(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 446 059 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
26.06.2024 Bulletin 2024/26

(21) Application number: **17786489.9**

(22) Date of filing: **18.04.2017**

(51) International Patent Classification (IPC):
F28D 9/00 *(2006.01)* ***B81B 1/00*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F28F 13/06; F28D 15/0233; F28F 3/086; F28F 7/02; F28D 2021/0028; F28F 2260/02; F28F 2265/24

(86) International application number:
PCT/US2017/028183

(87) International publication number:
WO 2017/184635 (26.10.2017 Gazette 2017/43)

(54) LAMINATED MICROCHANNEL HEAT EXCHANGERS

LAMINIERTE MIKROKANAL-WÄRMETAUSCHER

ÉCHANGEURS DE CHALEUR À MICROCANAUX STRATIFIÉS

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **18.04.2016 US 201662324327 P**
10.01.2017 US 201715402511

(43) Date of publication of application:
27.02.2019 Bulletin 2019/09

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Description

Field of the Invention

[0001] This invention relates to microchannel-based heat exchangers, including microchannel-based evaporators used to cool heat sources with high heat fluxes such as electronic devices.

Background of the Invention

[0002] Fluid heat exchangers are used to remove waste heat from high-heat flux heat sources (typically in excess of 5 watts/cm^2, and often substantially higher) by accepting and dissipating thermal energy therefrom. Examples of such high-heat flux heat sources include microelectronics, such as microprocessors and memory devices, solid-state light emitting diodes (LEDs) and lasers, insulated-gate bipolar transistor (IGBT) devices, such as power supplies, photovoltaic cells, radioactive thermal generators and fuel rods, and internal combustion engines.

[0003] The fluid heat exchangers dissipate heat by thermally conducting the heat into internal passages of the exchanger, through which a coolant fluid flows, absorbing the heat conducted across the walls of the exchanger, and then transporting the fluid outside the exchanger, where the heat is rejected to an external heat sink. While the coolant fluid flowing through the exchanger may be a gas, it is generally preferable to use a liquid, as liquids have higher heat capacities and heat transfer coefficients than gases. The liquid may remain in a single phase, or the liquid may partially or completely evaporate within the internal passages of the exchanger.

[0004] The flow of coolant liquid fed to the fluid heat exchanger may be driven by a pump, or by natural convection due to density differences and/or elevation between the incoming and exiting fluid (e.g. thermosyphons), or by capillary action in the internal passages of the exchanger, or by a combination of these mechanisms.

[0005] Evaporator-type exchangers rely on the boiling mode, and have the advantages of higher heat transfer coefficients (better heat transfer) per unit of fluid flow rate of the coolant fluid. They also require much less coolant flow, as the majority of the heat is absorbed through via the latent heat of vaporization of the boiling fluid, rather than the sensible heat (heat capacity) of a single-phase liquid or gas.

[0006] It is well known that the thermal performance and efficiency of fluid heat exchangers can be greatly enhanced if the internal passages are comprised of microchannels, i.e. channels having cross-sections with a smallest dimension of less than 1000 microns, and more typically, in the range of 50 - 500 microns.

[0007] US9310135 discloses a heat exchanger provided by assembling a plurality of individual plates having opposed faces, wherein flow channels are machined through those opposed faces, and the plates are interconnected with intervening shim plates. End plates are connected to an assembly of such plates and intermediate plates, to form a preform, which is then machined to a desired cross section. The resulting structure has a plurality of passages therethrough in one direction, and a second plurality of passages therethrough in a second direction, the passages fluidly isolated from one another. The resulting structure is configurable to a specific geometry of a flow passage, and enables heat exchange between fluids passing through the different flow channels

Summary of the Invention

[0008] In one general aspect, the invention features a microchannel heat exchanger according to claim 1.

[0009] In preferred embodiments, the thermally conductive sheets can further define access channel openings at each end of the lanes, which when stacked create access channels for the microchannels. The sheets can define a more dense packing of cross ribs in at least one inlet end of the heat exchanger to reduce the open cross-section at the inlet end of the lanes. The aspect ratio of the microchannels can be above 4: 1. The aspect ratio of the microchannels can be above 8: 1. The apparatus can further include thermally conductive separator sheets located between groups of the thermally conductive sheets to form a multilayer heat exchanger. The sheets can be made of at least one conductive metal. The sheets can be made of sinterable thermally conductive ceramics. The sheets can be bonded or fused. The microchannels can have a hydraulic diameter of below 500 microns. The microchannels can have a hydraulic diameter of below 200 microns. The base can be a base plate that is thicker than each of the sheets and the cover can include access channels in communication with the microchannels. The base can be thermally conductive yet electrically insulating. The heat exchanger can be constructed for boiling or evaporating fluid service, with the heat exchanger further including flow restrictors at the inlet ends of the microchannels. The flow restrictors can be formed by alternately closing an end of the first slot in a lane of slots with cross-ribs that are wider than the bulk of the cross-ribs between slots, with the alternating closed-ended lanes of slots being staggered with respect to the lanes of slots above or below, in alternating layers of slotted sheets, such that, when the sheets are stacked and bonded together, the cross-section of the parallel channels that are formed have a checkerboard pattern across the inlets of the plurality of channels, which serve as integral flow restrictors covering substantially 50% of a cross-sectional area of the main channels.

[0010] Systems according to the invention can help to suppress Ledinegg effects and thereby allow heat exchangers to work with two-phase systems. By providing inlet restrictions, microchannel evaporators according to the invention can avoid flow instabilities, due to the Led-

inegg effect, whereby boiling within multiple (parallel) microchannels might otherwise be non-uniform and due to the interaction of varying pressure drop as boiling develops in the various channels, resulting in periodic backflow into the inlet header or manifold. This can help to achieve stabilized and substantially uniform boiling flows and thereby result in improved and more stable thermal performance when cooling high-flux heat sources.

Brief Description of the Drawing

[0011]

Fig. 1 is a plan view of a first type of grooved sheet for inclusion in a grooved laminate structure that can be used to implement a microchannel heat exchanger;

Fig. 2 is a plan view of a portion of the first type of grooved sheet of Fig. 1 shown in rectangle 2 on Fig. 1;

Fig. 3 is a plan view of a portion of a second type of grooved sheet for inclusion in the grooved laminate structure;

Fig. 4 is a plan view of a separator sheet for inclusion in the grooved laminate structure;

Fig. 5 is a perspective cutaway of the laminate structure formed by alternating first and second sheet types as shown Figs. 1-4 in an orientation shown by arrow 5 in Figs. 2 and 3;

Fig. 6 is a more detailed cutaway view of the grooved laminate structure of Fig. 5;

Fig. 7 is a second perspective cutaway of the laminate structure of Fig. 5 showing flow paths through the structure of Fig. 5 in an orientation shown by arrow 7 in Figs. 2 and 3;

Fig. 8 is an exploded view of the laminated sheets for assembly into a grooved laminate core using the grooved laminated structure presented in Figs. 1-7;

Fig. 9 is an exploded perspective view of a portion of a microchannel heat exchanger using the laminated core of Fig. 8; and

Fig 10 is a cross-sectional view of the grooved laminate structure of Fig. 5, taken through a plane that defines flow restrictors in the grooved laminate structure.

Detailed Description of an Illustrative Embodiment

[0012] A microchannel heat exchanger can be assembled using a grooved laminated structure made up of a plurality of thermally conductive sheets. One such sheet of a first type 40 is shown in Fig. 1. It includes common cut-out areas 42 that are separated lines 44 of slots 46 that define the microchannels.

[0013] More specifically, the sheet of the first type 40 includes a plurality of lines 44 of multiple slots 46, with the slots in a given line being separated by thin wall that functions as a cross-rib 48. These lines span between the common cut-out areas connected to the slots at either end of each line of slots. The common cut-out areas align with each other to form input and output manifolds when sheets are stacked.

[0014] Referring also to Figs. 2 and 3, alternating two or more types of sheets allows the microchannels to be defined in three-dimensions. In particular, the laminated core structure is assembled by alternating slotted-and-ribbed sheets having the cross-ribs staggered with respect to each other when the sheets are stacked so that each line of slots forms a continuous but serpentine flow path (see also Figs. 5-7).

[0015] Referring to Fig. 4, thermally conductive un-slotted separator sheets 60 having cut-out areas 62 that align with the common cut-out areas of the slotted-and-ribbed sheets can also be used on the top and bottom of the core and/or to separate layers of microchannels.

[0016] Referring to Fig. 8, stacking sets of the alternating slotted-and-ribbed-sheets, flanked by un-slotted separator sheets allows the formation of a core structure that includes one or more layers each having a plurality of microchannels with interspersed cross-ribs that intermittently partially interrupt the flow path with providing lateral strengthening of the channel walls. The number of alternating slotted-and-ribbed-sheets in each layer, along with the sheet thickness and slot width, determines the channel depth : width aspect ratio of the channel layers. The layered stacked sheets are preferably bonded to ensure that all the sheets are in thermally conductive communication with each other.

[0017] Referring to Fig. 9, the resulting sub-assembly can then be bonded to a base plate 74 to ensure that the base plate is in thermally conductive communication with the microchannel layers, and a cover 78 can be placed and sealed on top of the resulting assembly of microchannel layers 76 bonded to the base plate, thereby forming a complete microchannel heat exchanger assembly 70.

[0018] Referring to Fig. 10, the input sides of the microchannels preferably include flow restrictors where the exchanger is used in boiling or evaporative service. These restrictors can be built into the laminate structure by providing extra cross-ribs 82 at the inputs of the microchannels.

[0019] The laminated structures described above enable microchannel heat exchangers having one or more layers of microchannels with hydraulic diameters of less than 500 microns, with the microchannels having arbitrarily high depth : width aspect ratios and with thin walls. The channels have internal cross-ribs connecting the channel's walls, and provide mechanical strength to the channel walls and way of breaking up the fluid stream lines to improve heat transfer. The thermally conductive sheet and base plate materials are preferably, but not limited to, metals and their alloys; non-metallic elements, thermally conductive carbon allotropes, or thermally conductive ceramics. Bonding of the sheets can be by any convenient means that ensure high thermal conduction

between the sheets and the base plate.

[0020] Multiple layers of microchannels are formed by inserting, between stacks of slotted-and-ribbed sheets, additional thermally conductive un-slotted separator sheets having cut-out areas that align with the common cut-out areas of the slotted-and-ribbed sheets. The microchannels of any layer the may have the same or different depth: width aspect ratio and hydraulic diameter compared to the microchannels in the other layers.

[0021] The depth: width aspect ratio of the resulting microchannels can be at least 2:1, and preferably between 4:1 and 15: 1. The walls between the resulting microchannels can be less than 200 microns and preferably between 40 and 100 microns thick. The base plate and microchannel walls can be fabricated from materials having thermal conductivities in excess of 100 W/m-K. The hydraulic diameter of the resulting microchannels can be less than 500 microns, and preferably between 50 and 200 microns.

[0022] The liquid inlet channels can be provided with flow restrictors, to prevent backflow or two-phase flow instabilities. These inlet restrictions are provided by closing-off the inlet-side ends of the slots (e.g. by adding additional cross-ribs) of alternate sheets in the stacks of slotted-and-ribbed sheets, thereby reducing the open cross-sectional area of the inlets to the channels relative to the main channel cross-section beyond the closed portions. Preferably, the length of the closed-off (restriction) portions of the microchannels is at least 1 mm.

[0023] The various components of the microchannel heat exchanger (e.g. microchannel stacks, base plate, and over plate) can be bonded or fused, so that the exchanger is hermetically sealed (with the exception of the fluid inlet and outlet ports that communicate with the manifolds), so that the exchanger can hold elevated internal pressures. Bonding or fusing may be accomplished by any convenient means.

[0024] The various components of the microchannel heat exchanger (e.g. microchannel stacks, base plate, and over plate) can also be held together by mechanical means, with suitable seals between components, so that the exchanger can hold elevated internal pressures.

[0025] In another embodiment, the bottom base of the layer of the microchannel exchanger is made from or is coated with a thermally conductive yet electrically insulating ceramic or dielectric solid, such as aluminum nitride, silicon carbide, beryllium oxide, diamond film, and the like. The microchannel exchanger then serves as the substrate for (heat generating) electronic components, which are mounted on, and in thermal contact with, the electrically insulating but thermally conductive underside surface of the exchanger.

Methods of Manufacture

[0026] The various components of the microchannel heat exchanger, e.g. the thermally conductive base, the microchannel layers, manifolds, covers, fluid inlet and outlet ports, the slotted-and-ribbed sheets, etc. may be fabricated by any convenient means consistent with the final assembly of the heat exchangers. Such means may include, but are not limited to, the following methods and combinations thereof:

- Subtractive manufacturing techniques such as mechanical machining, milling, etching, punching, photochemical machining, laser ablation or micromachining, electrical discharge machining (EDM), ultrasonic machining, water-jet cutting, etc.
- Mechanical deformation of material, e.g. by skiving, "plowing", stamping, coining, extrusion, etc.
- Laminating and bonding of patterned sheets, to form 3-dimensonal structures with internal features and passages. The sheets may have repeating areas of the patterns, so that after bonding, the bonded assemblies may be cut or diced into individual microchannel exchangers or exchanger sub-assemblies.
- Additive manufacturing techniques (3-D printing) as selective laser sintering, direct metal laser sintering, selective laser melting, stereo-lithography, fused deposition modeling, etc.
- Bonding or fusing techniques such diffusion bonding, brazing, soldering, welding, sintering, etc.
- Mechanical assembly techniques such as bolts, studs, clamps, adhesives, and the like, using seals, as appropriate, such as gaskets, O-rings, caulks, etc.

[0027] Embodiments according to the invention can be developed for a variety of different cooling configurations and applied to a variety of different cooling tasks. For example, they can implemented in connection with the teachings of published PCT application no. WO2009/085307, filed December 26, 2008 and published US application no. US-2009-0229794, filed on November 10, 2008.

[0028] The present invention has now been described in connection with a number of specific embodiments thereof. However, numerous modifications which are contemplated as falling within the scope of the present invention should now be apparent to those skilled in the art. Therefore, it is intended that the scope of the present invention be limited only by the scope of the claims appended hereto. In addition, the order of presentation of the claims should not be construed to limit the scope of any particular term in the claims.

Claims

1. A microchannel heat exchanger (70), comprising:

a cover (78) with a first access channel and a second access channel,
a thermally conductive base (74),
a plurality of thermally conductive sheets (40) between the cover (78) and the base (74) that

each define a series of side-by-side lanes (44) aligned with a flow direction, wherein the lanes (44) each include a plurality of aligned slots (46) that define microchannel segments that extend along the flow direction and are separated by cross ribs (48) extending across the lanes (44), wherein the sheets (40) further define common cut-out areas (42) in communication with the lanes (44) at either end of the lanes (44),
wherein the sheets (40) are stacked in a direction perpendicular to the flow direction between the base (74) and cover (78) so as to cause at least some of the ribs (48) to be offset from each other along the flow direction in adjacent sheets (40) and thereby allow the microchannel segments in the same lane (44) in adjacent sheets (40) to communicate with each other along the flow direction to define a plurality of adjacent, plural-sheet microchannels in the heat exchanger (70) that each extend between the cut-out areas (42) along the flow direction, and
wherein the sheets (40) are stacked between the base (74) and cover (78) so that the common cut-out areas (42) form at least one input manifold and at least one output manifold that are respectfully aligned with the first access channel and the second access channel on the cover (78).

2. The apparatus of claim 1 wherein the thermally conductive sheets (40) further define access channel openings at each end of the lanes (44), which when stacked create access channels for the microchannels.

3. The apparatus of claim 1 wherein the sheets (40) define a more dense packing of cross ribs (48) in at least one inlet end of the heat exchanger (70) to reduce the open cross-section at the inlet end of the lanes (44) relative to a cross-section of a portion of the lanes (44) between the inlet and outlet ends of the lanes (44).

4. The apparatus of claim 1 wherein the aspect ratio of the microchannels is above 4:1.

5. The apparatus of claim 1 wherein the aspect ratio of the microchannels is above 8:1.

6. The apparatus of claim 1 further including thermally conductive separator sheets (60) located between groups of the thermally conductive sheets (40) to form a multilayer heat exchanger (70).

7. The apparatus of claim 1 wherein the sheets (40) are made of at least one thermally conductive metal.

8. The apparatus of claim 1 wherein the sheets (40) are made of sinterable thermally conductive ceramics.

9. The apparatus of claim 1 wherein the sheets (40) are bonded or fused.

10. The apparatus of claim 1 wherein the microchannels have a hydraulic diameter of below 500 microns.

11. The apparatus of claim 1 wherein the microchannels have a hydraulic diameter of below 200 microns.

12. The apparatus of claim 1 wherein the base is a base plate (74) that is thicker than each of the sheets (40).

13. The apparatus of claim 1 wherein the base (74) is thermally conductive yet electrically insulating.

14. The apparatus of claim 1, wherein the heat exchanger (70) is constructed for boiling or evaporating fluid service, and wherein the heat exchanger (70) further includes flow restrictors at the inlet ends of the microchannels.

15. The apparatus of claim 14 wherein the flow restrictors are formed by closing an input end of every other lane (44) in each of the sheets (40) with a cross-rib (48), with the closed-ended lanes (44) of slots (46) being staggered with respect to each other in adjacent sheets (40) when the sheets (40) are stacked and bonded together to form a checkerboard pattern across the inlets of the plurality of channels.

Patentansprüche

1. Mikrokanal-Wärmetauscher (70), umfassend:

eine Abdeckung (78) mit einem ersten Zugangskanal und einem zweiten Zugangskanal,
eine wärmeleitende Basis (74),
eine Vielzahl von wärmeleitenden Platten (40) zwischen der Abdeckung (78) und der Basis (74), die jeweils eine Reihe nebeneinanderliegender, in einer Strömungsrichtung ausgerichteter Bahnen (44) definieren, wobei die Bahnen (44) jeweils eine Vielzahl ausgerichteter Schlitze (46) einschließen, die Mikrokanalsegmente definieren, die sich entlang der Strömungsrichtung erstrecken und durch Querrippen (48) getrennt sind, die sich über die Bahnen (44) erstrecken,
wobei die Platten (40) weiter gemeinsame Ausschnittbereiche (42) in Verbindung mit den Bahnen (44) an beiden Enden der Bahnen (44) definieren,
wobei die Platten (40) in einer Richtung senkrecht zur Strömungsrichtung zwischen der Ba-

sis (74) und der Abdeckung (78) gestapelt sind, so dass zumindest einige der Rippen (48) in benachbarten Platten (40) entlang der Strömungsrichtung gegeneinander versetzt sind und es dadurch den Mikrokanalsegmenten in derselben Bahn (44) in benachbarten Platten (40) ermöglicht wird, entlang der Strömungsrichtung miteinander zu kommunizieren, um eine Vielzahl von benachbarten Mikrokanälen mit mehreren Platten im Wärmetauscher (70) zu definieren, die sich jeweils zwischen den Ausschnittbereichen (42) entlang der Strömungsrichtung erstrecken, und
wobei die Platten (40) zwischen der Basis (74) und der Abdeckung (78) gestapelt sind, so dass die gemeinsamen Ausschnittbereiche (42) mindestens einen Eingangsverteiler und mindestens einen Ausgangsverteiler bilden, die jeweils mit dem ersten Zugangskanal und dem zweiten Zugangskanal auf der Abdeckung (78) ausgerichtet sind.

2. Vorrichtung nach Anspruch 1 wobei die wärmeleitenden Platten (40) weiter Zugangskanalöffnungen an jedem Ende der Bahnen (44) definieren, die, wenn sie gestapelt sind, Zugangskanäle für die Mikrokanäle schaffen.

3. Vorrichtung nach Anspruch 1 wobei die Platten (40) eine dichtere Packung von Querrippen (48) in mindestens einem Einlassende des Wärmetauschers (70) definieren, um den offenen Querschnitt am Einlassende der Bahnen (44) relativ zu einem Querschnitt eines Abschnitts der Bahnen (44) zwischen den Einlass- und Auslassenden der Bahnen (44) zu verringern.

4. Vorrichtung nach Anspruch 1 wobei das Seitenverhältnis der Mikrokanäle über 4:1 liegt.

5. Vorrichtung nach Anspruch 1 wobei das Seitenverhältnis der Mikrokanäle über 8:1 liegt.

6. Vorrichtung nach Anspruch 1, die weiter wärmeleitende Trennplatten (60) einschließt, die sich zwischen Gruppen der wärmeleitenden Platten (40) befinden, um einen mehrschichtigen Wärmetauscher (70) zu bilden.

7. Vorrichtung nach Anspruch 1 wobei die Platten (40) aus mindestens einem wärmeleitenden Metall hergestellt sind.

8. Vorrichtung nach Anspruch 1 wobei die Platten (40) aus sinterbarer wärmeleitender Keramik hergestellt sind.

9. Vorrichtung nach Anspruch 1 wobei die Platten (40) verklebt oder verschmolzen sind.

10. Vorrichtung nach Anspruch 1 wobei die Mikrokanäle einen hydraulischen Durchmesser von unter 500 Mikrometern aufweisen.

11. Vorrichtung nach Anspruch 1 wobei die Mikrokanäle einen Hydraulikdurchmesser von unter 200 Mikrometern aufweisen.

12. Vorrichtung nach Anspruch 1 wobei die Basis eine Basisplatte (74) ist, die dicker ist als jede der Platten (40).

13. Vorrichtung nach Anspruch 1 wobei die Basis (74) wärmeleitend, jedoch elektrisch isolierend ist.

14. Vorrichtung nach Anspruch 1, wobei der Wärmetauscher (70) für einen Einsatz mit siedendem oder verdampfendem Fluid ausgelegt ist, und wobei der Wärmetauscher (70) weiter Durchflussbegrenzer an den Einlassenden der Mikrokanäle einschließt.

15. Vorrichtung nach Anspruch 14 wobei die Durchflussbegrenzer dadurch gebildet sind, dass ein Eingangsende jeder zweiten Bahn (44) in jeder der Platten (40) mit einer Querrippe (48) verschlossen wird, wobei die Bahnen (44) von Schlitzen (46) mit verschlossenen Enden in Bezug aufeinander in benachbarten Platten (40) versetzt sind, wenn die Platten (40) gestapelt und miteinander verklebt sind, um ein Schachbrettmuster über den Einlässen der Vielzahl von Kanälen zu bilden.

Revendications

1. Échangeur de chaleur à microcanaux (70), comprenant :

un couvercle (78) avec un premier canal d'accès et un second canal d'accès,
une base thermoconductrice (74),
une pluralité de feuilles thermoconductrices (40) entre le couvercle (78) et la base (74) qui définissent chacune une série de couloirs (44) côte à côte alignés avec une direction d'écoulement, dans lequel les couloirs (44) incluent chacun une pluralité de fentes (46) alignées qui définissent des segments de microcanaux qui s'étendent le long de la direction d'écoulement et sont séparés par des nervures (48) transversales qui s'étendent à travers les couloirs (44),
dans lequel les feuilles (40) définissent en outre des zones (42) de découpe communes en communication avec les couloirs (44) à chaque extrémité des couloirs (44),
dans lequel les feuilles (40) sont empilées dans

une direction perpendiculaire à la direction d'écoulement entre la base (74) et le couvercle (78) de manière à ce qu'au moins certaines des nervures (48) soient décalées les unes par rapport aux autres le long de la direction d'écoulement dans des feuilles (40) adjacentes et permettre ainsi aux segments de microcanaux dans le même couloir (44) dans des feuilles (40) adjacentes de communiquer les uns avec les autres le long de la direction d'écoulement pour définir une pluralité de microcanaux adjacents à plusieurs feuilles dans l'échangeur de chaleur (70) qui s'étendent chacun entre les zones (42) de découpe le long de la direction d'écoulement, et

dans lequel les feuilles (40) sont empilées entre la base (74) et le couvercle (78) de sorte que les zones (42) de découpe communes forment au moins un collecteur d'entrée et au moins un collecteur de sortie qui sont alignés respectivement avec le premier canal d'accès et le second canal d'accès sur le couvercle (78).

2. Appareil selon la revendication 1 dans lequel les feuilles thermoconductrices (40) définissent en outre des ouvertures de canaux d'accès à chaque extrémité des couloirs (44), qui, lorsqu'elles sont empilées, créent des canaux d'accès pour les microcanaux.

3. Appareil selon la revendication 1 dans lequel les feuilles (40) définissent un empilement plus dense de nervures (48) transversales dans au moins une extrémité d'entrée de l'échangeur de chaleur (70) pour réduire la section transversale ouverte au niveau de l'extrémité d'entrée des couloirs (44) par rapport à une section transversale d'une partie des couloirs (44) entre les extrémités d'entrée et de sortie des couloirs (44).

4. Appareil selon la revendication 1 dans lequel le rapport d'aspect des microcanaux est supérieur à 4:1.

5. Appareil selon la revendication 1 dans lequel le rapport d'aspect des microcanaux est supérieur à 8:1.

6. Appareil selon la revendication 1 incluant en outre des feuilles séparatrices thermoconductrices (60) situées entre des groupes de feuilles thermoconductrices (40) pour former un échangeur de chaleur multicouche (70).

7. Appareil selon la revendication 1 dans lequel les feuilles (40) sont constituées d'au moins un métal thermoconducteur.

8. Appareil selon la revendication 1 dans lequel les feuilles (40) sont constituées de céramique thermoconductrice frittable.

9. Appareil selon la revendication 1 dans lequel les feuilles (40) sont collées ou fusionnées.

10. Appareil selon la revendication 1 dans lequel les microcanaux présentent un diamètre hydraulique inférieur à 500 microns.

11. Appareil selon la revendication 1 dans lequel les microcanaux présentent un diamètre hydraulique inférieur à 200 microns.

12. Appareil selon la revendication 1 dans lequel la base est une plaque de base (74) plus épaisse que chacune des feuilles (40).

13. Appareil selon la revendication 1 dans lequel la base (74) est thermoconductrice mais électriquement isolante.

14. Appareil selon la revendication 1, dans lequel l'échangeur de chaleur (70) est conçu pour fonctionner avec des fluides en ébullition ou en évaporation, et dans lequel l'échangeur de chaleur (70) inclut en outre des limiteurs de débit au niveau des extrémités d'entrée des microcanaux.

15. Appareil selon la revendication 14 dans lequel les limiteurs de débit sont formés en fermant une extrémité d'entrée d'un couloir (44) sur deux dans chacune des feuilles (40) avec une nervure (48) transversale, les couloirs à extrémités fermées (44) des fentes (46) étant décalés les uns par rapport aux autres dans des feuilles (40) adjacentes lorsque les feuilles (40) sont empilées et collées ensemble pour former un motif en damier à travers les entrées de la pluralité de canaux.

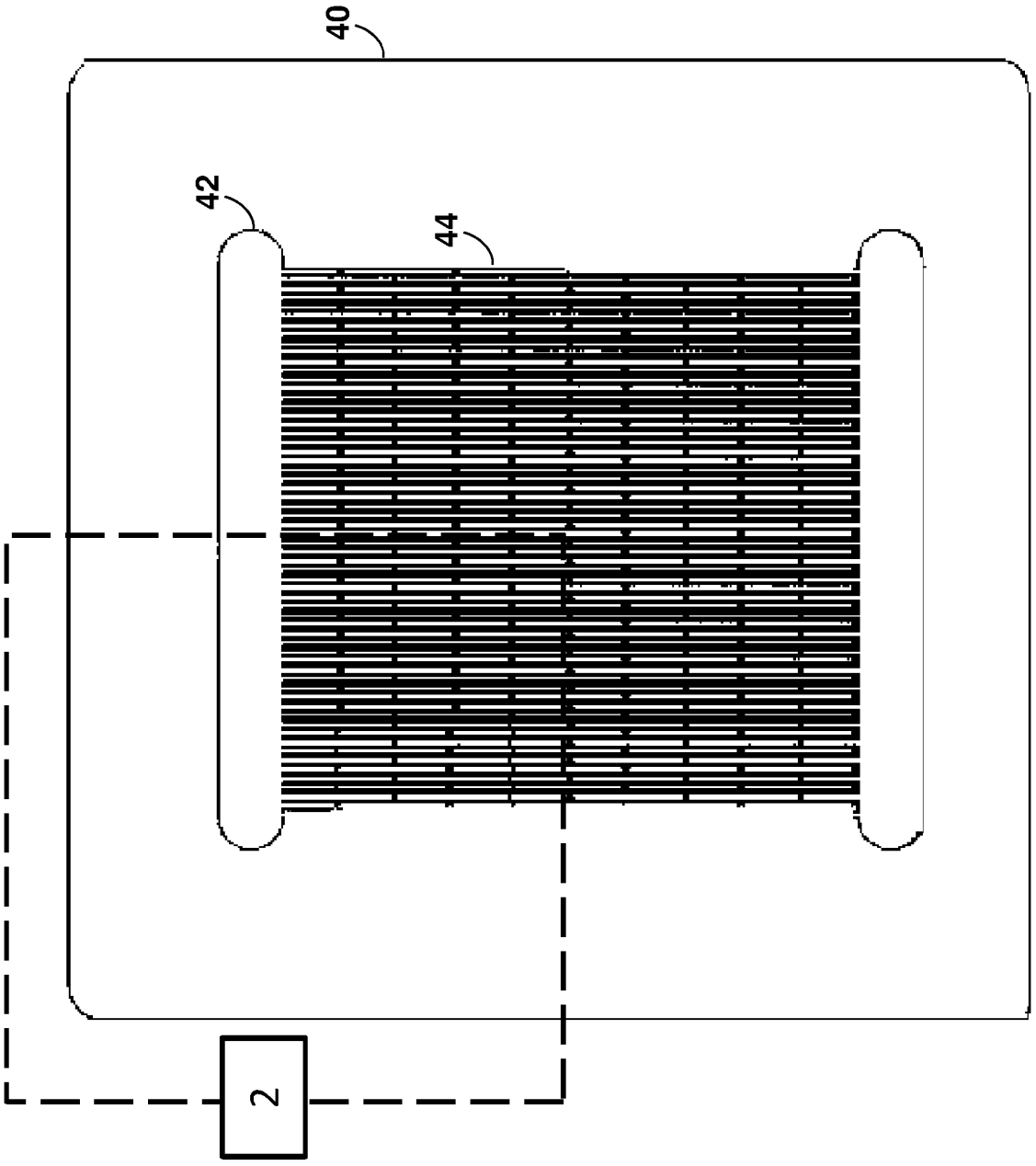


FIG. 1

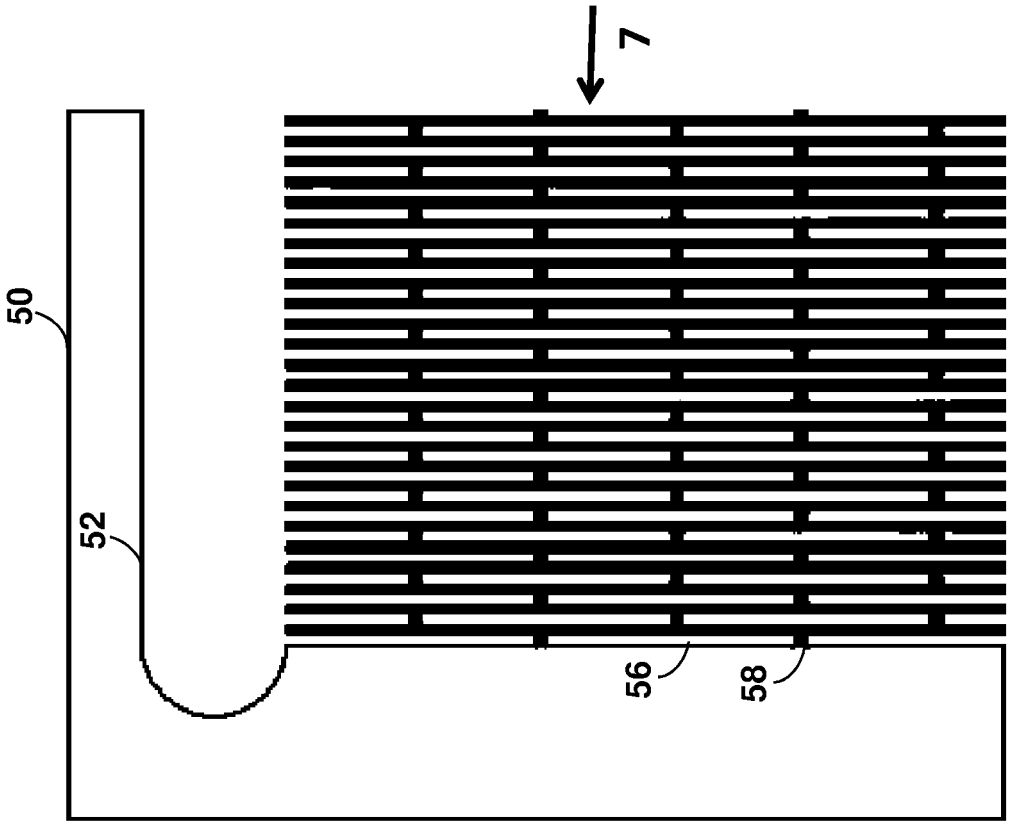


FIG.3

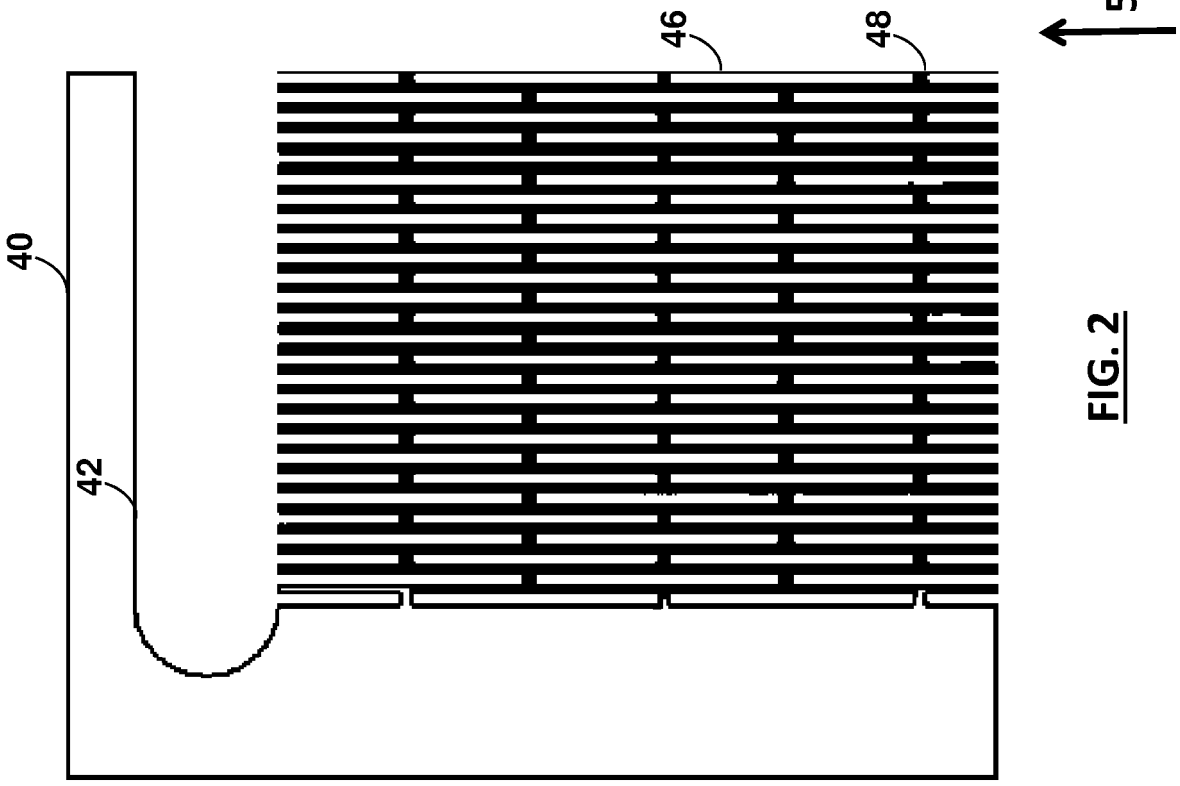


FIG. 2

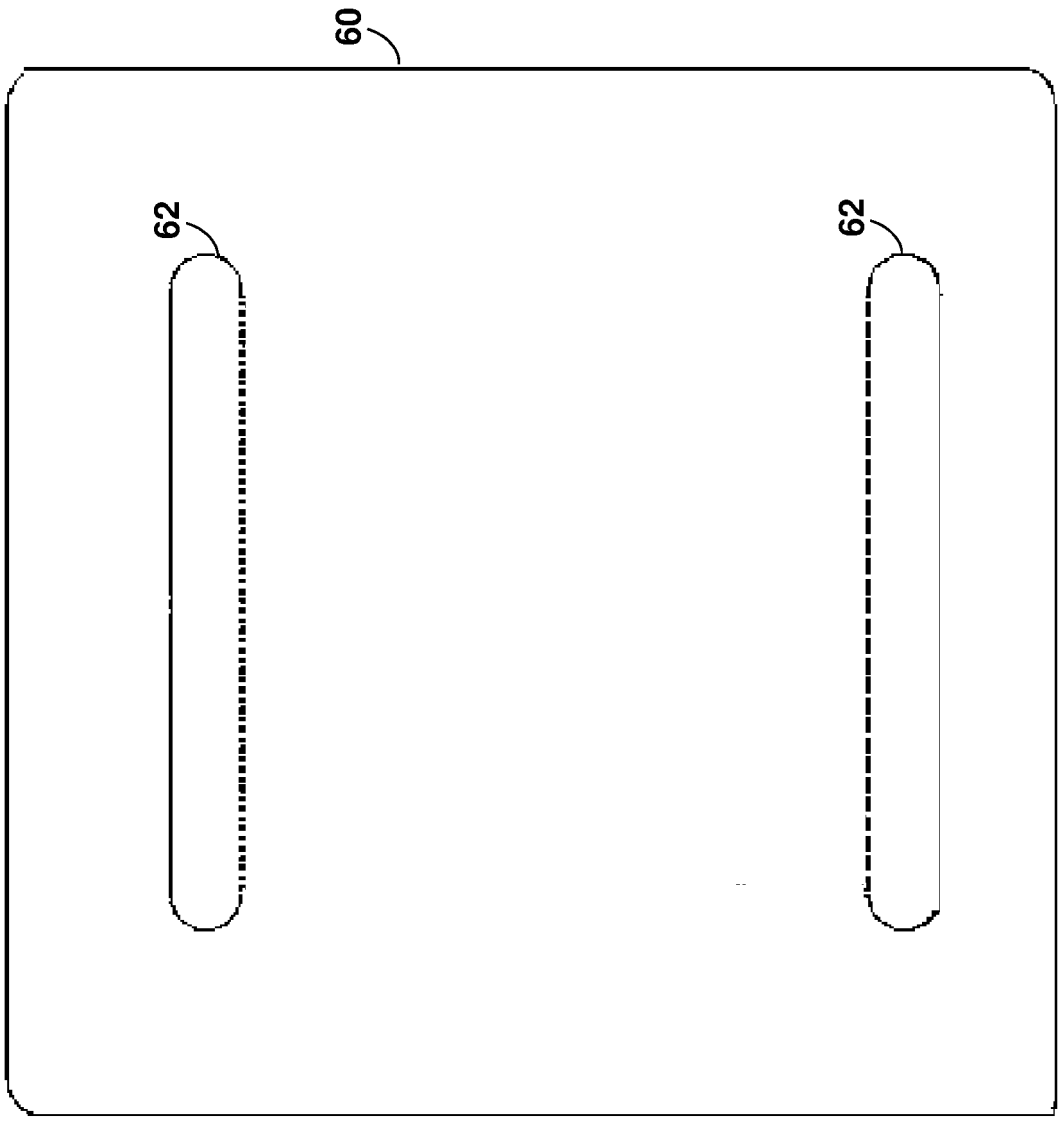


FIG. 4

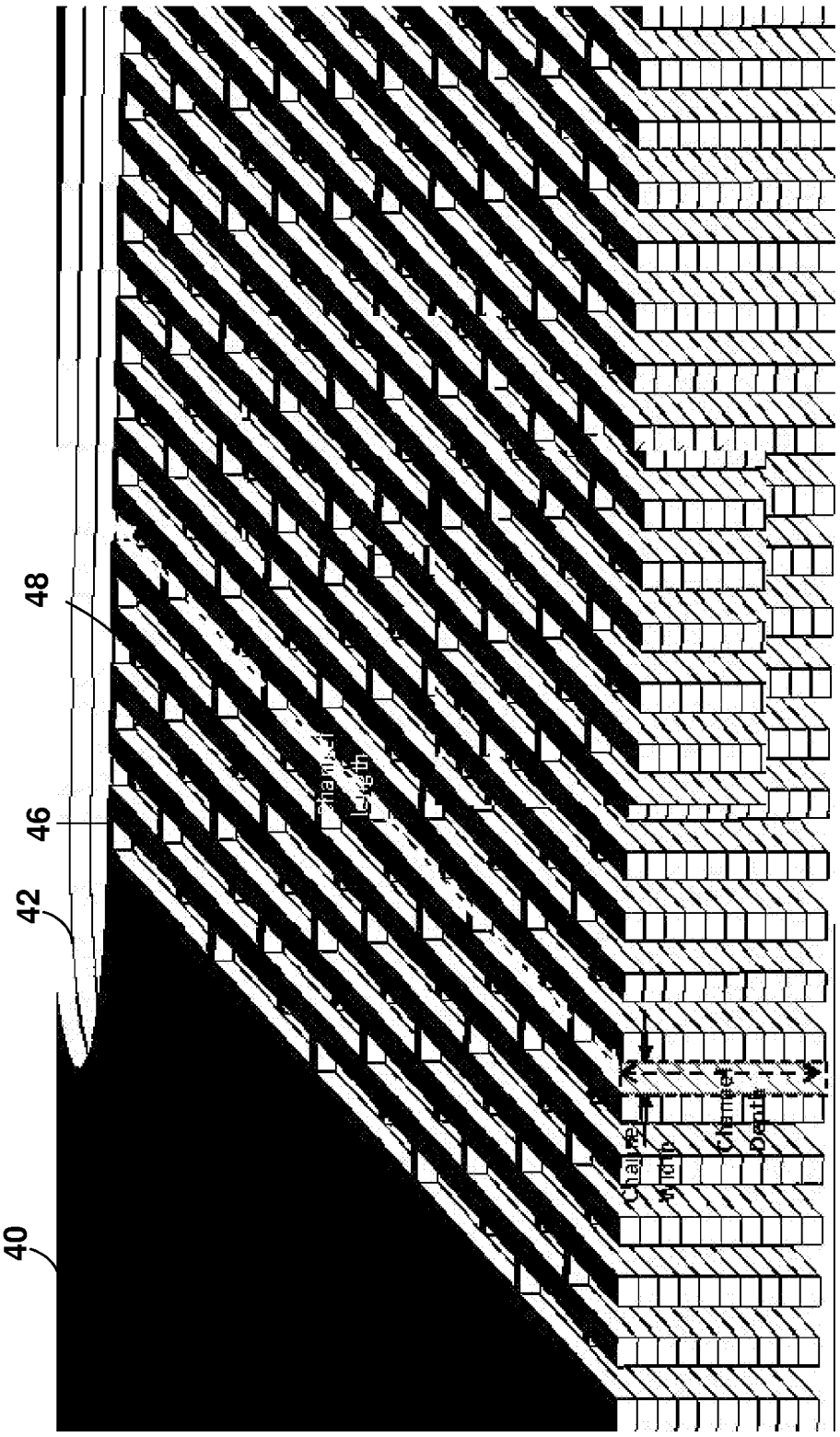


FIG. 5

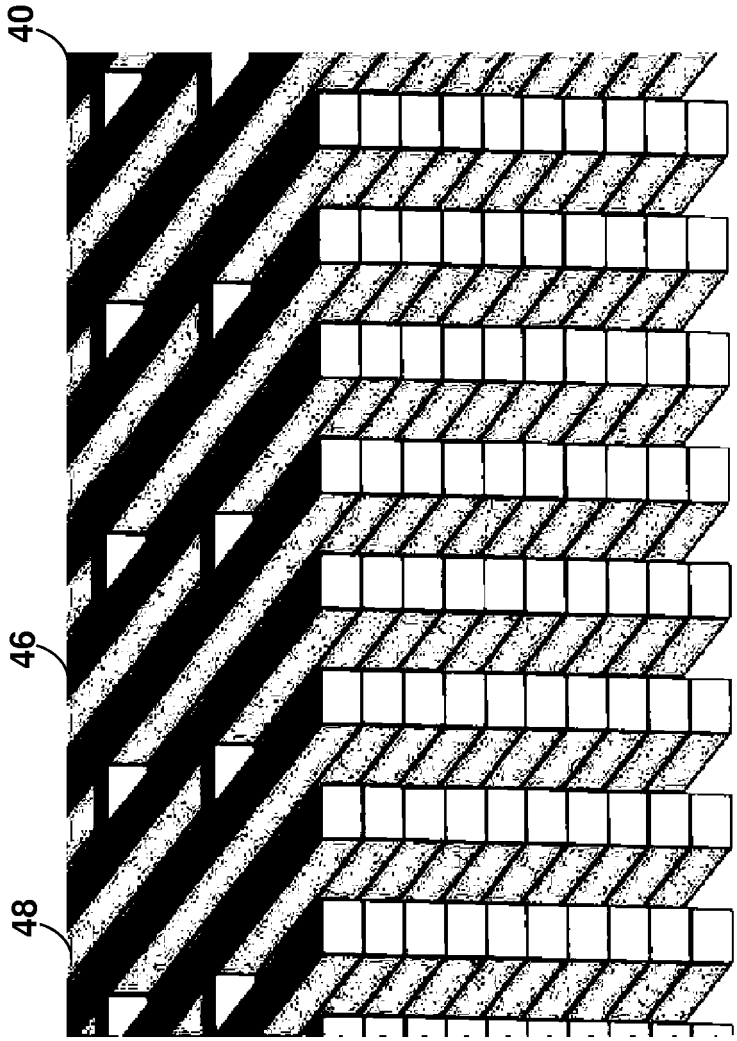


FIG. 6

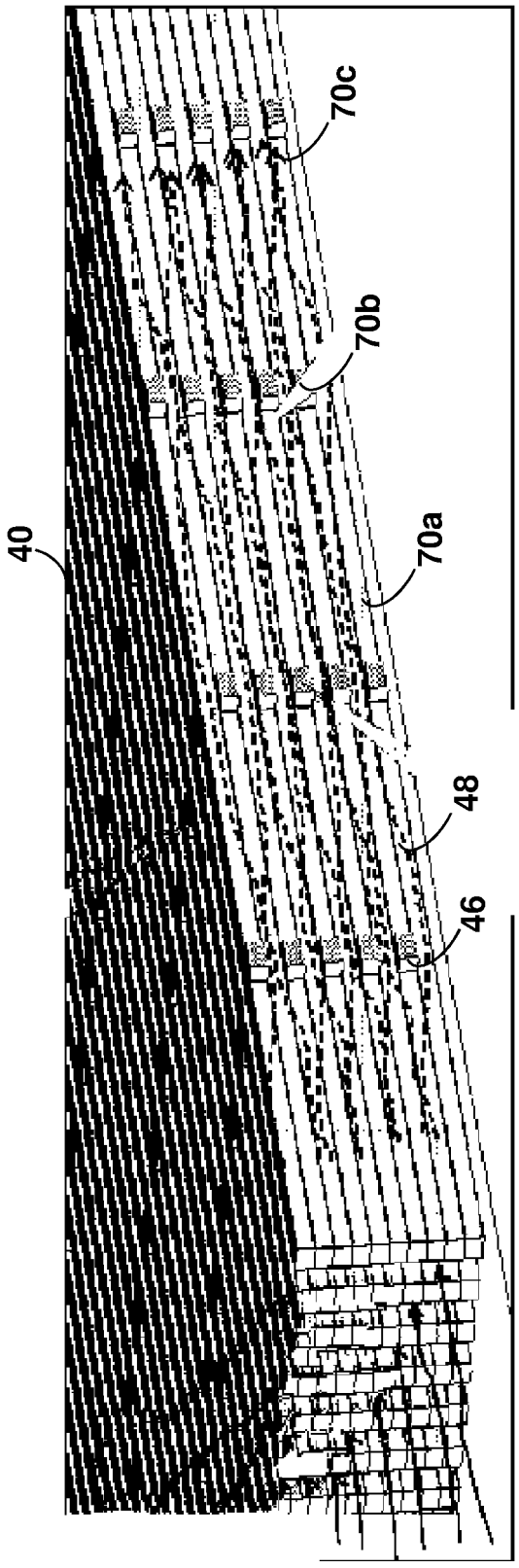


FIG. 7

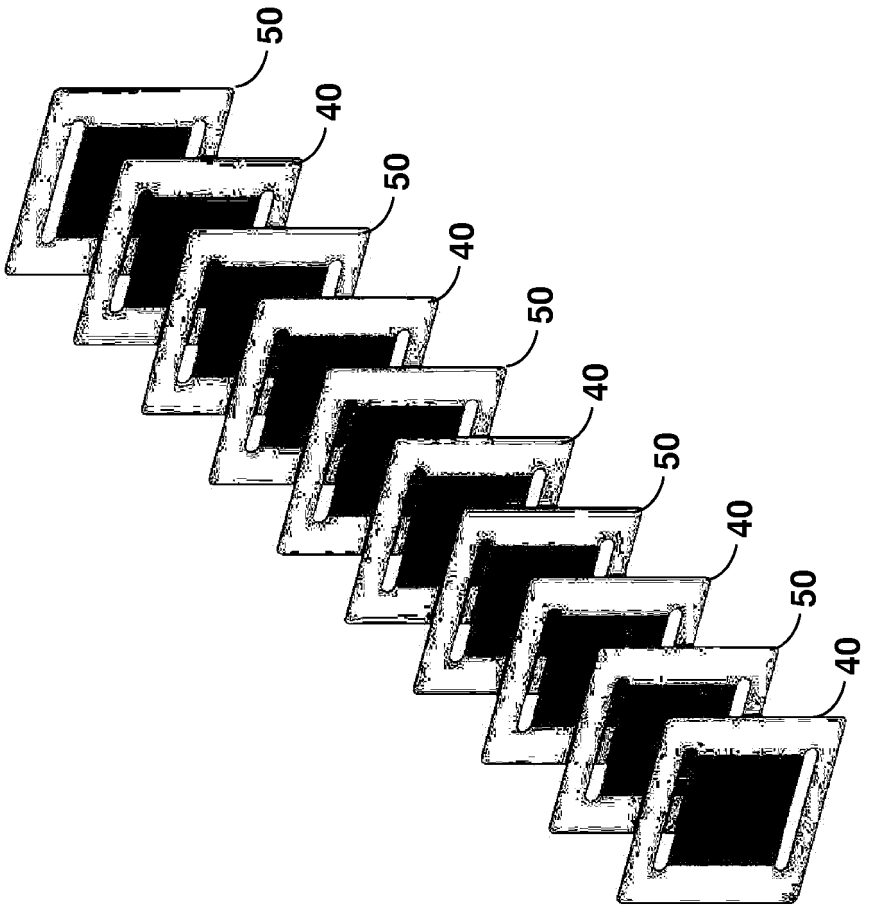


FIG.8

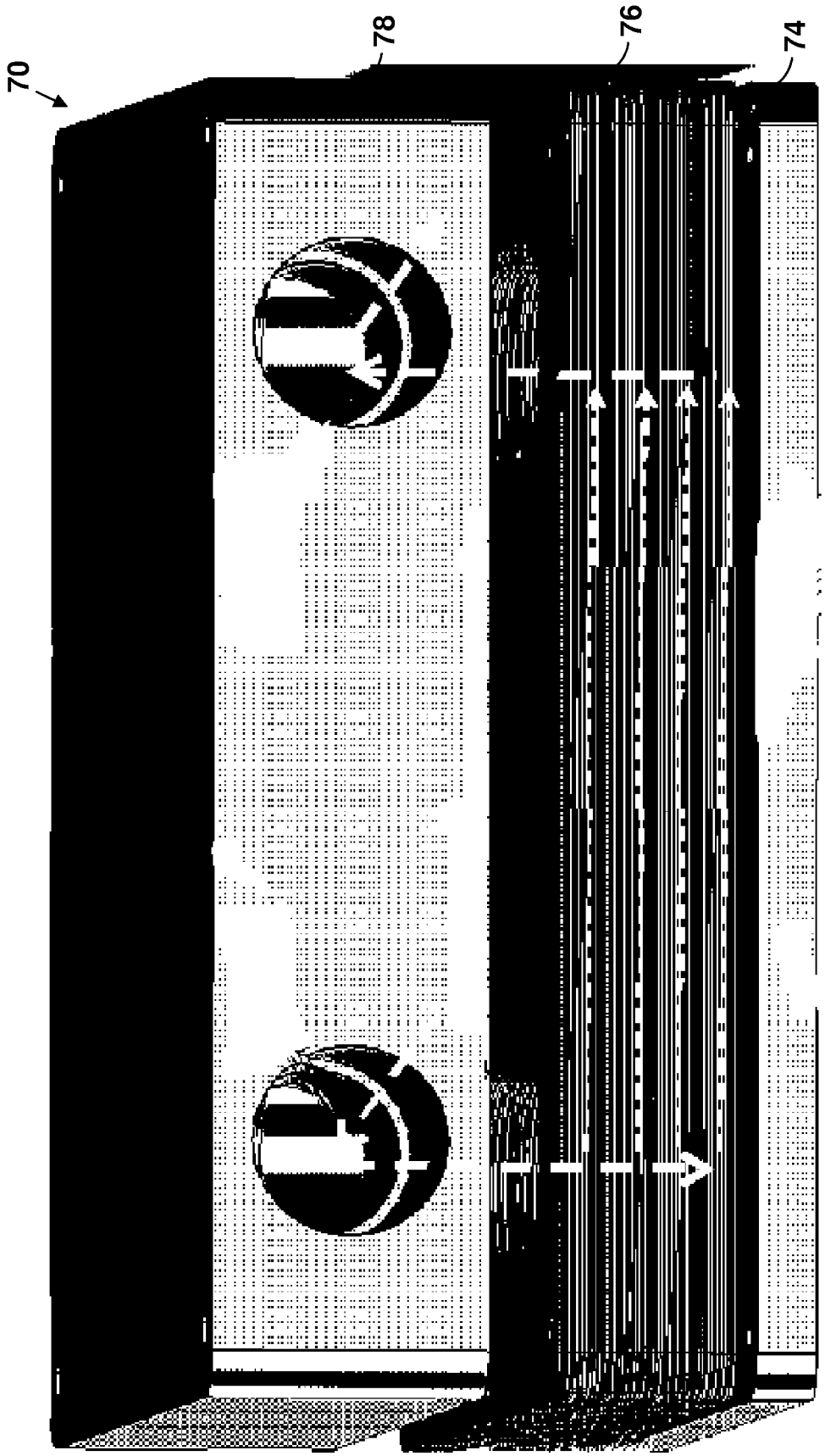


FIG. 9

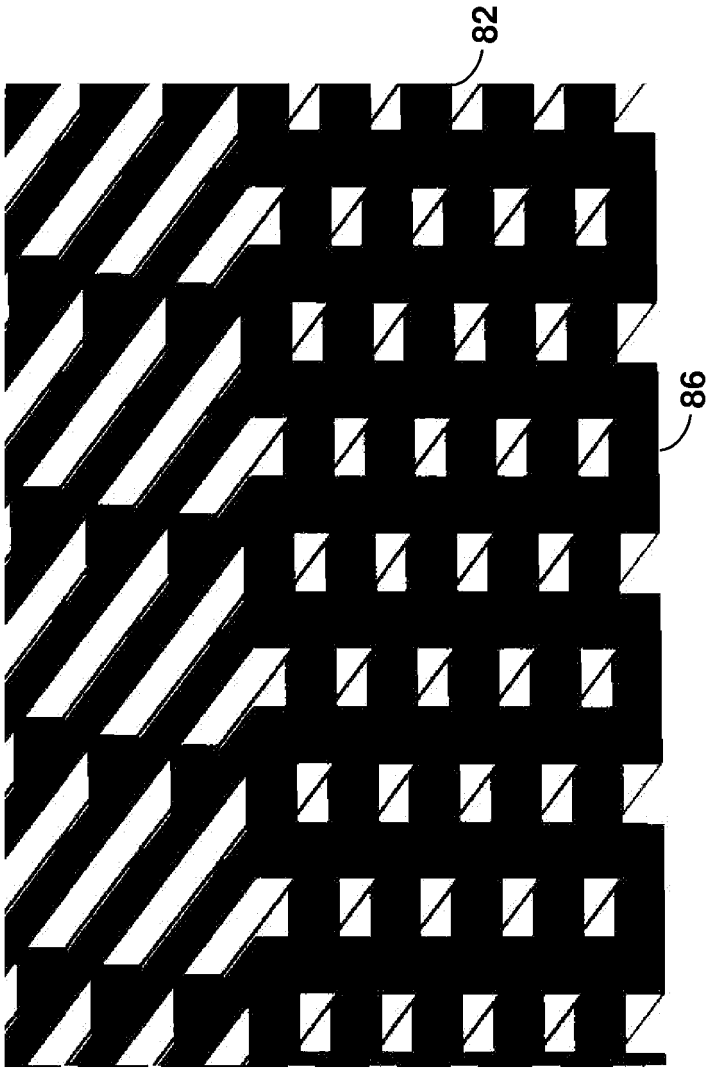


FIG. 10

REFERENCES CITED IN THE DESCRIPTION

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