to its initial state as shown in FIG. 7A. At this moment, since the fluid path is changed from the closed state to the opened state, the pressure in the fluid path between check valves 94 and 96 is relatively lowered. Although the lower pressure would allow the fluid to flow into fluid path between check valves 94 and 96, the pressure for generating the flow from check valve 94 to the area of displacement generator 92 in the fluid path is relatively small. On the other hand, the pressure for generating the flow from check valve 96 to the area of displacement generator 92 in the fluid path is relatively large. This pressure difference allows the fluid to come from check valve 96.

[0104] By repeating the above processes, the fluid flows from heatsink path 30 to inlet path 32, so that the fluid circulation is generated.

[0105] In addition, although the piezoelectric element according to this embodiment is formed of a material which expands and contracts in parallel with the fluid path, the present invention is not limited to such a construction. For

example, a material which expands and contracts in a thickness direction of the piezoelectric element (across the electrodes) may be used.

[0106] According to a third embodiment of the present invention, since fluid transport units **90** and **98** include displacement generator **92** formed of a piezoelectric material and two check valves **94** and **96**, the construction is simple, and a large driving force can be generated. As a result, a control circuit unit can have a simple construction, and simultaneously, the flux of the transported fluid can be significantly increased.

[0107] In addition, if the heat generating portions are connected to cooling paths **20** and **22**, and the heatsink fins are connected to heatsink path **30** using this sheet type fluid circulating apparatus, the heat generated in the heat generating portions can be output from heatsink path **30** through the heatsink fins using the fluid. The heat can be efficiently output even though amount of heat in the heat generating portions is relatively large because the heat is transported using the fluid.

[0108] In addition, although the displacement generators of the fluid transport units are operated by an electrostatic force according to first and second embodiments, the same effect can be achieved by forming the displacement generator using a piezoelectric material as described in association with a third embodiment. Furthermore, although the displacement generator of the fluid transport unit is formed of a piezoelectric material according to a third embodiment, the displacement generator may be constructed using an electrostatic force. As described above, the present invention is not limited to the constructions of the sheet type fluid circulating apparatus according to first to third embodiments, the construction of the flexible sheet and the construction of the fluid transport unit may be appropriately combined.

Fourth Embodiment

[0109] FIG. **8A** is a plan view illustrating a construction of an electronic device cooler structure according to a fourth embodiment of the present invention, and FIG. **8B** is a cross-sectional view along a line **8B-8B** of FIG. **8A**.

[0110] The electronic device cooler structure according to a fourth embodiment includes heat generating portions **110** and **112** having a plurality of heat sources, a fluid circulating apparatus for cooling a plurality of heat generating portions **110** and **112**, and heatsink unit **116** for cooling the fluid of the fluid circulating apparatus. Sheet type fluid circulating apparatus **1** according to a first embodiment may be used as the fluid circulating apparatus of the electronic device cooler structure according to a fourth embodiment. At least part of cooling paths **20** and **22** of sheet type fluid circulating apparatus **1** is connected to heat generating portions **110** and **112**. In addition, the fluxes flowing through cooling paths **20** and **22** are adjusted depending on the amount of heat generated in heat generating portions **110** and **112**.

[0111] In this case, heatsink unit **116** is constructed of heatsink fins. The heatsink fins are connected to heatsink path **30** of sheet type fluid circulating apparatus **1**. Heat generating portions **110** and **112** are electronic components mounted on circuit board **108**. Specifically, the heat generating portion generating a large amount of heat may be a

CPU, and the heat generating portion generating a small amount of heat may be a resistor, a capacitor, or a sensor formed of resin having low thermal resistance. Although other electronic components **114** may be additionally mounted on circuit board **108**, if they do not generate heat, they are not necessary to be cooled. In this embodiment, the casing for storing circuit board **108** and sheet type fluid circulating apparatus **1** is not shown.

[0112] As shown in FIG. **8B**, sheet type fluid circulating apparatus **1** having flexibility covers heat generating portions **110** and **112** to make contact with each other. At this moment, if the amount of heat generated in heat generating portions **110** and **112** is estimated in advance, it is possible to effectively cool the electronic device by setting the flux of fluid flowing through fluid transport unit **42** and the shape of diaphragm **24** based on the amount of heat.

[0113] For example, a temperature sensor may be provided in heat generating portion **112** such as a CPU, and the data obtained from the sensor may be processed by the control circuit unit (not shown in the drawing) of sheet type fluid circulating apparatus **1**, so that fluid transport unit **42** can be driven based on the processed data to control the flux of the cooling fluid.

[0114] Furthermore, the variation of the electric characteristic of heat generating portion **112** such as a CPU may be detected in a controller (not shown in the drawing) of the electronic device (not shown in the drawing) mounted on the circuit board, and then a signal generated based on the electric characteristic may be processed by the control circuit unit (not shown in the drawing) of sheet type fluid circulating apparatus **1**, so that the flux of the cooling fluid can be controlled by driving fluid transport unit **42** to control the variation of the electric characteristic of the heat generating portion.

[0115] The electronic device cooler structure according to the present invention is not limited to the above constructions, and the sheet type fluid circulating devices according to first to third embodiments of the present invention may be used. For example, since sheet type fluid circulating apparatus **3** has fluid transport units **42** and **62** for cooling paths **20** and **22**, respectively, it is possible to reduce power consumption and individually implement an optimal cooling if each fluid transport unit **42** and **62** is individually controlled by detecting the amount of heat in heat generating portion **112** such as a CPU and the temperature of heat generating portion **110** such as a sensor which generate little heat but has small thermal resistance. In addition, in the case of sheet type fluid circulating apparatus **4** having fluid transport unit **70** in heatsink path **30**, it is possible to further improve efficiency of fluid transportation by arranging fluid transport unit **70** on a flat surface of the electronic device cooler structure or the heatsink fins.

[0116] Furthermore, it is possible to actively cool the fluid by arranging an electronic cooler in addition to the heatsink fins as a heatsink unit. In this case, it is possible to effectively cool the electronic device even when a cooling under a room temperature is required. For example, a Peltier effect cooler may be used as the electronic cooler.

[0117] Moreover, if the fluid in the heatsink path is heated or cooled to a predetermined temperature, the fluid can be circulated with a constant temperature, so that it is possible

to constantly maintain the temperature of a specimen even in a temperature sensitive inspection such as a DNA analysis.

Fifth Embodiment

[0118] FIG. 9A is a plan view illustrating a sheet type fluid circulating apparatus according to a fifth embodiment of the present invention, FIG. 9B is a cross-sectional view along a line 9B-9B of FIG. 9A, and FIG. 9C is a cross-sectional view along a line 9C-9C of FIG. 9A.

[0119] Sheet type fluid circulating apparatus 210 according to a fifth embodiment of the present invention includes fluid path 215 having a closed structure provided in the inner space of stacked flexible sheet 211, fluid (not shown in the drawing) filled in fluid path 215, fluid transport units 220 and 230 provided in part of fluid path 215 of flexible sheet 211 to circulate the fluid in fluid path 215, electromagnetic shield film 212 formed in at least one surface of flexible sheet 211, a control circuit unit (not shown in the drawing) for driving the fluid transport units, and a ground section (not shown in the drawing) for grounding electromagnetic shield film 242.

[0120] When flexible sheet 211 of sheet type fluid circulating apparatus 210 is connected to, for example, a heat generating portion of the electronic device, sheet type fluid circulating apparatus 210 is constructed such that fluid path 215 provided in fluid transport units 220 and 230 is also connected to the heat generating portion.

[0121] In this case, sheet type fluid circulating apparatus 210 uses an electrostatic force in order to drive fluid transport units 220 and 230.

[0122] For this reason, as shown in FIGS. 9A and 9B, fluid transport units 220 and 230 have eight displacement generators 221 to 228 and 231 to 238, respectively, for deforming flexible sheet 211 by applying a voltage. In addition, each of displacement generators 221 to 228 and 231 to 238 has conductive films provided in both surfaces of upper and lower sheets 212 and 213 to face each other. These displacement generators 221 to 228 and 231 to 238 are deformed by applying corresponding setup voltages for a predetermined time period using a control circuit unit.

[0123] As shown in FIG. 9B, some portions of upper and lower sheets 212 and 213 are protruded from spacer 214 provided to bond them, and a flexible wiring board is connected to these protruded portions.

[0124] Electromagnetic shield film 242 is formed on the almost entire surface of lower sheet 213. This electromagnetic shield film 242 is formed by, for example, depositing a conductive material using a physical deposition method or a printing method. The physical deposition method may be performed by depositing metal such as copper and aluminum in vacuum. The printing method may be performed by forming a solid film on the entire surface or a mesh shape film using a paste containing a conductive material such as carbon or a silver paste.

[0125] Lower sheet 213 is provided with insulating protection film 243 for protecting electromagnetic shield film 242. In this case, an opening is provided in insulating protection film 243, so that insulating protection film 243 can be connected to the ground section by interposing the flexible wiring board therebetween.

[0126] In sheet type fluid circulating apparatus 210 having the above construction, the fluid is circulated in fluid path 215 provided in the inner space of flexible sheet 211 using fluid transport units 220 and 230. Accordingly, if a heater, heatsink fins, or an electronic cooler is connected to part of fluid path 215, the fluid can be heated, cooled, or maintained in a constant temperature. If an electronic device is connected to part of fluid path 215 where the heated or cooled fluid flows, the electronic device can be heated, cooled, or maintained in a constant temperature.

[0127] Flexible sheet 211 is constructed by bonding upper and lower sheets 212 and 213 formed of resin such as polyimide resin, polyester resin, or polyethylene terephthalate resin with each other using spacer 214, which may be formed of similar materials. Fluid path 215 is previously provided in spacer 214, and upper and lower sheets 212 and 213 are bonded to both surfaces of spacer 214, so that fluid path 215 having a closed structure can be formed.

[0128] In addition, the conductive films provided in a plurality of displacement generators 221 to 228 and 231 to 238 of fluid transport units 220 and 230, respectively, are formed, for example, by a deposition method or a sputtering method using an aluminum film or a copper film.

[0129] In order to facilitate deformation, only the areas of upper sheet 212 corresponding to displacement generators 221 to 228 and 231 to 238 of fluid transport units 220 and 230, respectively, may be formed in a smaller thickness than those of other areas. Alternatively, these areas may be formed of a material more susceptible to elastic deformation.

[0130] Water having high electric resistance is preferably used as the fluid. Alternatively, ethylene glycol can be used as the fluid. The ethylene glycol can be advantageously used even in a cold and snowy climate. In addition to water, any fluid that has low viscosity and high electric resistance can be adopted without limitation.

[0131] Hereinafter, a mechanism of fluid transport units 220 and 230 for circulating fluid using sheet type fluid circulating apparatus 210 according to the present embodiment will be described shortly.

[0132] In this embodiment, since two fluid transport units 220 and 230 are separately disposed, and flexible sheet 211 is used, fluid path 215 is locally expanded or contracted by the pressure of the fluid. For this reason, each fluid transport unit 220 and 230 can be individually operated. While fluid transport unit 220 will be described hereinafter, fluid transport unit 230 may have a similar construction. Also, the fluid is assumed to flow in a counter clockwise direction in fluid path 215 in FIG. 9A.

[0133] Firstly, displacement generator 221 of fluid transport unit 220 is deformed, so that fluid path 215 corresponding to displacement generator 221 is nearly closed. The deformation allows fluid path 215 to contract in a thickness direction, so that the fluid existing in this area is squeezed to both directions. In addition, this deformation is generated by applying different polarity voltages to the conductive films of upper and lower sheets 212 and 213 of displacement generator 221 using a control circuit unit. For example, when a positive voltage is applied to the conductive film of lower sheet 213 of displacement generator 221, a negative voltage is applied to the conductive film of upper sheet 212 of displacement generator 221. For example, when the interval

between the conductive films of upper and lower sheets 212 and 213 is set to 100 μm , a voltage of about 100 V is preferably applied.

[0134] Then, while fluid path 215 corresponding to displacement generator 221 is closed by deforming displacement generator 221, displacement generator 222 is similarly deformed. Similarly to displacement generator 221, this deformation is generated by applying different polarity voltages to the conductive films of upper and lower sheets 212 and 213 of displacement generator 222. As a result, fluid path 215 corresponding to displacement generator 222 is deformed similarly to fluid path 215 corresponding to displacement generator 221. When displacement generator 222 is deformed, fluid path 215 corresponding to displacement generator 221 is nearly closed in advance, so that the fluid is squeezed from displacement generator 221 to displacement generator 222.

[0135] Subsequently, while fluid path 215 corresponding to displacement generator 222 is nearly closed, displacement generator 223 is deformed, so that fluid path 215 corresponding to displacement generator 223 is nearly closed. Simultaneously, displacement generator 221 is restored to its initial state. At this moment, similarly to displacement generator 222, different polarity voltages are applied to the conductive films of upper and lower sheets 212 and 213 of displacement generator 223. On the other hand, the same polarity voltages are applied to the conductive films of upper and lower sheets 212 and 213 of displacement generator 221. Accordingly, a repelling electrostatic force is generated between the conductive films of upper and lower sheets 212 and 213 of displacement generator 221 to separate each other. As a result, fluid path 215 corresponding to displacement generator 221 is restored to its initial state, so that fluid path 215 is opened. This deformation allows the fluid existing in displacement generator 223 to be squeezed from displacement generator 222 to displacement generator 223.

[0136] Subsequently, while fluid path 215 corresponding to displacement generator 223 is nearly closed, displacement generator 224 is deformed, so that fluid path 215 corresponding to displacement generator 224 is nearly closed. Simultaneously, displacement generator 222 is restored to its initial state, and fluid path 215 corresponding to displacement generator 221 is closed. At this moment, similarly to displacement generator 223, different polarity voltages are applied to the conductive films of upper and lower sheets 212 and 213 of displacement generator 224. On the other hand, the same polarity voltages are applied to the conductive films of upper and lower sheets 212 and 213 of displacement generator 222. Accordingly, a repelling electrostatic force is generated between the conductive films of upper and lower sheets 212 and 213 of displacement generator 222 to separate each other. As a result, fluid path 215 corresponding to displacement generator 222 is restored to its initial state, so that fluid path 215 is opened.

[0137] This allows the fluid existing in displacement generator 224 to be squeezed in a direction from displacement generator 223 to displacement generator 224. On the other hand, the fluid flows into displacement generator 222, and portions of fluid path 215 corresponding to neighboring displacement generators 221, and 223 are closed.

[0138] Subsequently, while portions of fluid path 215 corresponding to displacement generators 221 and 224 are

nearly closed, displacement generators 222 and 225 are deformed, so that fluid path 215 is nearly closed. Simultaneously, displacement generator 223 is restored to its initial state. At this moment, similarly to displacement generators 221 and 224, different polarity voltages are applied to the conductive films of upper and lower sheets 212 and 213 of displacement generators 222 and 225. On the other hand, the same polarity voltages are applied to the conductive films of upper and lower sheets 212 and 213 of displacement generator 223. Accordingly, a repelling electrostatic force is generated between the conductive films of upper and lower sheets 212 and 213 of displacement generator 223 to separate each other. As a result, fluid path 215 corresponding to displacement generator 223 is restored to its initial state, so that fluid path 215 is opened.

[0139] This allows the fluid existing in displacement generators 222 and 225 to be squeezed to displacement generators 223 and 226, respectively.

[0140] Then, while portions of fluid path 215 corresponding to displacement generators 222 and 225 are nearly closed, displacement generators 223 and 226 are deformed, so that fluid path 215 is nearly closed. Simultaneously, displacement generators 221 and 224 are restored to their initial states. At this moment, similarly to displacement generators 222 and 225, different polarity voltages are applied to the conductive films of upper and lower sheets 212 and 213 of displacement generators 223 and 226. On the other hand, the same polarity voltages are applied to the conductive films of upper and lower sheets 212 and 213 of displacement generators 221 and 224. Accordingly, a repelling electrostatic force is applied between the conductive films of upper and lower sheets 212 and 213 of displacement generators 221 and 224 to separate each other. As a result, portions of fluid path 215 corresponding to displacement generators 221 and 224 are restored to their initial states, so that fluid path 215 is opened.

[0141] This allows the fluid existing in displacement generators 223 and 226 to be squeezed to displacement generators 224 and 227, respectively.

[0142] Then, while portions of the fluid path 215 corresponding to displacement generators 223 and 226 are nearly closed, displacement generators 221, 224, and 227 are deformed, so that fluid path 215 is nearly closed. Simultaneously, displacement generators 222 and 225 are restored to their initial states. At this moment, similarly to displacement generators 223 and 226, different polarity voltages are applied to the conductive films of upper and lower sheets 212 and 213 of displacement generators 221, 224, and 227. On the other hand, the same polarity voltages are applied to the conductive films of upper and lower sheets 212 and 213 of displacement generators 222 and 225. Accordingly, a repelling electrostatic force is generated between the conductive films of upper and lower sheets 212 and 213 of displacement generators 222 and 225 to separate each other. As a result, portions of fluid path 215 corresponding to displacement generators 222 and 225 are restored to their initial state, so that fluid path 215 is opened.

[0143] This allows the fluid existing in displacement generators 221, 224, and 227 to be squeezed to displacement generators 222, 225, and 228, respectively.

[0144] Then, while portions of fluid path 215 corresponding to displacement generators 221, 224, and 227 are nearly

closed, displacement generators **222**, **225**, and **228** are deformed, so that fluid path **215** is nearly closed. Simultaneously, displacement generators **223** and **226** are restored to their initial states. At this moment, similarly to displacement generators **221**, **224**, and **227**, different polarity voltages are applied to the conductive films of upper and lower sheets **212** and **213** of displacement generators **222**, **225**, and **228**. On the other hand, the same polarity voltages are applied to the conductive films of upper and lower sheets **212** and **213** of displacement generators **223** and **226**. Accordingly, a repelling electrostatic force is generated between the conductive films of upper and lower sheets **212** and **213** of displacement generators **223** and **226** to separate each other. As a result, portions of fluid path **215** corresponding to displacement generators **223** and **226** are restored to their initial states, so that fluid path **215** is opened.

[0145] This allows the fluid existing in displacement generators **222**, **225**, and **228** to be squeezed to displacement generators **223**, **226**, and **231**, respectively.

[0146] By repeating the above operations, the fluid in fluid path **215** existing in fluid transport unit **220** can be successively circulated in the arrow direction of FIG. 9A. In addition, it is possible to more effectively circulate the fluid by performing the above operations for fluid transport unit **230**.

[0147] In order to easily understand the circulation of the fluid using the displacement generators, operations of displacement generators **221** to **228** have been sequentially described in detail. In reality, according to a fifth embodiment of the present invention, a series of operations are performed by grouping a set of displacement generators **221**, **224**, and **227**, a set of displacement generators **222**, **225**, and **228**, and a set of displacement generators **223** and **226**.

Sixth Embodiment

[0148] FIG. 10A is a plan view illustrating an electronic device cooler structure according to a sixth embodiment of the present invention, and FIG. 10B is a cross-sectional view along a line 10B-10B of FIG. 10A. In FIGS. 10A and 10B, although the reference numerals of components of the sheet type fluid circulating apparatus **210** are omitted, the descriptions are made by referring to the reference numerals of FIGS. 9A and 9C.

[0149] The electronic device cooler structure according to a sixth embodiment of the present invention includes the sheet type fluid circulating apparatus according to a fifth embodiment, a heater or a cooler provided in part of the fluid path, and a circuit board connected to the fluid path of the sheet type fluid circulating apparatus. This structure allows the electronic components mounted on the circuit board to be effectively cooled.

[0150] Firstly, as shown in FIG. 10A, in sheet type fluid circulating apparatus **210** of the electronic device cooler structure, flexible wiring boards **244** and **255** are connected to the conductive films of displacement generators **221** to **228** and **231** to **238** of fluid transport units **220** and **230**, respectively. Flexible wiring board **244** is connected to the conductive films of displacement generators **221** to **228** of fluid transport unit **220**. For example, the conductive films of upper and lower sheets **212** and **213** of displacement generator **221** are connected to wiring pattern **247** of flexible

wiring board **244**. In addition, wiring pattern **247** is provided in both surfaces of flexible wiring board **244**, and connected to the conductive films of upper and lower sheets **212** and **213** of displacement generator **221**. Similarly, displacement generators **222** to **228** are connected to wiring patterns **248** to **254** of flexible wiring board **244**, respectively.

[0151] Wiring pattern **246** provided in both sides is connected to electromagnetic shield film **242** provided in lower sheet **213**.

[0152] Flexible wiring board **255** is connected to the conductive films of displacement generators **231** to **238** of fluid transport unit **230**. For example, the conductive films of upper and lower sheets **212** and **213** of displacement generator **231** are connected to wiring pattern **257** of flexible wiring board **255**. In addition, wiring pattern **257** is provided in both surfaces of flexible wiring board **255**, and connected to the conductive films of upper and lower sheets **212** and **213** of displacement generator **231**. Similarly, displacement generators **232** to **238** are connected to wiring patterns **258** to **264** of flexible wiring board **255**, respectively.

[0153] Wiring pattern **246** provided in both sides is connected to electromagnetic shield film **242** of lower sheet **213**.

[0154] Wiring patterns **247** to **254** and **257** to **264** of flexible wiring boards **244** and **255** are connected to a control circuit unit (not shown in the drawing). In addition, wiring pattern **246** of flexible wiring boards **244** and **255** is connected to the ground section (not shown in the drawing).

[0155] Sheet type fluid circulating apparatus **210** combined with flexible wiring boards **244** and **255** covers circuit board **266** on which electronic components **265** including semiconductor elements such as a CPU, passive elements, and low heat resistance elements are mounted to allow sheet type fluid circulating apparatus **210** to be connected to electronic components **265** that should be cooled as shown in FIG. 10B. Heatsink fins **267** are provided to make contact with part of fluid path **215** of sheet type fluid circulating apparatus **210**. Heatsink fins **267** may be forcibly cooled using a fan (not shown in the drawing) as necessary.

[0156] As described above, the electronic device cooler structure has been made.

[0157] It is possible to cool electronic component **265** by circulating the fluid cooled by heatsink fins **267** when fluid transport units **220** and **230** of sheet type fluid circulating apparatus **210** are driven while sheet type fluid circulating apparatus **210** is in contact with electronic component **265**. In this case, since sheet type fluid circulating apparatus **210** has flexibility, it can be in contact with electronic component **265** even when electronic component **265** has various shapes. For this reason, flexible sheet **211** of sheet type fluid circulating apparatus **210** is deformed to have protrusions or hollows according to the shape of electronic component **265**. However, fluid path **215** of sheet type fluid circulating apparatus **210** is also deformed according to the protrusions or hollows. Therefore, the fluid can flow without obstacles.

[0158] According to a sixth embodiment of the present invention, it is possible to obtain an electronic device cooler structure that can cool the electronic component by allowing the flexible sheet type fluid circulating apparatus to make contact with the electronic component.

[0159] The electromagnetic noises generated from the fluid transport unit are blocked by the electromagnetic shield film provided in the lower sheet so that the erroneous operation of the electronic component can be prevented. Furthermore, since the entire surface of the fluid path is covered by the electromagnetic shield film, the leakage of the fluid is prevented, so that the flexible sheet type fluid circulating apparatus can be safely used for a long time.

[0160] Although the electromagnetic shield film is provided in the lower sheet in this embodiment, it may be also provided in the upper sheet. This allows the electromagnetic noises from the fluid transport unit to be blocked for other electronic devices as well as the electronic components on the circuit board. In addition, this further prevents the leakage of the fluid.

[0161] Although a sixth embodiment has been described by exemplifying a circuit board as an electronic device to be cooled, the present invention is not limited thereto. For example, the present invention can be adopted when a specimen should be maintained in a constant temperature in other electronic or biomedical applications. In addition, when the electronic device should be maintained in a condition lower than a room temperature, an electronic cooler may be in contact with part of the fluid path of the sheet type fluid circulating apparatus instead of the heatsink fins to cool the fluid. Furthermore, when a heating is required to store the electronic device in a constant temperature, a heater may be in contact with part of the fluid path of the sheet type fluid circulating apparatus. In these cases, a temperature sensor may be provided in a device to be maintained in a constant temperature, and the temperature of the cooler or heater may be controlled based on the measurement result.

Seventh Embodiment

[0162] FIG. 11 is a cross-sectional view illustrating a sheet type fluid circulating apparatus according to a seventh embodiment of the present invention.

[0163] The sheet type fluid circulating apparatus according to a seventh embodiment includes a fluid path having a closed structure provided in the inner space of the stacked flexible sheet, fluid filled in the fluid path, a fluid transport unit provided in the fluid path of the flexible sheet to circulate the fluid in the fluid path, an electromagnetic shield film provided on both surfaces of the flexible sheet, and a ground section for grounding the electromagnetic shield film. In addition, the fluid transport unit is constructed of a heat pipe including a vapor path provided in the entire fluid path and a capillary path for circulating the fluid.

[0164] As shown in FIG. 11, the heat pipe is constructed by mounting upper and lower sheets 274 and 278 to face each other with flexible spacer 279 being interposed therebetween and sealing them with sealing member 282 provided in both ends. Vapor path 281 and capillary path 280 are provided in a plurality of fluid paths provided by upper sheet 274 and spacer 279. The heat pipe shown in FIG. 11 has a panel shape expanding in a vertical direction of the drawing.

[0165] In this case, upper sheet 274 has a 3-layer structure in which conductive film 272 is interposed between resin films 271 and 273. Similarly, lower sheet 278 has a 3-layer

structure in which conductive film 276 is interposed between resin films 275 and 277. These conductive films 272 and 276 are commonly connected, although not shown in the drawing, and then connected to the ground G.

[0166] Similarly to a first embodiment, the sheet type fluid circulating apparatus having the above construction covers heat generating component 284 such as a semiconductor device such as a CPU. In this case, heat generating component 284 is mounted on circuit board 283 to constitute an electronic circuit in association with other electronic components although they are not shown in the drawing.

[0167] According to this embodiment, the heat generated in heat generating component 284 vaporizes the fluid of the heat pipe corresponding to the sheet type fluid circulating apparatus, and the vapor flows through a heatsink fin area expanded in a vertical direction to the drawing by vapor path 281. In the heatsink fin area, the vapor is cooled and re-converted into the fluid. The fluid flows through capillary path 280, and then, the contact area of heat generating component 284. By repeating these processes, it is possible to effectively cool heat generating component 284.

[0168] Conductive films 272 and 276 provided in upper and lower sheets 274 and 278 of sheet type fluid circulating apparatus effectively shield radiation of the electromagnetic noises to or from the electronic components including heat generating components 284 mounted on circuit board 283.

[0169] Reliability such as a life cycle of the heat pipe can be improved by providing conductive films 272 and 276 for preventing the fluid or the vaporized vapor from being leaked to upper and lower sheets 274 and 278.

[0170] As described in association with first to seventh embodiments of the present invention, it is possible to implement a compact and thin sheet type fluid circulating apparatus capable of effectively cooling other electronic components that have different shapes or generate a different amount of heat by connecting them to the fluid circulating apparatus, and an electronic device cooler structure using the same.

[0171] Hereinafter, another sheet type fluid circulating apparatus applied to a plasma display device according to eighth and ninth embodiments of the present invention will be described.

[0172] Conventionally, it has been known that a plasma display device (hereinafter, referred to as a PDP) generates a large amount of heat as its display brightness increases, this increases the temperature of the display panel, and irregular temperature distribution generates display quality degradation on its entire surface. When there is a large temperature difference on a display panel surface, a glass panel included in the display panel may be distorted and broken down finally.

[0173] Specifically, as shown in FIG. 22, when a conventional PDP display panel 800 is vertically erected, and the display panel surface is turned on by arranging it in parallel with a vertical direction, the temperature on the display panel surface is distributed in such a way that the upper center portion of the display panel has a higher temperature and the lower center and horizontal end portions have a lower temperature by virtue of a natural thermal convection principle. In this case, ten-odd Celsius degrees of tempera-

ture difference can be generated between the high temperature portion such as the upper center on the display panel and the low temperature portion such as the lower or horizontal end portions.

[0174] For this reason, a conventional PDP has a plurality of cooler fans provided on the rear surface of the display panel using a spacer interposed therebetween and generates wind from the cooler fans to the display panel in order to reduce the temperature of the entire display panel. Although the conventional PDP having the cooler fans may entirely reduce the temperature of the display panel, it is difficult to reduce the temperature difference locally generated in the surface of the display panel.

[0175] Accordingly, a plasma display device for solving the above problem will be described in association with the following embodiments of the present invention.

Eighth Embodiment

[0176] FIGS. 12A and 12B illustrate a plasma display device having a fluid circulating apparatus according to an eighth embodiment of the present invention. FIG. 12A is a cross-sectional view along a line 12A-12A of FIG. 12B, and FIG. 12B is a cross-sectional view along a line 12B-12B of FIG. 12A.

[0177] That is, in this embodiment, the sheet type fluid circulating apparatus is used as a fluid circulating apparatus for cooling the plasma display device.

[0178] The PDP according to an eighth embodiment of the present invention includes a display panel, and a fluid circulating apparatus that is provided on the rear surface of the display panel and has at least an upper cover and a bottom panel, in which the fluid for cooling the heat generated in the display panel is circulated, wherein a plurality of fluid path partitions for forming a fluid circulation path in the inner space of the fluid circulating apparatus are provided.

[0179] As shown in FIG. 12B, the plasma display device includes at least display panel 301 and fluid circulating apparatus 300 for cooling the heat generated in display panel 301. Although not shown in the drawing, display panel 301 is constructed by facing two glass panels and arranging a plurality of discharge cells therebetween. Fluid circulating apparatus 300 includes upper cover 304 and bottom panel 305 facing each other with external wall 309 being interposed therebetween, a plurality of fluid path partitions 306 provided therebetween for forming circulation path 307 of the fluid such as ethylene glycol, and heatsink path 313 having fluid outlet/inlet 312 interposed therebetween. Furthermore, fluid circulating apparatus 300 is bonded with the surface of rear panel 302 in display panel 301 using, for example, a thermal-conductive paste.

[0180] The heat generated from display panel 301 is absorbed by the fluid circulated in circulation path 307 of fluid circulating apparatus 300, and externally radiated through heatsink path 313.

[0181] Generally, display panel 301 of the PDP is used in a vertically erected state, and the temperature distribution on the surface of display panel 301 is determined in this state. Therefore, directions of display panel 301 are defined as follows. In other words, in each drawing, a Y-direction

denotes a vertical direction when display panel 301 is vertically erected, and an X-direction denotes a horizontal direction of display panel 301.

[0182] Hereinafter, an upper or upward direction of display panel 301 denotes a Y-direction, and a lower or downward direction denotes a reverse Y-direction.

[0183] Hereinafter, a construction of fluid circulating apparatus 300 will be described in detail with reference to FIG. 12A.

[0184] Fluid circulating apparatus 300 includes at least upper cover 304 and bottom panel 305, and a plurality of fluid path partitions 306 formed of metal such as aluminum having excellent thermal conductivity with a predetermined arrangement between upper cover 304 and bottom panel 305.

[0185] In this case, fluid path partition 306 and bottom panel 305 are preferably integrated in a single body. This allows a material for fluid path partitions 306 to be the same as that of the bottom panel. The cross-sectional shape of the fluid path partition 306 may be, for example, a rectangular or trapezoidal shape, and is not particularly limited if the width of fluid circulation path 307 can be arbitrarily formed.

[0186] As described with reference to FIG. 22, fluid path partitions 306 are provided according to the temperature distribution in display panel 301. For example, as shown in FIG. 12A, in an area E where the temperature of display panel 301 is high, the width w of fluid path partition 306 is set to be narrow, and the width d of fluid circulation path 307 is set to be wide in order to increase the flux of the fluid. On the other hand, in an area F where the temperature of display panel 301 is low, the width w of fluid path partition 306 is set to be wide, and the width d of fluid circulation path 307 is set to be narrow, in order to reduce the flux of the fluid.

[0187] In addition, although it is shown that fluid path partitions 306 are divided in a vertical direction, and fluid circulation paths 307 are formed in a horizontal direction by interposing separating sections 308 therebetween, fluid path partitions 306 may entirely extend in a Y-direction on display panel 301 as shown in FIGS. 13A and 13B, illustrating a first variation of the plasma display device according to eighth embodiment of the present invention. Separating sections 308 provided in fluid path partitions 306 for allowing part of the fluid to flow in a horizontal direction in fluid circulating apparatus 300 may partially removed in order to allow the fluid to flow through at least part of fluid path partitions 306 or entirely dividing fluid path partitions 306.

[0188] Accordingly, in the high temperature portion E in display panel 301, the amount of heat absorption is increased due to a large flux of the fluid, so that the temperature increase is controlled. As a result, since the temperature increase in the high temperature portion E in display panel 301 is controlled, the temperature distribution on the surface of display panel 301 becomes uniform.

[0189] In addition, in order to be forcibly circulated the fluid in fluid circulating apparatus 300 from the upper side to the lower side, circulating pump 310 may be installed in internal or external heatsink path 313 of fluid circulating apparatus 300.

[0190] In order to effectively externally radiate the heat absorbed by the circulating fluid, heatsink cooler 311 having

concave and convex shapes such as aluminum heatsink fins may be connected to at least a part of heatsink path 313 of fluid circulating apparatus 300, for example, with a thermal conductive sheet being interposed therebetween.

[0191] As a result, the fluid is forcibly circulated by circulation pump 310, and the heat of the fluid is effectively externally discharged through heatsink cooler 311, so that it is possible to more effectively reduce the temperature of display panel 301, and provide uniform temperature distribution.

[0192] Although it has been described that the flux of the fluid is controlled by changing the width w of fluid path partition 306 according to an eighth embodiment, the present invention is not limited thereto. For example, dimensions such as the depth h of the hollow formed between fluid path partitions 306, the width d of fluid circulation path 307, or the length L of fluid path partition 306 may be gradually changed based on the temperature distribution. In other words, the depth of the hollow and the width of fluid circulation path 307 may be increased and the length of fluid path partition 306 may be reduced in the high temperature portion of display panel 301.

[0193] Accordingly, the flux of the fluid flowing across fluid path partitions 306 can be optimally controlled based on the temperature distribution. Therefore, it is possible to reduce the temperature difference in display panel 301 as well as provide uniform temperature distribution.

[0194] Although it has been described in an eighth embodiment that the fluid circulated across fluid path partitions 306 flows from the upper side to the lower side by circulation pump 310, the present invention is not limited thereto. For example, the fluid may flow from the lower side to the upper side by virtue of natural convection, or the fluid may flow in any arbitrary direction depending on the arrangement of fluid path partitions 306 and the location or rotating direction of circulation pump 310. When display panel 301 is disposed on a ceiling horizontally or with a slanted angle, the temperature distribution in display panel 301 is changed in comparison with that shown in FIG. 22. Therefore, the shape and arrangement of fluid path partitions 306 are preferably changed so that the fluid can effectively cool the high temperature portions depending on the temperature distribution.

[0195] Although it has been described in an eighth embodiment that fluid circulating apparatus 300 is attached to the rear surface of display panel 301 with the thermal conductive paste being uniformly applied and interposed therebetween, the present invention is not limited thereto. For example, display panel 301 and fluid circulating apparatus 300 may be bonded with a thermal conductive sheet interposed therebetween. In this case, the thermal conductive sheet may include an aluminum thin film, a copper thin film, a carbon sheet, or a rubber sheet containing various thermal conductive materials.

[0196] Accordingly, the heat generated in display panel 301 can be more effectively transferred to fluid circulating apparatus 300.

[0197] In addition, a material of upper cover 304 or bottom panel 305 of fluid circulating apparatus 300 may include thermal conductive organic or inorganic materials such as aluminum, copper, aluminum nitride, carbon having

excellent thermal conductivity, or a polymer sheet containing the above materials or a thermal conductive inorganic material having high thermal conductivity.

[0198] The fluid circulated in fluid circulating apparatus 300 may include a fluid material having low viscosity, high fire resistance, high ignition resistance, and a high boiling point, such as ethylene glycol, hydrocarbon based liquid.

[0199] Hereinafter, the result of measuring the temperature distribution in display panel 301 when fluid circulating apparatus 300 having the above construction is bonded with a high-resolution plasma display panel 301 having a wide area of 60 inches.

[0200] In this case, fluid circulating apparatus 300 has a plurality of fluid path partitions 306 of which the intervals and widths are gradually changed between the areas E and F, as shown in FIG. 12A. In addition, the ethylene glycol is forcibly circulated by circulation pump 310, and fluid circulating apparatus 300 has heatsink 311.

[0201] Generally, the temperature distribution in display panel 301 has been measured when a white color is displayed on the entire surface of display panel 301 assuming that the temperature difference in display panel 301 becomes highest in this condition.

[0202] As a result, it was identified that the temperature distribution in display panel 301 can be made to be uniform when the temperature difference between the areas E and F of display panel 301 is not larger than 5° C.

[0203] As described above, according to an eighth embodiment, it is possible to reduce the temperature of the entire display panel as well as provide uniform temperature distribution. As a result, it is possible to provide a highly-reliable plasma display device in which the display quality in the display panel is improved, and the difference of life cycles of the discharge cells caused by the temperature distribution is controlled. This effect is more remarkable in a wide-area high-resolution plasma display device.

[0204] Hereinafter, a second variation of a plasma display device according to an eighth embodiment of the present invention will be described with reference to FIG. 14.

[0205] FIG. 14 is a cross-sectional view illustrating a second variation of the plasma display device according to an eighth embodiment of the present invention. In FIG. 14, like reference numerals denote like elements in association with FIGS. 12A and 12B, and their detailed descriptions are omitted.

[0206] In FIG. 14, the arrangement of fluid path partitions 306 linked in a vertical direction is different from that of FIG. 12A.

[0207] Referring to FIG. 14, fluid path partitions 306 linked in a vertical direction are arranged such that the area of circulation path 307 is enlarged in at least a high temperature portion, e.g., the area E, in display panel 301. For example, in fluid circulation apparatus 300, fluid path partitions 306 are not provided in the upper side of the area E corresponding to a high temperature portion of the display panel of FIG. 22, while fluid path partitions 306 are arranged as shown in FIGS. 12A and 12B in the area F or the lower side of the area E corresponding to a low temperature portion.

[0208] Accordingly, since fluid path partitions 306 are not provided in the upper side of the area E corresponding to a high temperature portion in display panel 301 shown in FIG. 22, the area where the fluid can flow through is large in the high temperature portion. On the contrary, since a plurality of fluid path partitions 306 are provided in the area F or the lower side of the area E corresponding to the low temperature portion, the area where the fluid flows through is reduced in the low temperature portion.

[0209] According to the above construction, since a fluid contact area is large in the high temperature portion, the absorbed heat amount can be large. On the contrary, since a fluid contact area is small in the low temperature portion, the absorbed heat amount is small. As a result, the temperature difference in the display panel can be reduced, and more uniform temperature distribution can be provided.

[0210] Although circulation path 307 was formed by dividing the fluid path in a vertical direction with fluid path partitions 306 and in a horizontal direction by interposing separating sections 308 across fluid path partitions 306, fluid path partitions 306 may be arranged to entirely extend in a Y-direction of display panel 301, but part of fluid path partitions 306 disposed in the high temperature portion may have a shorter length, as shown in FIGS. 15A and 15B which illustrates the plasma display device according to a third variation of an eighth embodiment. As a result, fluid path partitions 306 can be formed in a simple manner, and the uniform temperature distribution can be provided in display panel 301.

[0211] Although it has been described in an eighth embodiment that the lengths of the fluid path partitions or the arrangement of the fluid path partitions are changed between the high and low temperature portions, the present invention is not limited thereto. For example, the same effect can be obtained by arranging the fluid path partitions having predetermined unit length so as to have a lower concentration in the high temperature portion and have a high concentration in the low temperature portion.

Ninth Embodiment

[0212] Hereinafter, a plasma display device according to a ninth embodiment of the present invention will be described with reference to FIGS. 16A and 16B.

[0213] FIG. 16A is a cross-sectional view along a line 16A-16A of FIG. 16B for describing a plasma display device according to a ninth embodiment of the present invention. FIG. 16B is a cross-sectional view along a line 16B-16B of FIG. 16A. In FIGS. 16A and 16B, like reference numerals denote like elements in association with FIGS. 12A and 12B, and their detailed descriptions will be omitted.

[0214] Fluid circulating apparatus 330 shown in FIGS. 16A and 16B is different from that shown in FIGS. 12A and 12B in that a plurality of fluid path partitions 326 are arranged with a constant interval, and a plurality of flux controller 320 are provided in order to control the flux of the fluid flowing through circulation path 307.

[0215] The plasma display device according to a ninth embodiment of the present invention is characterized in that uniform temperature distribution can be obtained even when display panel 301 is disposed in any arbitrary direction such as a vertical, horizontal, or inclined manner.

[0216] As shown in FIG. 16B, the plasma display device includes display panel 301, and fluid circulating apparatus 330 that is disposed on the surface of display panel 301 and circulates the fluid so as to discharge the heat generated in display panel 301. Fluid circulating apparatus 330 includes bottom panel 325 bonded to display panel 301 and upper cover 324 made of a flexible sheet such as a polyimide resin film having a thickness of 100 μm , with fluid path partitions 326 and external walls 309 disposed in the circumferences of fluid circulating apparatus 330 being interposed therebetween.

[0217] In fluid circulating apparatus 330, a plurality of fluid path partitions 326 having a constant width and a constant height (or a depth), for example, 500 μm are arranged with a constant interval in order to provide circulation path 307 for circulating the fluid in its inner space.

[0218] Fluid circulating apparatus 330 further includes flux controller 320 for controlling or adjusting the flux of the fluid, for example, across each of fluid path partitions 326 depending on the temperature distribution of display panel 301 in order to automatically reduce the temperature difference in display panel 301 and provide uniform temperature distribution. Flux controller 320 includes flux control electrodes 321 that are disposed between upper cover 324 and lower panel 325 of fluid circulating apparatus 330, for example, across fluid path partitions 326. Flux control electrodes 321 of each flux controller 320 are connected to a control circuit unit (not shown in the drawing).

[0219] According to the above construction, the flux of the fluid can be controlled by adjusting an electrostatic force generated between each flux control electrode 321 by a voltage signal applied from the control circuit unit to generate displacement in sheet-shaped upper cover 324 and change the interval between upper cover 324 and bottom panel 325 across fluid path partitions 326.

[0220] In addition, a plurality of temperature sensors (not shown in the drawing) such as a thermistor are provided in at least a part of fluid circulating apparatus 330, for example, a plurality of places on the surface of display panel 301, to detect the temperature of display panel 301.

[0221] It is possible to control or adjust the flux of the fluid flowing through circulation path 307 provided between fluid path partitions 326 by automatically changing, at least, an interval between upper cover 324 and bottom panel 325 across fluid path partitions 326 using an electrostatic force based on information from the temperature sensors.

[0222] In other words, the control of the control circuit unit is performed such that the flux of the fluid is increased in the high temperature portion and reduced in the low temperature portion by changing the cross-sectional area of circulation path 307 using an electrostatic force based on the temperature information corresponding to the temperature distribution of display panel 301.

[0223] Accordingly, it is possible to automatically control the flux of the fluid in fluid circulating apparatus 330 in response to the temperature distribution of display panel 301 that can be varied depending on the environmental condition or method that display panel 301 is disposed, or a turn-on time of display panel 301. As a result, it is possible to automatically reduce the temperature difference of display panel 301 during operation to provide uniform temperature distribution.

[0224] According to a ninth embodiment of the present invention, it is possible to obtain a highly-reliable plasma display device capable of reducing the temperature of the display panel and providing uniform temperature distribution in the display panel.

[0225] Although a ninth embodiment of the present invention has been described by exemplifying a case that fluid path partitions having a constant width are provided with a constant interval, the present invention is not limited thereto. For example, the interval or the height of the fluid path partition, the depth of the hollow, the width or length of the fluid path partition may be differently provided or adjusted in advance in at least a part of the surface of the fluid circulation apparatus in order to provide uniform temperature distribution in the display panel.

[0226] Accordingly, it is possible to reduce the power consumption in the flux controller.

[0227] Although a ninth embodiment has been described by exemplifying a flux controller provided between the fluid path partitions, the present invention is not limited thereto. For example, the flux controller may be provided at least a part of the fluid path partitions. Specifically, the flux controller may be formed on the surface in a high temperature portion, and the intervals of the fluid path partitions may be reduced in other portions. Alternatively, the flux controller may be formed on the surface in a low temperature portion, and a constant flux may flow without the controlling in a high temperature portion.

[0228] Accordingly, since the flux controller provided in at least part of the fluid path partitions automatically controls the flux of the fluid, it is possible to obtain a plasma display device capable of providing uniform temperature distribution in the display panel with a simple construction.

[0229] Although a ninth embodiment has been described by exemplifying a flux controller which applies an electrostatic force between the flux control electrodes provided on the upper cover and the bottom panel to control the flux of the fluid, the present invention is not limited thereto. For example, a micro-electromagnetic valve may be provided across the fluid path partitions to control the flux of the fluid by switching the electromagnetic valve based on the temperature information. As a result, it is possible to automatically reduce the temperature difference in the display panel using a simple method.

[0230] Although a ninth embodiment has been described by exemplifying the polyimide resin film as a material of the upper cover of the fluid circulating apparatus to provide the flux control electrodes of the flux controller, the present invention is not limited thereto. For example, the upper cover of the fluid circulating apparatus may be formed of an electrically conductive metal thin-film such as an aluminum thin film laminated with resin, and an electrostatic force generated between the electrodes against the bottom panel using the metal thin film as a solid electrode may displace the laminated metal thin film.

[0231] Accordingly, it is possible to provide the flux control electrode in a simple construction, and use the flux control electrode disposed in one side as the upper cover as well. Therefore, it is possible to provide the fluid circulating apparatus with low cost.

[0232] Although a ninth embodiment has been described by exemplifying the flux control electrodes formed on inner surfaces of the upper cover and the bottom panel of the fluid circulation apparatus, the present invention is not limited thereto. For example, the flux control electrodes may be provided in the outer surface of at least one of the upper cover and the bottom panel. Accordingly, it is possible to simplify an extracting electrode construction for connection with the control circuit unit and eliminate necessity of forming an insulation film for coating the surface of the flux control electrode which is necessary to form in the inner surface. Therefore, it is possible to improve productivity of the fluid circulating apparatus.

[0233] Although it has been described in eighth and ninth embodiments that the fluid flows through the gap between the upper cover and the bottom panel as a fluid circulating apparatus, the present invention is not limited thereto. For example, as shown in FIGS. 17A and 17B, fluid circulating apparatus 350 may be formed by burying heat pipe 340 or self oscillating flow heat pipe 340 in the resin film. In this case, FIG. 17A is a cross-sectional view along a line 17A-17A of FIG. 17B, and illustrates another variation of the plasma display device according to each embodiment of the present invention. FIG. 17B is a cross-sectional view along a line 17B-17B of FIG. 17A.

[0234] In other words, if heat pipe 340 is used, the temperature of display panel 301 is uniformly controlled by giving and receiving latent heat between hot and cold areas. Specifically, the fluid is vaporized in the high temperature portion, while the vapor is liquefied in the low temperature portion.

[0235] If self oscillating flow heat pipe 340 is used, the pressure difference is generated by volume expansion due to the phase change generated when the fluid is vaporized in the high temperature portion. This pressure difference circulates the fluid, so that the uniform temperature distribution can be provided in display panel 301.

[0236] Although it has been described in eighth and ninth embodiments that the fluid is circulated using a circulation pump, the present invention is not limited thereto. For example, a micro-pump shown in FIGS. 18A and 18B may be used. In this case, the micro-pump is provided between heat-radiation paths in such a way that the outlet/inlet of one side is connected in series to the inlet/outlet of the other side.

[0237] Hereinafter, a construction of a micro-pump and a method of transporting fluid will be described with reference to FIGS. 18A, 18B, and 19A to 19D.

[0238] FIG. 18A is a perspective plan view illustrating a micro-pump, and FIG. 18B is a cross-sectional view along a line 18B-18B of FIG. 18A.

[0239] As shown in FIG. 18B, the micro-pump has a thickness of 20 μm . For example, the micro-pump has first member 401 that is formed of flexible resin film such as polyimide and has a circular shape, and second member 402 that is formed of an insulation resin substrate or an insulation silicon substrate, has a circular shape, and includes outlet/inlet 408 in its center, with first and second members 401 and 402 facing each other. Sealing member 403 is provided in at least circumferences of first and second members 401 and 402 in order to maintain an interval of, for example, 100 μm and to provide inlet/outlet 409. In this case, the rela-

tionship between outlet/inlet 408 of second member 402 and inlet/outlet 409 of sealing member 403 means that, if one of them functions as an inlet, the other functions as an outlet.

[0240] As shown in FIG. 18A, first electrode section 404 having a plurality of electrodes 405 formed in a coaxial form toward the center is provided on the inner surface of second member 402 facing first member 401. For example, first electrode section 404 may be formed of metal such as aluminum or a transparent electrode such as ITO and have an outermost diameter of, for example, 300 μm . Similarly, second electrode section 406 having a plurality of electrodes 407 formed on the inner surface of second member 402 in a coaxial form is provided to face coaxial electrodes 405 of first electrode section 404.

[0241] Although not shown in the drawing, the surfaces of first and second electrode sections 404 and 406 preferably have an insulation film. Accordingly, it is possible to prevent the short-circuit between the facing electrodes and transport other kinds of fluid than the insulating fluid.

[0242] As shown in FIG. 18A, first and second electrode sections 404 and 406 are preferably formed such that a plurality of coaxial electrodes 405 and 407 are sequentially widened toward the coaxial center in width. Particularly, the areas of the neighboring electrodes 405 and 407 are preferably set to be equal to each other. Accordingly, the fluid having the same volume can be sequentially transported from the inlet to the outlet.

[0243] Also, the micro-pump having the above construction generates an electrostatic force between facing electrodes 405 and 407 by applying a predetermined voltage signal to coaxial electrodes 405 and 407 of the first and second electrode sections 404 and 406 facing each other. In this case, when the same polarity voltages are applied to the facing electrodes, a repelling force is generated. When different polarity voltages are applied, an electrostatic attracting force is generated. As a result, first member 401 formed of a flexible material is coaxially displaced by this electrostatic force.

[0244] Accordingly, the fluid input from inlet/outlet 409 is transported in a coaxial diameter direction and output from outlet/inlet 408 by coaxially gap 410 functioning as a fluid path formed between first and second members 401 and 402 with sealing member 403 being interposed using an electrostatic force. Similarly, the fluid input from outlet/inlet 408 can be output from inlet/outlet 409 of sealing member 403.

[0245] According to the above construction, since the fluid is coaxially transported, it is possible to obtain a micro-pump having a minute size but a large flux.

[0246] Since first and second electrode sections 404 and 406 are formed on the inner surfaces of first and second members 401 and 402, it is possible to obtain a large electrostatic force that is inversely proportional to the square of the electrode interval. Therefore, it is possible to reduce the applied voltage. This allows a control element having a low electric strength to be adopted, so that it is possible to implement a micro-pump with low cost.

[0247] The shape of electrode 405 or 407 is not limited to the coaxial form. For example, it may have a coaxial elliptical shape or a polygonal shape such as a rectangular.

[0248] Hereinafter, operations of the micro-pump will be described in detail with reference to FIGS. 19A and 19D.

[0249] FIGS. 19A to 19D are cross-sectional views schematically illustrating operations of a micro-pump.

[0250] Although it has been described in FIGS. 19A to 19D that first electrode section 404 of first member 401 has a plurality of electrodes 405, and second electrode section 406 of second member 402 has one electrode, second electrode section 406 may have a plurality of coaxial electrodes with the same voltage.

[0251] Although it has been described that first and second electrode sections 404 and 406 are formed on the outer surfaces of first and second members 401 and 402, the same effect can be obtained by forming them on the inner surfaces.

[0252] Firstly, as shown in FIG. 19A, for example, a voltage of +50 V is applied to coaxial electrodes 551 and 552 of first electrode section 404, and a voltage of -50 V is applied to second electrode section 406. Accordingly, an electrostatic attraction force is generated between electrodes 551 and 552 and second electrode section 406 opposite to each other, so that gap 410 is closed, an initial state is returned.

[0253] As shown in FIG. 19B, for example, a voltage of -50 V is applied to coaxial electrode 551 of first electrode section 404, and a voltage of -50 V is applied to second electrode section 406. Accordingly, a repelling force is generated between electrode 551 and second electrode section 406, and the area corresponding to electrode 551 is coaxially expanded, so that the fluid is input from inlet/outlet 409 of sealing member 403 in coaxial gap 410 as shown in the arrow direction. In this case, a voltage of 0V may be applied to electrode 551, and gap 410 may be opened by the elastic force of first member 401.

[0254] As shown in FIG. 19C, for example, a voltage of +50 V is applied to coaxial electrode 551 of first electrode section 404, and a voltage of +50 V is applied to electrode 552 and second electrode section 406. Accordingly, gap 410 corresponding to electrode 551 is closed, and gap 410 corresponding to electrode 552 is opened. As a result, the fluid existing in electrode 551 is coaxially squeezed toward outlet/inlet 408 of second member 402, and output from outlet/inlet 408.

[0255] As shown in FIG. 19D, if the voltage applied to coaxial electrode 552 is changed from -50 V to +50 V, gap 410 of the fluid path between second electrode section 406 and electrode 551 is coaxially closed, so that all of the fluid existing in the fluid path is output from outlet/inlet 408. Accordingly, an initial state shown in FIG. 19A is returned. By repeating the above processes, the fluid can be sequentially transported.

[0256] While the micro-pump is operated, the voltages applied to each electrode are changed from a positive value to a negative value, but a predetermined voltage is being always applied.

[0257] The value of the voltages applied to the electrodes of each electrode section is optimally set by adjusting viscosity of the fluid, a shape of the electrode, a gap between the opposite electrodes, or the like. For example, in the above example, it has been described that the electrodes are

formed on the outer surfaces of the first and second members, and receive a voltage of ± 50 V. However, when the electrodes are formed on the inner surfaces, and the gap between the electrodes is set to $\frac{1}{2}$ of an original, the micro-pump can be driven with a voltage of ± 10 V to ± 20 V.

[0258] According to the above operations, the micro-pump having a plurality of coaxial electrodes formed at least one of the first and second electrode sections sequentially opens/closes the gap in a coaxial diameter direction depending on the polarity of the voltage applied between the electrodes of the first and second electrode sections. When the gap is sequentially closed/opened, the fluid path is sequentially closed/opened, so that the fluid input from the inlet is coaxially transported to the outlet, and finally, output from the outlet.

[0259] Although it has been described that the coaxial electrodes of the second electrode section provided in the second member are set to the same voltage in the above micro-pump, the present invention is not limited thereto. For example, a plurality of coaxial electrodes or one electrode may be set the same voltage in the first electrode section, and the polarity of the voltage applied to a plurality of the coaxially neighboring electrodes of the second electrode section may be changed. As a result, as described above, the fluid can be transported by displacing the first member that is flexible.

[0260] Although it has been described that the first electrode section has two electrodes in the above micro-pump, the present invention is not limited thereto. For example, three or more electrodes can be provided, so that the fluid is stored in electrode portions of the opened gap by at least applying different polarity voltages to the coaxially neighboring electrodes, and the fluid can be intermittently transported with a predetermined time interval.

[0261] As describe above, it is possible to obtain a thin fluid circulating apparatus that can provide uniform temperature distribution in the display panel such as a plasma display panel by using a micro-pump that has a minute size and excellent transport efficiency and is able to transport a large flux of the fluid. In addition, since there is no driving noise generated from a circulation pump, it is possible to provide a silent thin plasma display panel.

What is claimed is:

1. A sheet type fluid circulating apparatus, comprising:
 - a fluid path having a closed structure provided in an inner space of a stacked flexible sheet;
 - fluid filled in the fluid path;
 - a fluid transport unit provided in at least a part of the fluid path of the flexible sheet to circulate the fluid in the fluid path; and
 - a control circuit unit for controlling the fluid transport unit.
2. The sheet type fluid circulating apparatus according to claim 1, wherein the fluid transport unit has at least one displacement generator for deforming the flexible sheet by applying a voltage, and the control circuit unit applies the voltage to the displacement generator.
3. The sheet type fluid circulating apparatus according to claim 2, wherein the displacement generator of the fluid transport unit includes a plurality of electrodes formed on

both opposite surfaces of the flexible sheet, and the fluid is moved by an electrostatic force generated by applying the voltage to the opposite electrodes from the control circuit unit.

4. The sheet type fluid circulating apparatus according to claim 2, wherein the displacement generator of the fluid transport unit is formed of a piezoelectric element provided on at least one surface of the flexible sheet, and the fluid is moved by a piezoelectric displacement generated by applying a voltage to the piezoelectric element from the control circuit unit.

5. The sheet type fluid circulating apparatus according to claim 1, wherein a flux of the fluid is adjusted by controlling the fluid transport unit using a control circuit unit.

6. The sheet type fluid circulating apparatus according to claim 5, wherein the control circuit unit controls at least one of an applied voltage and an applied time period to adjust the flux of the fluid.

7. The sheet type fluid circulating apparatus according to claim 1, wherein the fluid path includes a plurality of cooling paths, a heatsink path connected to the cooling paths, and inlet and outlet paths for connecting the cooling paths with the heatsink path.

8. The sheet type fluid circulating apparatus according to claim 7, wherein a plurality of the cooling paths have different conductance values.

9. The sheet type fluid circulating apparatus according to claim 7, wherein the fluid transport unit is provided in at least one of inlet and outlet sides of the cooling paths according to a plurality of the cooling paths.

10. The sheet type fluid circulating apparatus according to claim 1, further comprising:

an electromagnetic shield film formed on at least one surface of the flexible sheet; and

a ground section for grounding the electromagnetic shield film.

11. The sheet type fluid circulating apparatus according to claim 10, wherein the electromagnetic shield film is formed of a conductive material using a physical deposition method or a printing method.

12. The sheet type fluid circulating apparatus according to claim 11, wherein the conductive material is formed in a mesh shape in the electromagnetic shield film.

13. The sheet type fluid circulating apparatus according to claim 1, wherein the fluid transport unit is a heat pipe including a vapor path provided in the fluid path and a capillary path for circulating the fluid.

14. An electronic device cooler structure, comprising:

a heat generating portion having a plurality of heat generating sources;

a fluid circulating apparatus for cooling a plurality of the heat generating sources; and

a heatsink portion for cooling fluid in the fluid circulating apparatus,

wherein the sheet type fluid circulating apparatus according to claim 1 is used as the fluid circulating apparatus, and

wherein at least a part of the fluid paths of the sheet type fluid circulating apparatus are in contact with the heat generating sources, and a flux of the fluid flowing through the fluid path is changed based on the amount of heat generated in the heat generating sources.

15. The electronic device cooler structure according to claim 14, wherein the heatsink portion includes heatsink fins or an electronic cooler, and is in contact with at least a part of the fluid paths.

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