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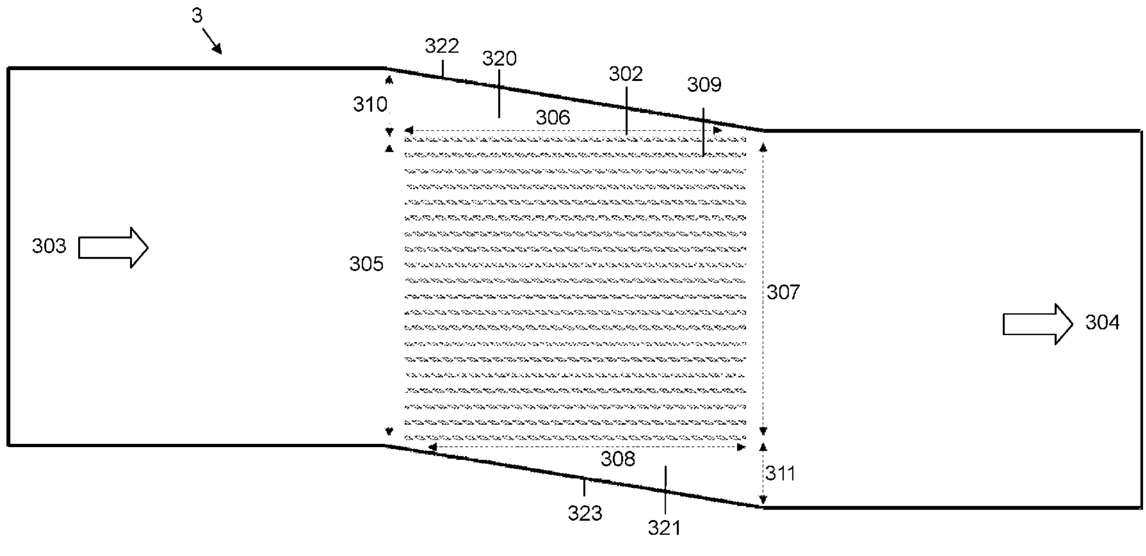
(54) Title: A HEAT SINK ASSEMBLY

Figure 3



(57) Abstract: The invention relates to a heat sink assembly comprising: a flow domain; an inlet arranged to allow fluid to enter the heat sink assembly; an outlet arranged to allow fluid to exit the heat sink assembly; and a heat transfer zone intermediate the inlet and the outlet, the heat transfer zone further comprises a plurality of fins defining a plurality of transverse channels and a plurality of secondary channels in fluidic communication with the transverse channels, the transverse channels and secondary channels are arranged to allow fluid to flow from the inlet to the outlet, wherein the flow domain comprises an inlet extended section and an outlet extended section, wherein the flow domain is arranged to deliver fluid from the inlet to the heat transfer zone through the inlet side and inlet extended section, and from the heat transfer zone to the outlet through the outlet side and outlet extended section.

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Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

A heat sink assembly

Field of the invention

The invention relates to the dissipation of heat from electronic devices using a heat sink assembly. In particular, the invention relates to the flow domain in such devices.

Background of the invention

Microchannel heat sinks are used for thermal transfer. Heat sinks are positioned within a flow domain within a heat sink assembly. Once edges or side walls are introduced in a heat sink assembly, flow was observed to start migrating from one side of the oblique finned heat sink to the other, resulting in a flow maldistribution. The edge, from which the flow was escaping was called the draining edge; while the edge to which the flow was migrating was called the filling edge. Although the fluid flow rates through the central channels were uniform, those in the vicinity of the draining and the filling edges were below and above the flow rates at the central – fully periodic – portion of the heat sink, respectively. It was observed that the flow maldistribution reduced the heat transfer performance in the vicinity of the edges of the oblique-finned heat sink design, resulting in an increase in the heat sink temperature.

Therefore, there is a need for an improved heat sink assembly to eliminate the flow maldistribution and maximize the benefits of convective heat transfer.

Summary of the invention

In a first aspect, the present invention relates to a heat sink assembly comprising: a flow domain; an inlet arranged to allow fluid to enter the heat sink assembly; an outlet arranged to allow fluid to exit the heat sink assembly; and a heat transfer zone intermediate the inlet and the outlet, the heat transfer zone further comprises a plurality of fins defining a plurality of transverse channels and a plurality of secondary channels in fluidic communication with the transverse channels, the transverse channels and secondary channels are arranged to allow fluid to flow from the inlet to the outlet, wherein the flow domain comprises an inlet extended section and an outlet extended section, wherein the flow domain is arranged to deliver fluid from the inlet to the heat transfer zone through the inlet side and inlet extended section, and from the heat transfer zone to the outlet through the outlet side and outlet extended section.

Brief description of the figures

Figure 1 is an isometric view of a heat sink.

Figure 2 is a detailed top view of the heat sink.

Figure 3 is top view of a flow domain of the present invention.

Figure 4A is a top view of an alternative flow domain.

Figure 4B is a top view of another alternative flow domain.

Figure 4C is a top view of an alternative flow domain.

Figure 4D is a top view of yet another alternative flow domain. Figure 5 is a graph of the non-uniform cumulative secondary flow rate distribution.

Figures 6A-6C are graphs of the distribution of the cumulative secondary flow rates within the confined flow domain and the improved header design at various flow domain enlargement ratios.

Figures 7A-7B are graphs of experimental Nusselt numbers and the friction factors of the confined flow domain and the improved header design.

Figure 8 is a graph showing the improvement in the junction temperature of the planar, air-cooled, oblique-finned heat sink with the use of the confined flow domain and the improved header design.

Detailed description of the invention

The figures are schematic and not drawn to scale. A small leakage bypassing the heat transfer zone is possible and negligible.

Figure 1 shows an isometric view of a heat sink 1 comprising an array of fins 102. For example, the fins may be oblique fins.

Figure 2 shows a detailed top view of a section of a heat sink 2 showing the orientation of fins 201, transverse channels 202 and secondary channels 203. For example, the secondary channels may be oblique channels. The transverse channels 101 are parallel with the inlet and/or outlet flow of the heat transfer fluid. The fins 102 may have oblique cross-sections, although any other suitable shapes may be used. Secondary channels 103 are introduced at a certain angle with respect to the transverse channels 101. The secondary channels 103 may be collinear not collinear depending on the fabrication technique. The heat transfer zone is defined within the perimeter of the heat sink. It will be appreciated that fins and channels of other configurations may be used.

Embodiments of the heat sink assemblies of the present invention are described below.

Figure 3 shows a flow domain 3 of the present invention. The draining edge 306 and/or the filling edge 308 may be parallel to the transverse channels. The total width of the flow domain 3 is increased without allowing the flow to bypass the heat sink 302. The width of the flow domain 3 is increased in a different manner at the inlet 303 and outlet 304 sections of the heat transfer zone 302, in consideration of the direction of the flow migration. The flow domain 3 includes an inlet extended section 320 defined by the draining edge 306, an inlet extension 310 from the side of the draining edge 306 to the inlet wall 322, and the inlet wall 322. Similarly, the flow domain 3 includes an outlet extended section 321 defined by the filling edge 308, the outlet extension 311 from the side of the filling edge 308 to the outlet wall 323, and the outlet wall 323. The inlet extended section 320 and outlet extended section 321 could direct the flow through the heat transfer zone 302 in the direction of the secondary channels 309. The inlet extended section 320 and outlet extended section 321 may have different sizes and shapes, depending on the direction of the flow migration and fins. For the purposes of illustration, the figures show oblique fins. It would be appreciated that fins of other shapes may be used with the flow domains of the present invention.

The incoming flow is allowed to enter the heat transfer zone 302 not only at the inlet side 305, but also from the extended section 320 of the draining edge 306. While the outgoing flow is allowed to leave the heat transfer zone 302 not only at the outlet side 307, but also from the extended inlet section 321 of the filling edge 308. The widened inlet section 320 allows a portion of the flow to be introduced from the side of the heat transfer zone to prevent the drainage of the flow. The widened outlet section 321 allows a portion of the flow to be discharged from the side of the heat transfer zone to prevent the accumulation of the flow. Therefore, this invention makes the flow migration more uniform through the entire heat transfer zone by preventing the flow from accumulating at the filling edge and depleting at the draining edge. The inlet wall 322 may be angled from the draining edge 306 to accommodate the extended section 320. The outlet wall 323 may also be angled from the filling edge 308 to accommodate the extended section 321. Alternatively, the inlet wall and outlet wall may be straight.

In an embodiment, the extended inlet section 320 and extended outlet section 321 may direct the flow through the heat transfer zone in the direction of the secondary channels. The inlet wall 322 and outlet wall 323 may have the same incline as the secondary channels.

Figure 4A shows an alternative flow domain 4 which has straight inlet walls 422 and outlet walls 423. The flow domain 4 includes an inlet extended section 420 defined by the draining edge 406, an inlet extension 410 from the side of the draining edge 406 to the inlet wall 422, and the inlet wall 422. The flow domain 4 also includes an outlet extended section 421 defined by the filling edge 408, an outlet extension 411 from the side of the filling edge 408 to the outlet wall 423, and the outlet wall 423. Incoming flow 403 enters the heat transfer zone 402 from the inlet side 405 and the inlet extended section 420. Outgoing flow 404 leaves the heat transfer zone 402 at the outlet side 407 and the outlet extended section 421. Similar to Figure 3, the inlet wall 422 and the outlet wall 423 may have the same incline as the secondary channels.

In this embodiment, there is a small gap between the inlet wall 422 and a first edge 431 of a first corner fin. The amount of flow that bypasses the heat transfer zone through the gap is negligible. Alternatively, the inlet wall contacts a first edge of a first corner fin so as to allow flow into said secondary channels for a full length of said heat transfer zone. Accordingly, this ensures that all fluid enters the heat transfer zone and does not bypass the heat transfer zone. The alternative arrangement may also be possible, whereby the inlet channel directs flow into the secondary channels for only a portion of the length of the heat transfer zone.

In this embodiment, there is a small gap between the outlet wall 423 and a second edge 432 of a second corner fin. The amount of flow that bypasses the heat transfer zone through the gap is negligible. Alternatively, the inlet wall contacts a second edge of a second corner fin so as to allow flow from said secondary channels for a full length of said heat transfer zone. Accordingly, this prevents backflow and ensures that the fluid exiting the heat transfer zone does not return to the inlet. The alternative arrangement may also be possible, whereby the outlet channel receives flow from the secondary channels for only a portion of the length of the heat transfer zone.

Figure 4B shows another alternative flow domain 5 which has inlet wall 522 and outlet wall 523. The inlet wall 522 is angled at a point 524 along the draining edge 506, while the outlet wall 523 is angled at a point 525 along the filling edge 508. The flow domain includes an inlet extended section 520 defined by the draining edge 506, an inlet extension 510 from the side of the draining edge 506 to the inlet wall 522, and the inlet wall 522. The flow domain 5 also includes an outlet extended section 521 defined by the filling edge 508, an outlet extension 511 from the side of the filling edge 508 to the outlet wall 523, and the outlet wall 523. Incoming flow 503 enters the heat transfer zone 502 from the inlet side 505 and the inlet extended section 520. Outgoing flow 504 leaves the heat transfer zone 502 at the outlet side 507 and the outlet extended section 521.

It is important that the fluid does not bypass the heat transfer zone. For example, the inlet wall may contact the edge of the heat transfer zone (Figure 4A). The inlet extended section may be adjacent to the whole length of the draining edge. Alternatively, the inlet wall may contact the mid-point or another point along the draining edge of the heat transfer zone (Figure 4B). The inlet extended section may then be adjacent to a portion of the draining edge of the heat transfer zone.

Figure 4C shows another alternative flow domain 6 which has inlet wall 622 and outlet wall 623. The inlet wall 622 curves towards the draining edge 606, while the outlet wall 623 curves towards the filling edge 608. The flow domain includes an inlet extended section 620 defined by the draining edge 606, an inlet extension 610 from the side of the draining edge 606 to the inlet wall 622, and the inlet wall 622. The flow domain 6 also includes an outlet extended section 621 defined by the filling edge 608, an outlet extension 611 from the side of the filling edge 608 to the outlet wall 623, and the outlet wall 623. Incoming flow 603 enters the heat transfer zone 602 from the inlet side 605 and the inlet extended section 620. Outgoing flow 604 leaves the heat transfer zone 602 at the outlet side 607 and the outlet extended section 621.

Figure 4D shows yet another alternative flow domain 7 which has inlet wall 722 and outlet 723. The difference between the flow domain of Figure 4C and Figure 4D lies in the curvatures of the inlet wall and outlet wall. In Figure 4D, the inlet wall 722 curves outwards from the draining edge 706, while the outlet wall 723 curves outwards from the filling edge 708. Incoming flow 703 enters the heat transfer zone 702 from the inlet side 705 and the inlet extended section 720. Outgoing flow 704 leaves the heat transfer zone 702 at the outlet side 707 and the outlet extended section 721.

It will be appreciated that a flow domain may contain a combination of an inlet wall and an outlet wall from different embodiments, i.e. an inlet wall and an outlet wall may have different curvatures. For example, the inlet wall may curve towards the draining edge and the outlet wall may curve outwards from the filling edge. Alternatively, the inlet wall may be straight and the outlet wall may be curved.

The embodiments of Figures 3 and 4A-4D are flow domains which increase the average cumulative secondary flow rates, and increase the secondary flow rates through the secondary channels in the vicinity of the draining edge and the filling edge. The invention makes the flow migration more uniform through the entire heat transfer zone by preventing the flow from accumulating at the filling edge and depleting at the draining edge. As a result, the improved flow domain significantly improves heat transfer performance.

Figure 5 shows the migration of flow in a non-uniform cumulative secondary flow rate distribution in a conventional heat sink assembly. As the Reynolds number increases, the maldistribution of the cumulative secondary flow rates increases. This feature is the problem with existing heat sink assemblies, and the heat sink assembly of the present invention solves this problem. Figures 6-8 show the secondary flow rate, heat transfer, and friction factor data for the conventional heat sink assembly and the claimed heat sink assembly.

Figures 6A-6C show the cumulative secondary flow rate distribution through the planar, oblique-finned heat sink within the confined flow domain and the proposed header design at three different Reynolds numbers 239 (Figure 6A), 989 (Figure 6B), and 2490 (Figure 6C). The proposed header design, both increases the average cumulative secondary flow rates, and increases the secondary flow rates through the secondary channels in the vicinity of the draining edge and the filling edge. The higher the secondary flow rates, the more effective the boundary layer reinitialization and the flow mixing phenomena, resulting a higher heat transfer performance.

The advantages of the proposed header design were validated with the experimental investigations with an air-cooled, planar, oblique-finned heat sink. Figures 7A-7B show the experimental Nusselt numbers (Figure 7A) and the friction factors (Figure 7B) obtained with the confined flow domain and the proposed header design with the planar, air-cooled, oblique-finned heat sink at various Reynolds numbers. The heat transfer performance was improved significantly for up to 65%, while the pressure drop penalty increased slightly for the medium Reynolds number range by up to 20%.

The improvement in the thermal performance can be better observed from the junction temperatures in Figure 8. With the implementation of the proposed header design, the junction temperature of the planar, air-cooled, oblique-finned heat sink was improved for up to 5°C at 20W and 15°C at 60W heater power.

Regardless of the type of the coolant, whether liquid or gas, the planar, oblique-finned heat sink suffers from flow migration as long as the flow domain is confined between side walls. The maldistribution of the flow through the planar, oblique-finned heat sink adversely affects the heat transfer performance. The present invention eliminates these adverse effects and improves the thermal performance significantly at a smaller pressure drop penalty.

The planar, oblique-finned heat sink can be used for the thermal management of electronic devices. By installing guide vanes to modify the flow domain according to the present invention, it is possible to greatly enhance the heat transfer performance by maintaining a reasonable fan power.

In one embodiment, the heat sink assembly comprises an inlet arranged to allow fluid to enter the heat sink assembly; an outlet arranged to allow fluid to exit the heat sink assembly; and a heat transfer zone intermediate the inlet and the outlet, the heat transfer zone further comprises a plurality of fins defining a plurality of transverse channels and a plurality of secondary channels in fluidic communication with the transverse channels, the transverse channels and secondary channels are arranged to allow fluid to flow from the inlet to the outlet, wherein the inlet further comprises an inlet channel, the inlet channel is positioned so as to direct fluid into the secondary channels.

Such an arrangement increases the total width of the flow domain without allowing the fluid flow to bypass the heat sink. Hence, instead of entering the heat transfer zone only through the transverse channels, fluid is allowed to enter the heat transfer zone via both the transverse and the secondary channels.

As such, unlike conventional systems, the present invention allows fluid to easily enter the secondary channels via the inlet channel, thereby resulting in a more favourable distribution of flow rates through the secondary channels throughout the entire heat sink assembly. As a result, flow maldistribution is minimized and heat transfer performance is enhanced.

In an embodiment, the inlet channel includes an inlet wall inclined in the same direction as the secondary channels.

In an embodiment, the outlet further comprises an outlet channel arranged to receive fluid directly from the secondary channels.

In conventional systems, due to the direction of the secondary channels, flow in the secondary channels will inevitably accumulate at an edge 306 of the heat transfer zone. Hence, when an outlet channel is positioned at the edge 306, fluid can easily drain out of the secondary channels into the outlet channel. Accordingly, this ensures that fluid do not accumulate at the edge 306, thereby reducing fluid maldistribution and enhancing the heat transfer performance of the heat sink.

In an embodiment, the outlet wall inclines in the same direction as the secondary channels.

The inclined outlet wall serves to guide fluid flowing out of the secondary channels into the main outlet of the heat sink assembly and exit the heat sink assembly.

The planar, oblique-finned heat sink can be used for the thermal management of electronic devices. By installing guide vanes to modify the flow domain according to the present invention, it is possible to greatly enhance the heat transfer performance by maintaining a reasonable fan power.

In an embodiment, the invention relates to a header comprising a flow domain for the planar, oblique-finned heat sink for computer liquid cooling solution systems and methods.

In another embodiment, the invention relates to an oblique-finned heat sink without header design for computer liquid cooling solution systems and methods.

Claims

1. A heat sink assembly, comprising:

a flow domain;

an inlet arranged to allow fluid to enter the heat sink assembly;

an outlet arranged to allow fluid to exit the heat sink assembly; and

a heat transfer zone intermediate the inlet and the outlet, the heat transfer zone further comprises a plurality of fins defining a plurality of transverse channels and a plurality of secondary channels in fluidic communication with the transverse channels, the transverse channels and secondary channels are arranged to allow fluid to flow from the inlet to the outlet,

wherein the flow domain comprises an inlet extended section and an outlet extended section;

wherein the flow domain is arranged to deliver fluid from the inlet to the heat transfer zone through the inlet side and inlet extended section, and from the heat transfer zone to the outlet through the outlet side and outlet extended section.

2. The heat sink assembly according to claim 1, wherein the inlet wall contacts a first edge of a first corner fin so as to allow flow into said secondary channels for a full length of said heat transfer zone.

3. The heat sink assembly according to claim 2, wherein the outlet wall contacts a second edge of a second corner fin so as to allow flow from said secondary channels for a full length of said heat transfer zone.

4. The heat sink assembly according to any one of claims 1-3, wherein the inlet extended section and/or the outlet extended section is arranged to direct flow through the heat sink in the direction of the secondary channels.

5. The heat sink assembly according to any one of claims 1-4, wherein the incline of the extended section is arranged to maximize contact surface of the fluid with the secondary channels.

6. The heat sink assembly according to any one of claims 1-5, wherein the inlet channel includes an inlet wall inclined in the same direction as the secondary channels.

7. The heat sink assembly according to any one of claims 1-6, wherein the outlet wall inclines in the same direction as the secondary channels.

8. The heat sink assembly according to any one of claims 1-7, wherein the fins are oblique.

Figure 1

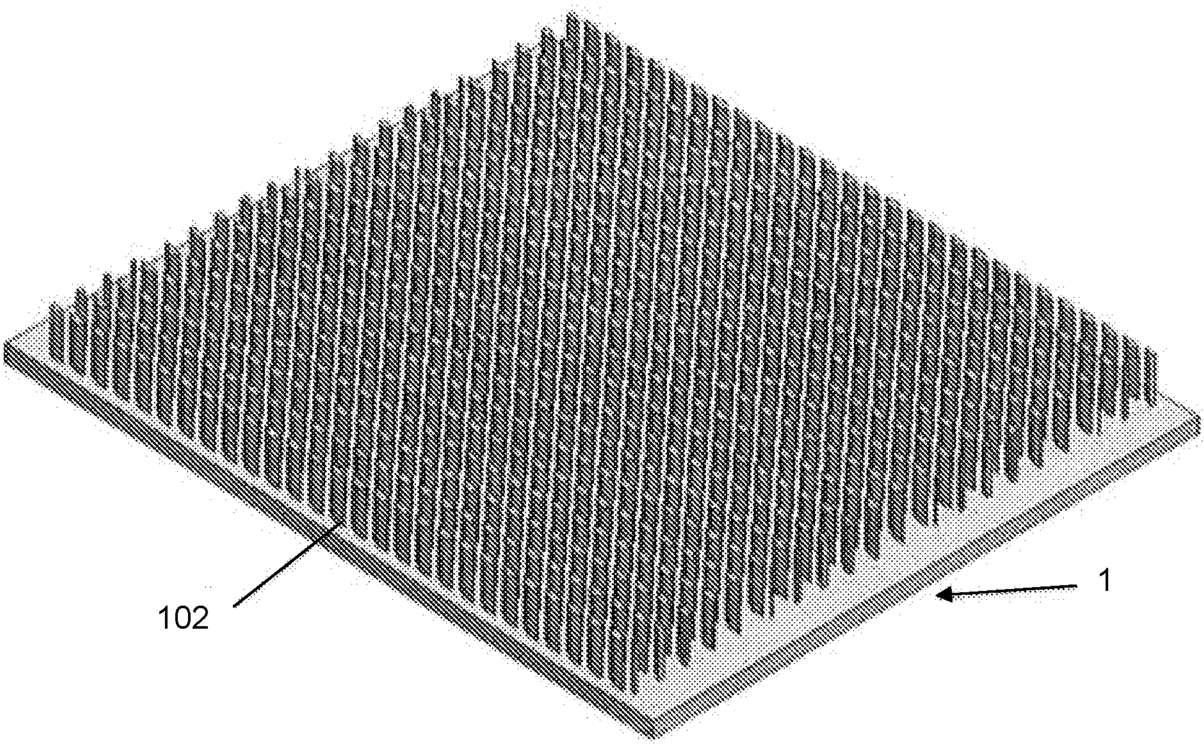
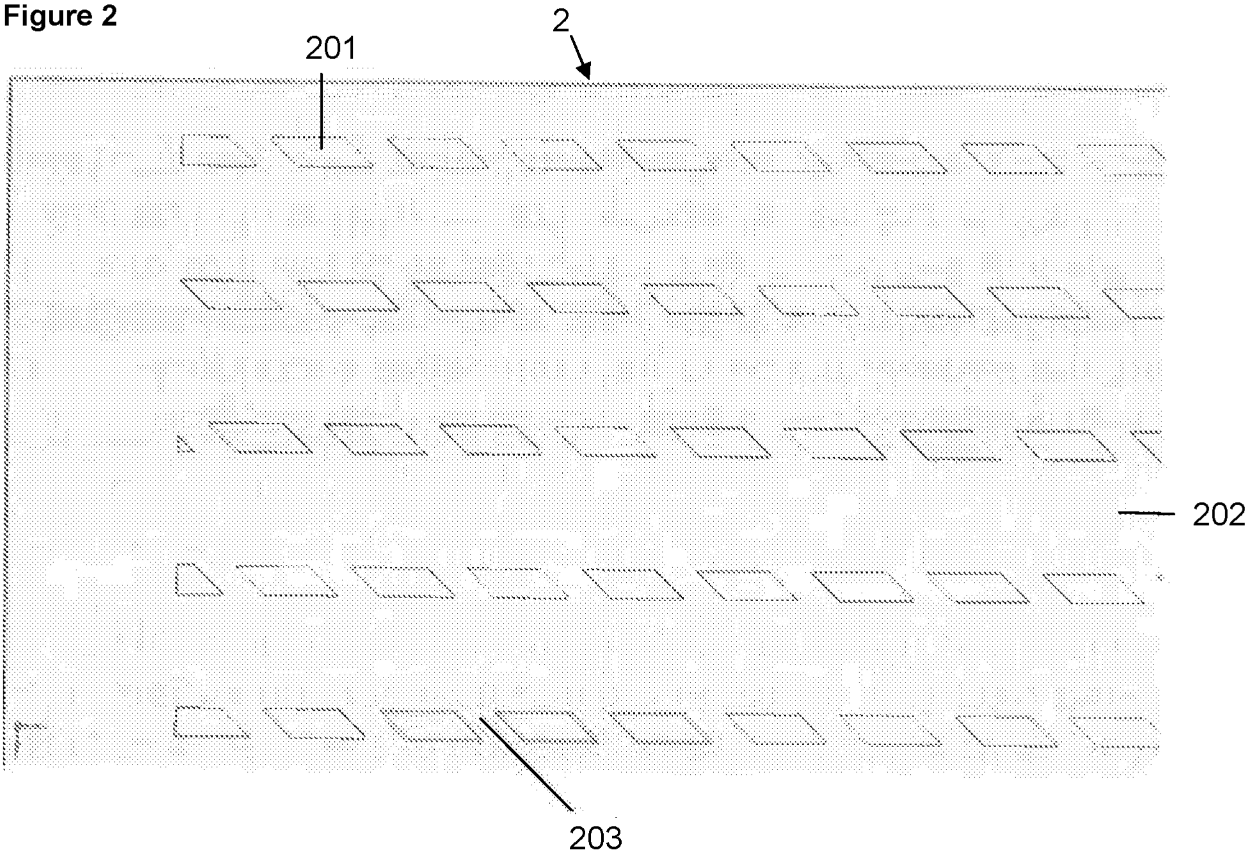


Figure 2



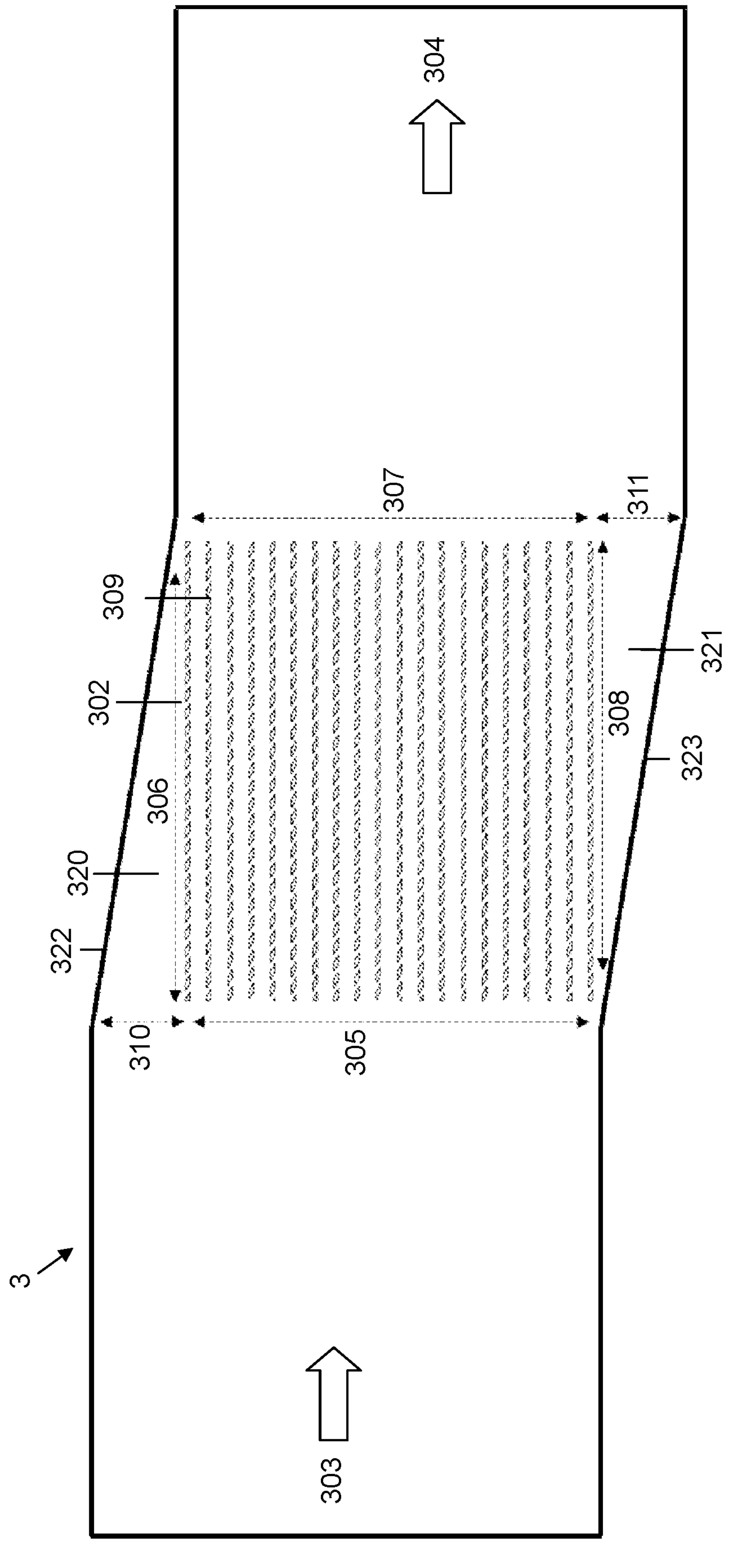


Figure 3

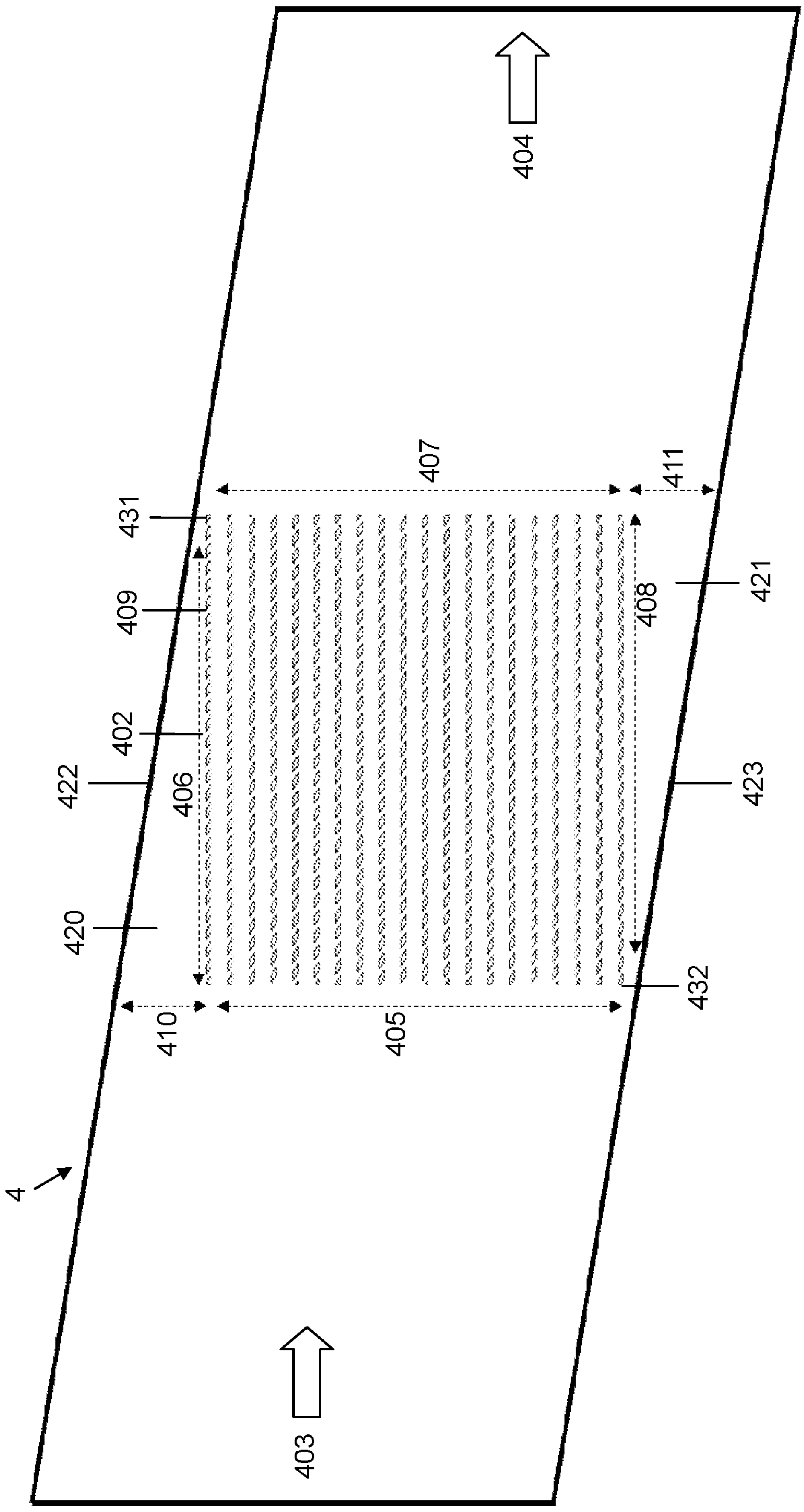


Figure 4A

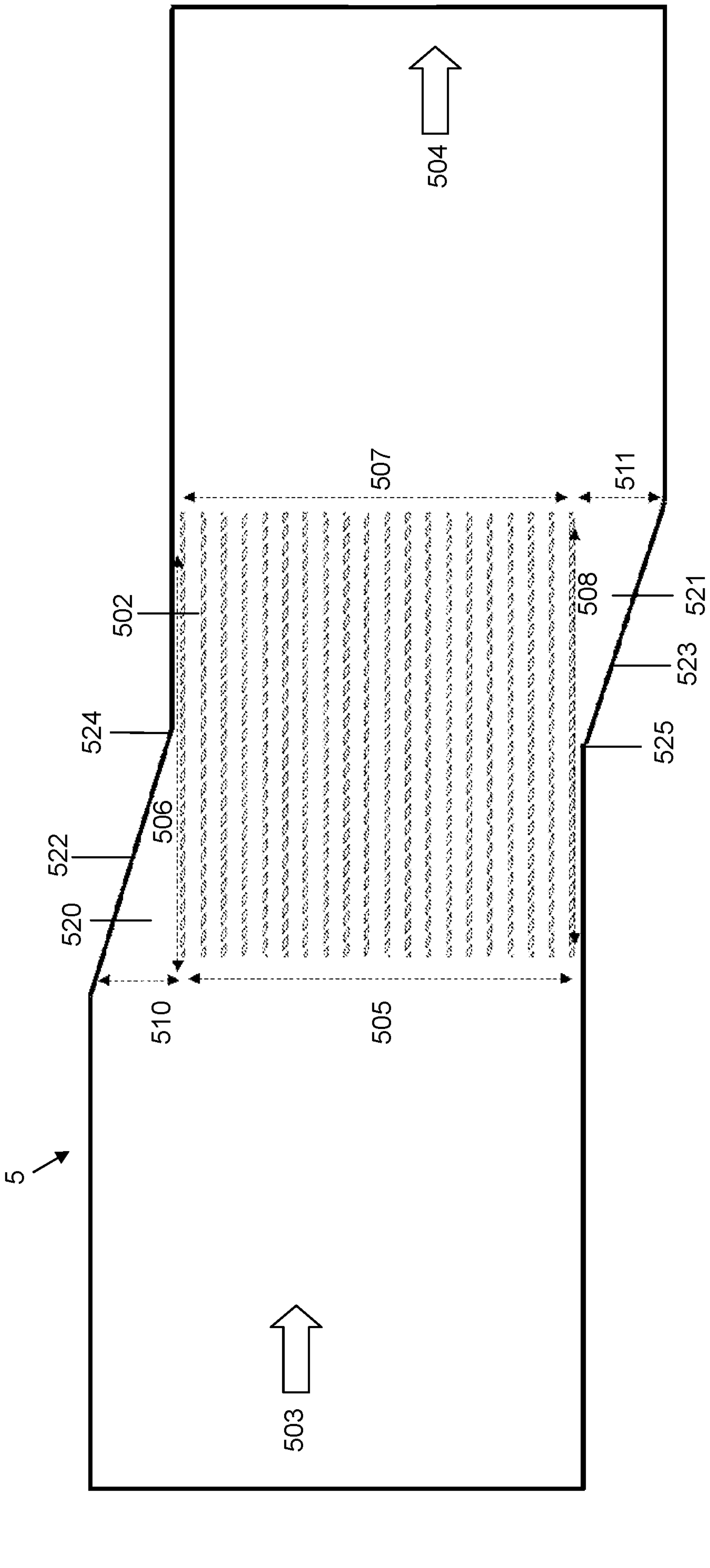


Figure 4B

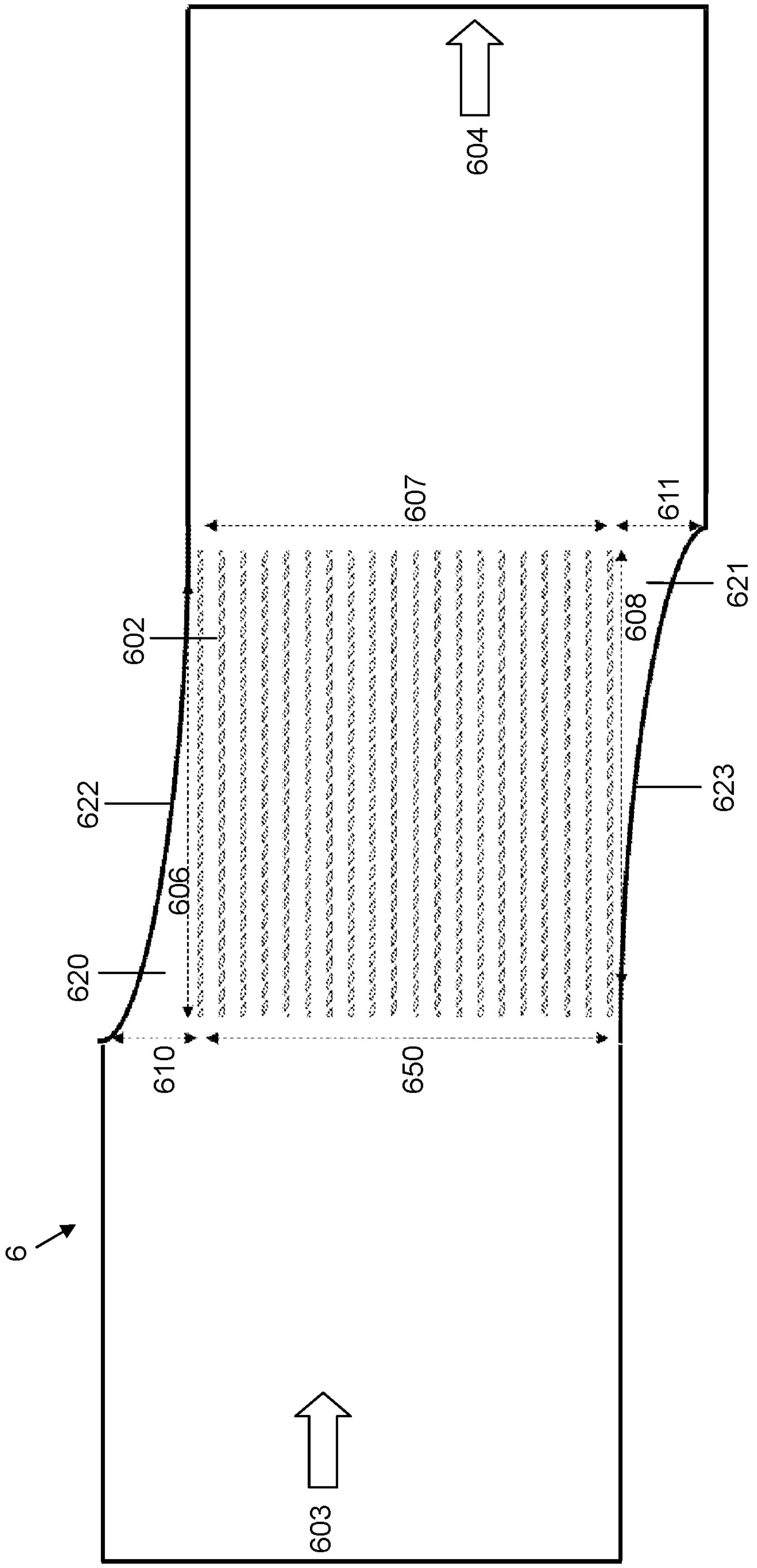


Figure 4C

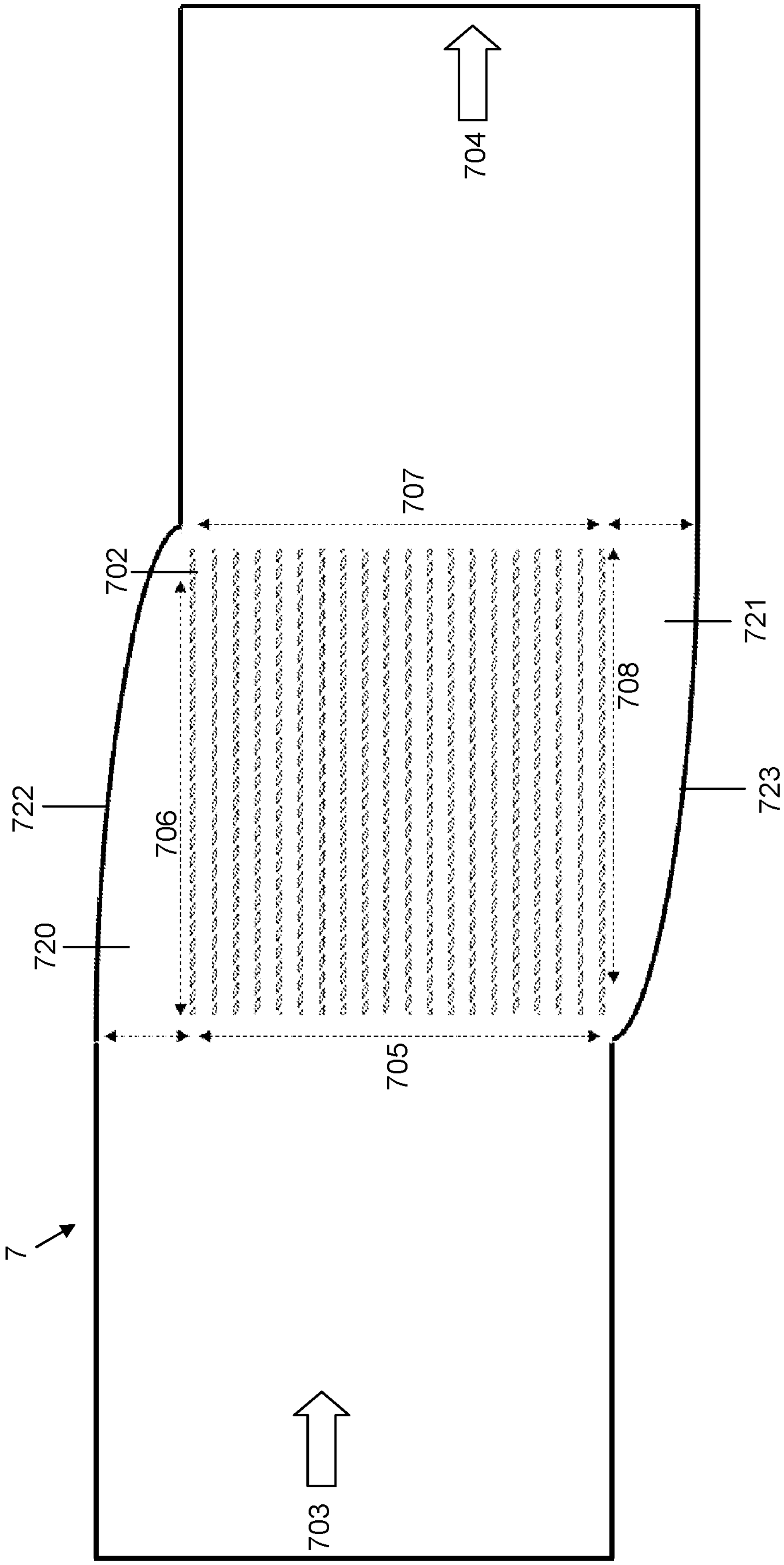
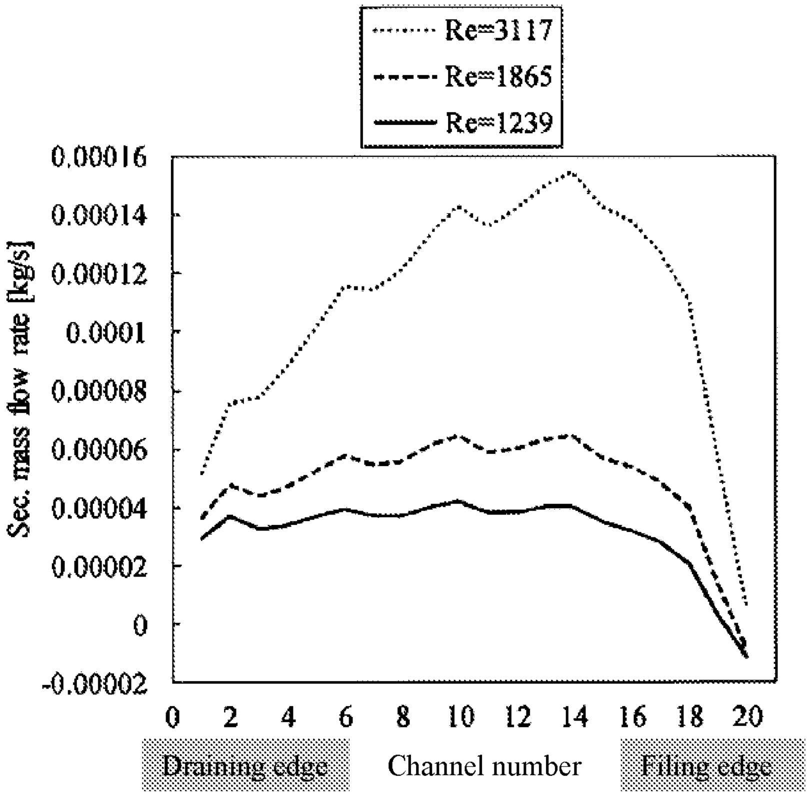


Figure 4D

6/10

Figure 5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0
-0.00002
Sec. mass flow rate [kg/s]
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2
4
6
8
10
12
14
16
18
20
Draining edge
Channel number
Filing edge

Figure 6A

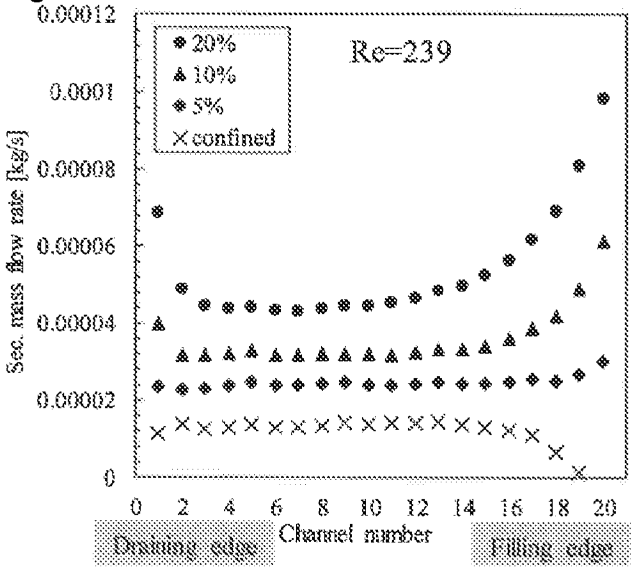


Figure 6B

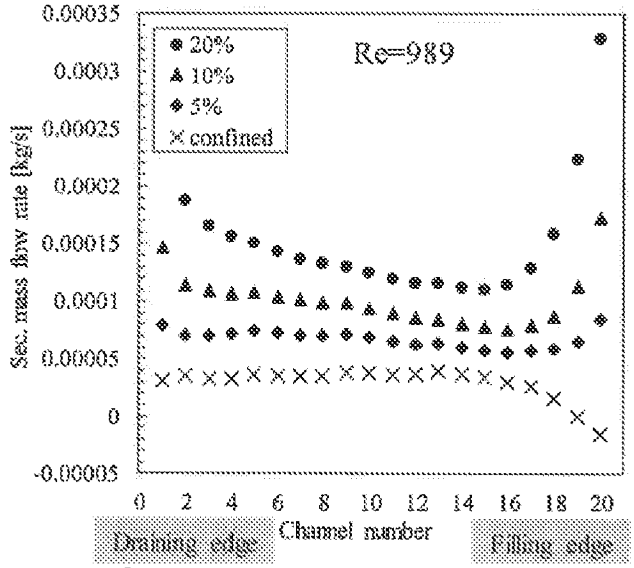


Figure 6C

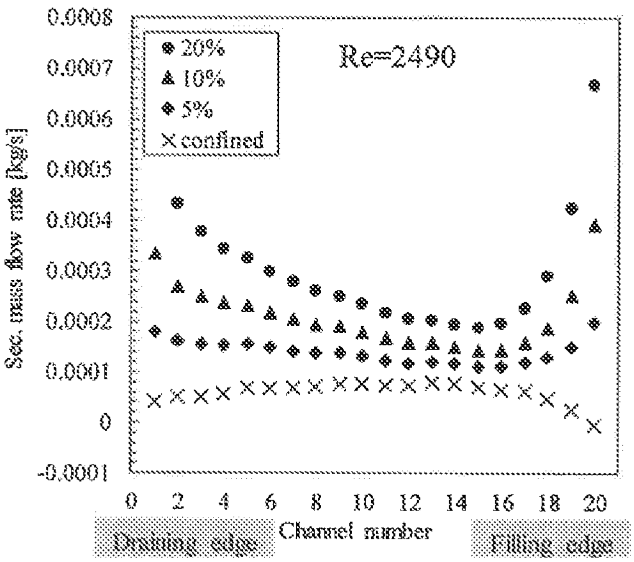


Figure 7A

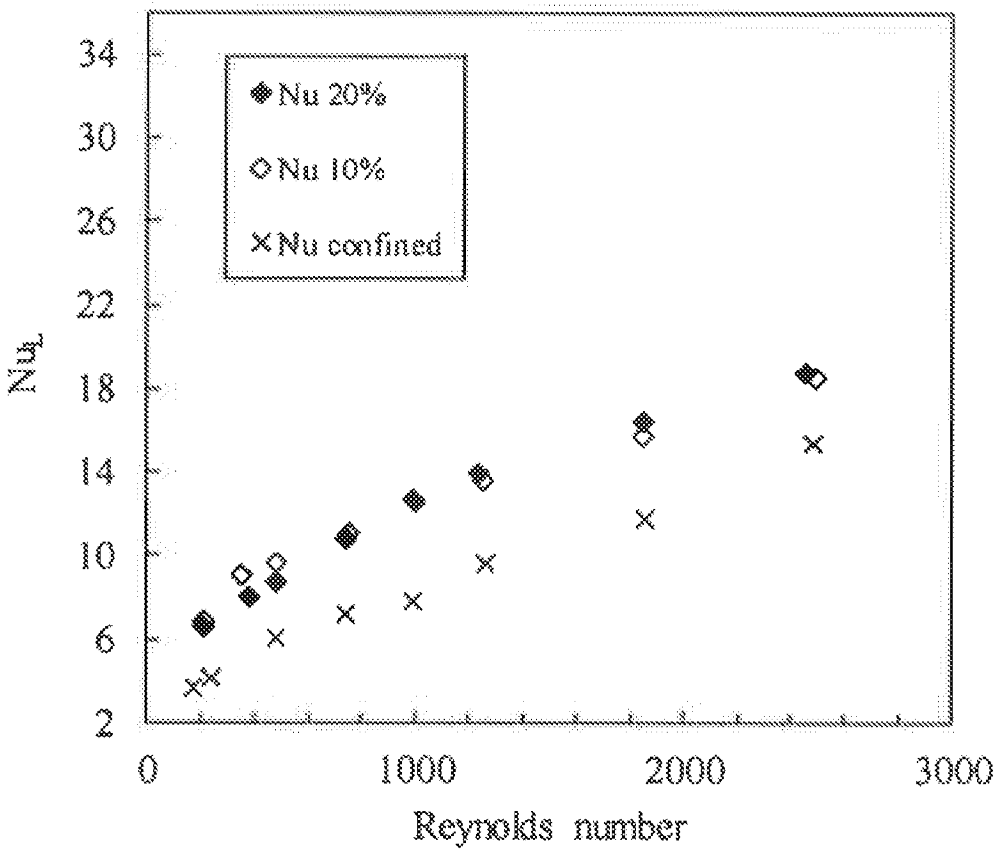


Figure 7B

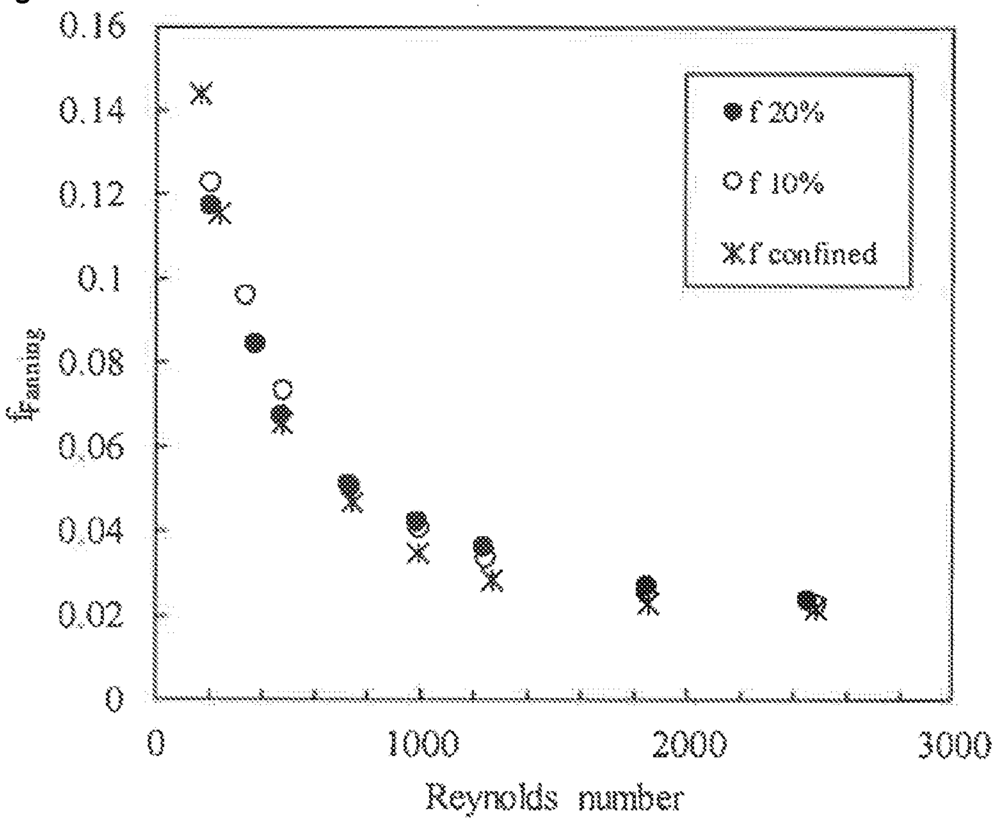
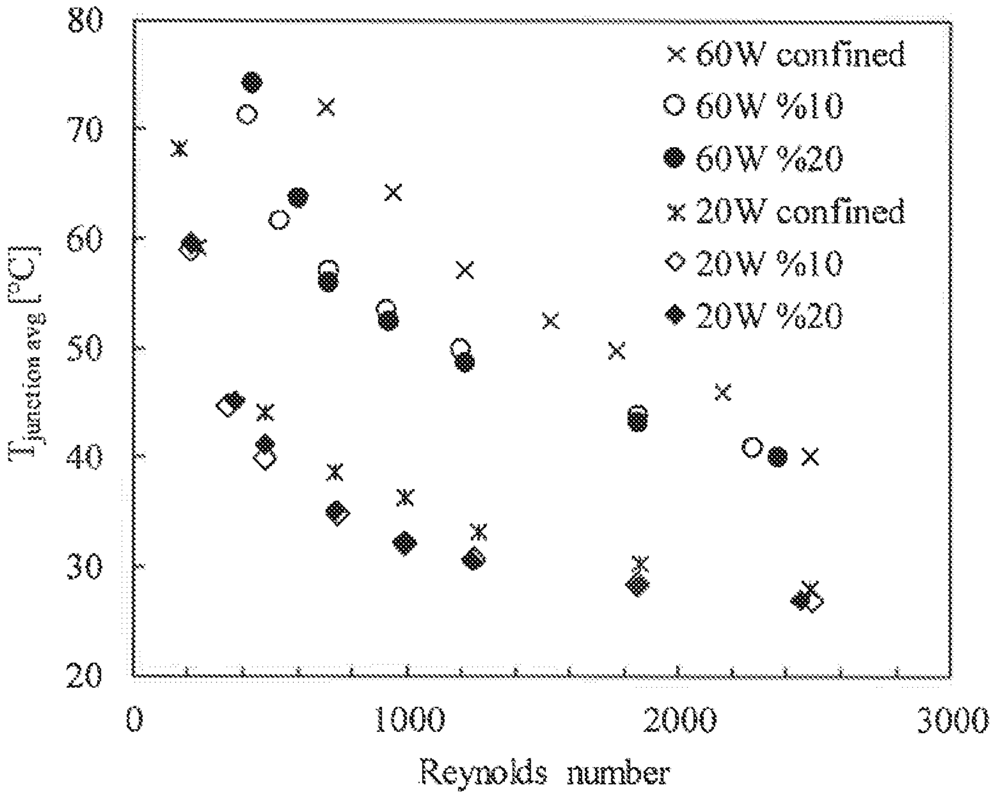


Figure 8


80
70
60
50
40
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20
0
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3000
Reynolds number
T junction avg [°C]
× 60W confined
○ 60W %10
● 60W %20
✱ 20W confined
◇ 20W %10
◆ 20W %20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2019/050276

A. CLASSIFICATION OF SUBJECT MATTER

H01L 23/46 (2006.01) H01L 23/367 (2006.01) *F28D 21/00 (2006.01)*

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L, F28D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

FAMPAT: heat sink, oblique fins, diamond, inclined wall, uniform flow, 散热片, 倾斜, 菱形 and related terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	CN 107403775 A (BEIJING INST RADIO MEASUREMENT) 28 November 2017 Figures1, 3, 4 and the whole document of the machine translation	1-5, 8 6, 7
X A	US 2014/0091453 A1 (MORI S. ET AL.) 3 April 2014 Figures 1, 2	1-5, 8 6, 7
X A	US 2018/0024599 A1 (SAKATA, K. ET AL.) 25 January 2018 Figures 5, 8, 9	1-5, 8 6, 7

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20/08/2019 *(day/month/year)*	*03/09/2019* *(day/month/year)*

Name and mailing address of the ISA/SG	Authorized officer
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Email: pct@ipos.gov.sg	IPOS Customer Service Tel. No.: (+65) 6339 8616

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2019/050276

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014/0054762 A1 (NAGAUNE, F.) 27 February 2014	
A	CN 201294705 Y (WUXI SIDA SIFANG ELECTRIC CO LIMITED) 19 August 2009 The whole document of the machine translation	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SG2019/050276

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

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