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(54) WICK STRUCTURES AND HEAT PIPE NETWORKS

(57) A wick structure (307) for a heat pipe network, the wick structure (307) comprising multiple channels (305) defined by wall portions (303) protruding from a first surface (309) of the wick structure (307) and extend-

ing in an axial direction along a length of the wick structure (307), wherein at least one of the wall portions (303) comprises a tapered termination (304).

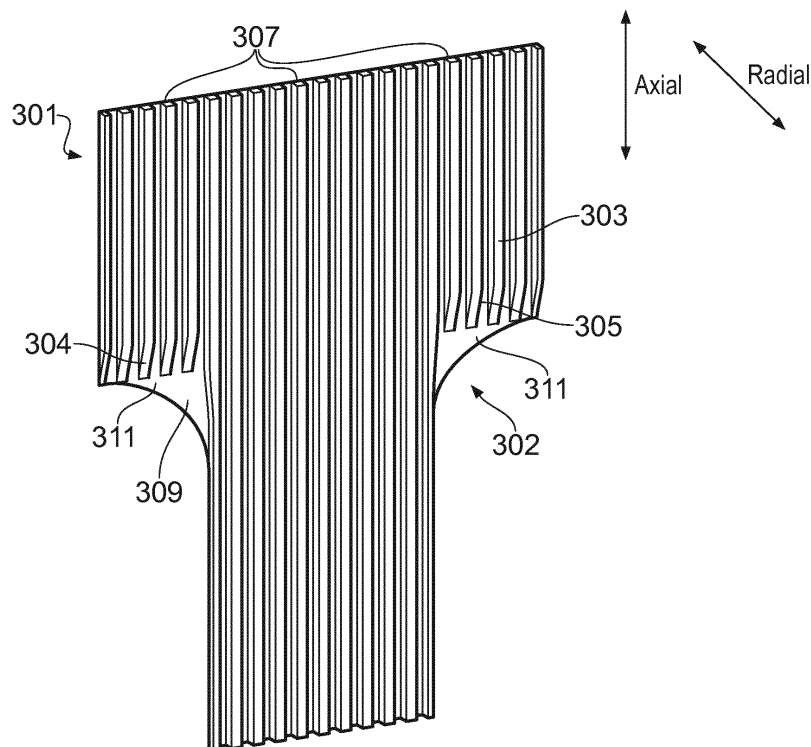


FIG. 3

EP 3 421 917 A1

Description

TECHNICAL FIELD

[0001] Aspects relate, in general, to a wick structure, a heat pipe network and a method.

BACKGROUND

[0002] Electronic devices include heat generating components which can be densely packed. This may be particularly apparent in the case of telecommunications equipment for example, where high data throughput to service a network along with the miniaturization of equipment as a result of advancing technology can result in a dense array of components with high heat flux.

SUMMARY

[0003] According to an example, there is provided a wick structure for a heat pipe network, the wick structure comprising multiple channels defined by wall portions protruding from a first surface of the wick structure and extending in an axial direction along a length of the wick structure, wherein at least one of the wall portions comprises a tapered termination. The wall portions can therefore extend or depend radially inwardly from an interior surface of the heat pipe. A wall portion can terminate in the region of a junction of the heat pipe with another heat pipe of the network. A junction is formed at the intersection of two or more heat pipes. The region of a junction is an area around an intersection between two or more heat pipes.

[0004] The wick structure can comprise a first wick portion configured to be located in a first heat pipe and a second wick portion configured to be located in a second heat pipe and the termination of the wall portion can be provided in the region between the first wick portion and second wick portion. Alternate wall portions can be provided with respective terminations. A wall portion can have a curved profile. A wall portion can be curved at said region between the first wick portion and the second wick portion.

[0005] According to an example, there is provided a heat pipe network comprising an evaporator section in fluid communication with multiple heat pipe branches each comprising a respective condenser section within the network, wherein a heat pipe branch includes a wick structure on an internal surface thereof to promote a fluid flow from the respective condenser section to the evaporator section, the wick structure comprising multiple channels defined by wall portions depending radially inwards from an interior surface of a branch and extending in an axial direction along a length of a branch, wherein at least one of the wall portions can comprise a tapered termination in a radial direction with respect to the heat pipe branch.

[0006] A termination of a wall portion can be provided

in the region of a junction between two branches of the condenser section. Alternate wall portions can be provided with respective terminations. A wall portion can have a curved profile. A wall portion can be curved around a junction between two branches of the condenser section. A heat pipe network can be at least partially embedded in a heat sink.

[0007] According to an example, there is provided a method, comprising depositing multiple layers of material to additively manufacture a heat pipe network comprising a wick structure with multiple channels defined by wall portions to depend radially inwards from an interior surface of a heat pipe and to extend in an axial direction along a length of a heat pipe, wherein at least one of the wall portions terminates by tapering in a radial direction. A heat sink can be formed around the heat pipe network. Wall portions can be formed such that alternate wall portions terminate. Wall portions can be formed with curved profiles.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Embodiments will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic representation of a heat pipe network;

Figures 2a-c are schematic representations of a junction from the heat pipe network according to an example;

Figure 3 is a schematic representation of a wick structure for a junction in a heat pipe network according to an example;

Figures 4a-b are schematic representations of a wick structure for a junction in a heat pipe network according to an example;

Figures 5a-b are schematic representations of a wick structure for a junction in a heat pipe network according to an example;

Figure 6 is a schematic representation of a wick structure for a junction in a heat pipe network according to an example;

Figure 7 is a schematic representation of a wick structure for a junction in a heat pipe network according to an example; and

Figure 8 is a schematic representation of a wick structure for a junction in a heat pipe network according to an example.

DESCRIPTION

[0009] Example embodiments are described below in sufficient detail to enable those of ordinary skill in the art to embody and implement the systems and processes herein described. It is important to understand that embodiments can be provided in many alternate forms and should not be construed as limited to the examples set forth herein.

[0010] Accordingly, while embodiments can be modified in various ways and take on various alternative forms, specific embodiments thereof are shown in the drawings and described in detail below as examples. There is no intent to limit to the particular forms disclosed. On the contrary, all modifications, equivalents, and alternatives falling within the scope of the appended claims should be included. Elements of the example embodiments are consistently denoted by the same reference numerals throughout the drawings and detailed description where appropriate.

[0011] The terminology used herein to describe embodiments is not intended to limit the scope. The articles "a," "an," and "the" are singular in that they have a single referent, however the use of the singular form in the present document should not preclude the presence of more than one referent. In other words, elements referred to in the singular can number one or more, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "includes," and/or "including," when used herein, specify the presence of stated features, items, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, items, steps, operations, elements, components, and/or groups thereof.

[0012] Unless otherwise defined, all terms (including technical and scientific terms) used herein are to be interpreted as is customary in the art. It will be further understood that terms in common usage should also be interpreted as is customary in the relevant art and not in an idealized or overly formal sense unless expressly so defined herein.

[0013] Efficient cooling of components is an important consideration since there may be strict temperature limits for reliability in a system. On the flip side of this, the volume occupied by a cooling solution should be minimal for multiple deployment options. In order to meet these criteria, a heat pipe network can be used.

[0014] Heat pipes typically comprise an evaporator section where heat from a heat generating component causes liquid in the heat pipe to evaporate. The vapor travels through the heat pipe to a condenser section where a heat sink allows dissipation of the heat from the heat pipe, condensing the vapor back to liquid. The liquid then travels back to the evaporator section typically along a wick structure which may take several different forms.

[0015] Heat pipes can be constructed from common metal processing techniques which constrains them to

simply shaped designs that are extrusions of two-dimensional objects (rectangular, circular, etc.), implying they typically have a uniform cross-section throughout the length of the heat pipe.

[0016] An example of a heat pipe network is shown in figure 1 in which three components 101, 103, 105 generate varying amounts of heat, Q_1 , Q_2 and Q_3 respectively. Each component is provided with a customized heat pipe network 107 based on heat generated from that component, while being isolated from other components. A heat pipe network with several junctions enables this approach by allowing efficient use of the space available.

[0017] In the example shown in figure 1, heat pipes are encased in a heat sink 109 which dissipates heat from the heat pipes to the atmosphere. The heat generated by the three components varies and the network approach caters to the needs of each component while minimizing the volume occupied.

[0018] The junctions in such a network of heat pipes form an important part of the network, serving to distribute the heat from the component to a larger surface area, and a wick structure is used to allow liquid from the condenser section to return to the evaporator section without disrupting the flow of hot vapour along the core of a heat pipe. If liquid flow is blocked, it may lead to the liquid pooling at the junction, thereby disrupting the fluid flow cycle in the heat pipe and leading to a dry out. This can occur at junctions (e.g. between two merging heat pipes) where complex wick structures meet and cause impediments to the efficient flow of liquid.

[0019] According to an example, an additively manufactured heat pipe is provided which comprises a wick structure with a complex inner geometry that enables the efficient flow of a condensed fluid at a junction in a heat pipe network, thereby reducing the risk of pooling at the junction.

[0020] Figure 2 is a schematic representation of a junction from a heat pipe network according to an example. The number of heat pipes combining in such a section may vary. An isometric view of a heat pipe junction 207 in which two heat pipes 203, 205 combine to form one 201 is shown in figure 2(a). To discuss an internal wick structure at the junction 207 according to an example, a cross-section of the heat pipe is taken, as shown in figure 2(b). This section is then unwrapped along the dotted line, as indicated by the 'scissor' symbol in figure 2(b). An illustration of the heat pipe when unwrapped is shown in figure 2(c), with the dotted line along which it was unwrapped shown for clarity. In figure 2, the heat pipe junction 207 is shown without any wick structure. In an example, a wick structure can be located on the inner wall 206 of the heat pipe.

[0021] Figure 3 is a schematic representation of a wick structure for a junction in a heat pipe network according to an example. The wick structure 307 comprises multiple channels 305 defined by wall portions 303 depending or extending radially inwardly from an interior surface 309

of a heat pipe and extending in an axial direction along a length of the heat pipe. A wall portion 303 may extend the full length of the heat pipe, or partway as desired. In an example, at least one of the wall portions terminates, and in the example of figure 3 the termination is by way of tapering 304, in a radial direction, along a portion of the length of a wall portion. Furthermore, the terminated wall portions are limited to those in the region of the junction 311. Thus, when the section of figure 3 is reconstructed to form a pipe, the terminated portions will be situated at the junction 207 of the heat pipe as depicted in figure 2a. Thus, at the intersection of the two heat pipes 203, 205 shown in figure 2a, the terminating wall portions do not interfere or provoke a complex or cumbersome inner geometry that may cause pooling of fluid leading to a reduction or failure in effectiveness of the heat pipe network.

[0022] Thus, as shown in figure 3, the upper part 301 of the heat pipe has a uniform cross section on approach to the junction. At the junction, some of the wall portions 303 are gradually tapered 304 to termination. That is, the wall portions 303 reduce in height in a radial direction to the interior surface 309 of the heat pipe. The taper may be gradual and continuous as shown, or stepwise with or without discontinuities. A termination may be such that the wall portion remains proud of the interior surface to some degree. According to an example, this can be done for each of the upper heat pipes 203, 205 in a network which combine into a single lower heat pipe 201 (which may itself then combine with another pipe and so on).

[0023] This provides an improvement from heat pipes of constant cross-section since a clear path is provided for some of the channels which take liquid to the evaporator section of the network.

[0024] Furthermore, while some channels are terminated, the tapered design minimizes contamination of the vapour core by the sudden leakage of liquid from the wick into the core. In an example, to minimize any inefficiencies due to the terminating channels, a junction with this cross-section can be placed at a hot spot in the heat pipe network. The available heat can be used to evaporate the liquid in the terminating channels, thereby minimizing the adverse effect of the junction. A wick structure as shown in figure 3 may be manufactured using conventional manufacturing techniques such as extrusion for example or by additive fabrication as described below.

[0025] Figure 4 is a schematic representation of a wick structure for a junction in a heat pipe network according to an example. As shown in figure 4a, alternate wall portions, e.g. 410, 411, are terminated, not just those that are in the region of a junction, as shown in figure 3. Intermediate wall portions (to those which terminate), e.g. 405, 415, are, in the example of figure 4, curved such that they join a wall portion in the lower heat pipe while the remaining wall portions are tapered down to terminate as shown and as described above with reference to figure 3. This structure is advantageous in that liquid from all channels in the upper heat pipe is allowed to flow into

the lower heat pipe.

[0026] As can be seen in figure 4b, the height 406 of wall portions in this example is constant since, during normal operation, the channels for liquid returning to the evaporator section created by the wick structure are not expected to be full of liquid. Therefore, the decrease in total volume available for the liquid to occupy as the liquid moves from multiple heat pipes 203, 205 to a single, common heat pipe 201 does not hinder operation of the heat pipe.

[0027] However, an area of further performance gain according to an example can be to vary the height of the wick structure such that the transition to a lower available volume as the liquid moves from multiple heat pipes to a single, common heat pipe is made more gradual or so that channel of increased height is provided to accommodate an increased volume of liquid.

[0028] Figure 5 is a schematic representation of a wick structure for a junction in a heat pipe network according to an example. As noted, while the heat pipe wick channels are not expected to be full of liquid at all times during the operation, there might be a scenario at the peak of performance when the channels are close to being full. Thus, in the example of figure 5 the height 510 of the wall portions is increased at the junction as can be seen in figure 5b in order to accommodate an increase in the volume of liquid at the junction region. In the example of figure 5, each alternate wall portion is combined such that liquid from all the channels 501 flows into the lower pipe 503 as shown in figure 5a. In this example, the height 510 of the wicks is higher at the junction to increase the available volume for liquid from multiple pipes to flow into a single pipe. The variation in height can be continuous as shown, or may be in the form of a step and so on.

[0029] According to an example, a heat pipe network as described above with reference to figures 2 to 5 can be generated using an additive manufacturing process. Such additive manufacturing enables heat pipes with complex inner geometries to be fabricated. For example, multiple layers of a material, such as metal, can be deposited using a rendering apparatus, such as a 3D printer for example, in order to additively manufacture a heat pipe network comprising a wick structure. The heat pipe network can be provided within a heat sink, which can be additively manufactured at the same time (such that the network is built up within the heat sink), or added after the network has been fabricated.

[0030] According to an example, directing a flow of condensed fluid in a wick structure efficiently into the lower heat pipe can be extended to heat pipes with other wick structure designs. In an example, one such design is that of a sintered wick. This can be composed of sintered metal powder.

[0031] Figure 6 is a schematic representation of a wick structure for a junction in a heat pipe network according to an example. Sintered metal wicks 601 can be manufactured by packing small metal particles between the inner heat pipe wall and a mandrel in powder form. This

assembly is then heated until the metal particles are sintered to each other and to the inner wall of the heat pipe. The resulting structure can be thought of as isotropic along the inner wall of the heat pipe.

[0032] According to an example, a sintered region can be shaped or modified such that it pre-empts a change in shape of the heat pipe, providing a more gradual change in direction for the liquid. The capillary pressure generated by the wick will keep the fluid from leaking out of the sintered region.

[0033] Figure 7 is a schematic representation of a wick structure for a junction in a heat pipe network according to an example. As shown in figure 7, the sintered wick structure 701 along the inner wall of the junction in the heat pipe is shaped 705 to pre-empt the termination of the heat pipe and provide a gradual change in direction to the liquid at the junction region. In the example, of figure 7, this is accomplished by providing an area 703 devoid of sintered material and by profiling the sintered material above the junction as shown to have a generally sinuous nature so as to avoid any discontinuities that would otherwise interrupt the natural flow of fluid in the wick structure.

[0034] Figure 8 is a schematic representation of a wick structure for a junction in a heat pipe network according to an example. In the example of figure 8, a sintered region 800 (whose directionality typically cannot be controlled using conventional manufacturing processes) is fabricated and made anisotropic. The directional sinter 801, 803 provides a path of least resistance to the liquid in the wick, thereby directing it 'around' the junction, generally in direction D, in order to avoid the effects of liquid pooling reducing the effectiveness of the network.

[0035] The sintered material can be the same material used for the heat pipe and/or a heat sink. The anisotropic property of the sintered material at the region of a junction can be provided using, for example, selective laser sintering.

[0036] Accordingly, a heat pipe network with several junctions can be provided by providing complex and bespoke wick structures for the inner walls of the junction. The wick structures allow the seamless flow of liquid from the condenser section to the evaporator section of the heat pipe.

[0037] According to an example a wick structure for a heat pipe network can comprise a first wick portion, a second wick portion and a third wick portion and being configured to allow a flow of a liquid from the first wick portion and the second wick portion to the third wick portion wherein the wick structure further comprises irregularities provided at least at a region between the first wick structure and the third wick structure and configured to assist the flow of the liquid from the first wick structure to the third wick structure.

[0038] In an example, the first wick portion can be provided on the inner wall of, for example, heat pipe 203, the second wick portion can be provided on the inner wall of, for example, heat pipe 205, and the third wick portion

can be provided on the inner wall of, for example, heat pipe 201. Irregularities provided at least at the region 207 between the first wick structure and the third wick structure can be in the form of a tapered structure as described with reference to figures 3 to 5 for example, or a sintered structure as described with reference to figures 7 or 8 for example. That is, the irregularities configured to assist the flow of the liquid from the first wick structure to the third wick structure can channels with tapered wall portions as described with reference to figures 3 to 5 for example, or an anisotropic sintered structure as described with reference to figures 7 or 8 for example.

[0039] In an example, the wick structure can further comprise irregularities provided at least at a region between the second wick structure and the third wick structure and configured to assist the flow of the liquid from the second wick structure to the third wick structure.

[0040] The wick structure can comprise channels defining walls and the irregularities can include terminations in the wall portions. In an example, the wick structure can comprise terminations in alternate wall portions.

[0041] In another example, the wick structure can comprise a sintered material and the irregularities can include an area devoid of sintered material configured to provide gradual change in the direction of the flow of the liquid and/or a region of sintered material configured to provide a path of flow having a resistance to flow which is lower than a resistance of flow of an adjacent area, as shown in figure 8 for example.

[0042] In an example, a wall portion of a channel can have a constant height, or may have a varying height.

[0043] The present embodiments can be realised in other specific apparatus and/or methods. The described embodiments are to be considered in all respects as illustrative and not restrictive. In particular, the scope of the disclosure is indicated by the appended claims rather than by the description and figures herein. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

Claims

1. A wick structure for a heat pipe network, the wick structure comprising:

multiple channels defined by wall portions protruding from a first surface of the wick structure and extending in an axial direction along a length of the wick structure, wherein at least one of the wall portions comprises a tapered termination.

2. A wick structure as claimed in claim 1, wherein the wick structure comprises a first wick portion configured to be located in a first heat pipe and a second wick portion configured to be located in a second heat pipe and the termination of the wall portion is provided in the region between the first wick portion

- and second wick portion.
3. A wick structure as claimed in claim 1 or 2, wherein alternate wall portions are provided with respective terminations. 5
 4. A wick structure as claimed in claims 2 or 3, wherein a wall portion has a curved profile.
 5. A wick structure as claimed in claim 4, wherein the wall portion is curved at said region between the first wick portion and the second wick portion. 10
 6. A heat pipe network comprising an evaporator section in fluid communication with multiple heat pipe branches each comprising a respective condenser section within the network, wherein a heat pipe branch includes a wick structure on an internal surface thereof to promote a fluid flow from the respective condenser section to the evaporator section, the wick structure comprising multiple channels defined by wall portions depending radially inwards from an interior surface of a branch and extending in an axial direction along a length of a branch, wherein at least one of the wall portions comprises a tapered termination in a radial direction with respect to the heat pipe branch. 15 20 25
 7. A heat pipe network as claimed in claim 6, wherein the termination of a wall portion is provided in the region of a junction between two branches of the condenser section. 30
 8. A heat pipe network as claimed in claim 6 or 7, wherein alternate wall portions are provided with respective terminations. 35
 9. A heat pipe network as claimed in any of claims 6 to 8, wherein a wall portion has a curved profile. 40
 10. A heat pipe network as claimed in claim 9, wherein the wall portion is curved around a junction between two branches of the condenser section.
 11. A heat pipe network as claimed in any of claims 6 to 10 wherein the heat pipe network is at least partially embedded in a heat sink. 45
 12. A method, comprising: 50
 - depositing multiple layers of material to additively manufacture a heat pipe network comprising a wick structure with multiple channels defined by wall portions to depend radially inwards from an interior surface of a heat pipe and to extend in an axial direction along a length of a heat pipe, wherein at least one of the wall portions terminates by tapering in a radial direction. 55
 13. A method as claimed in claim 12, further comprising forming a heat sink around the heat pipe network.
 14. A method as claimed in claim 12 or 13, forming wall portions such that alternate wall portions terminate.
 15. A method as claimed in any of claims 12 to 14, further comprising forming wall portions with curved profiles.

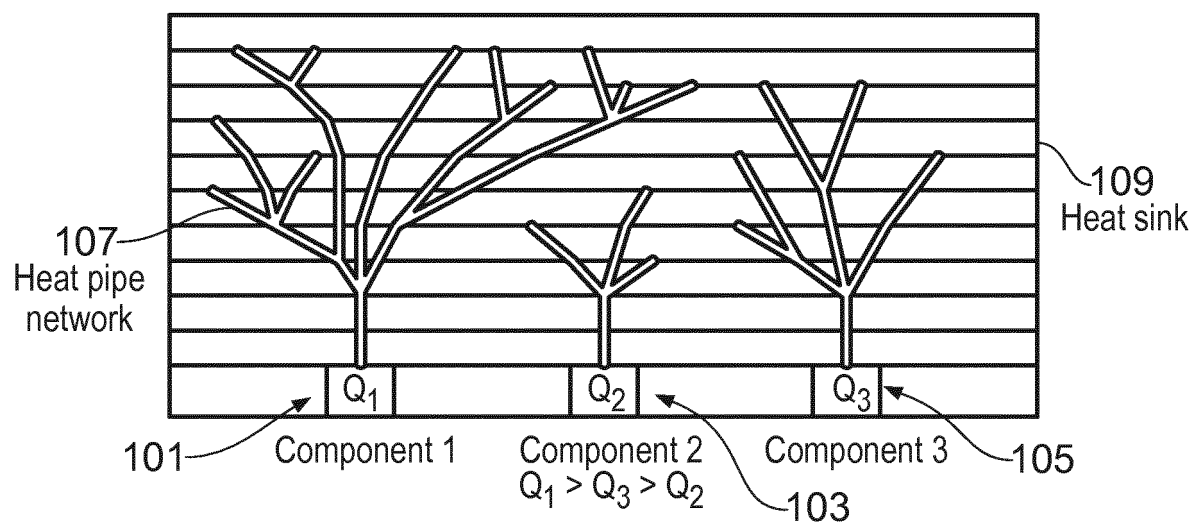
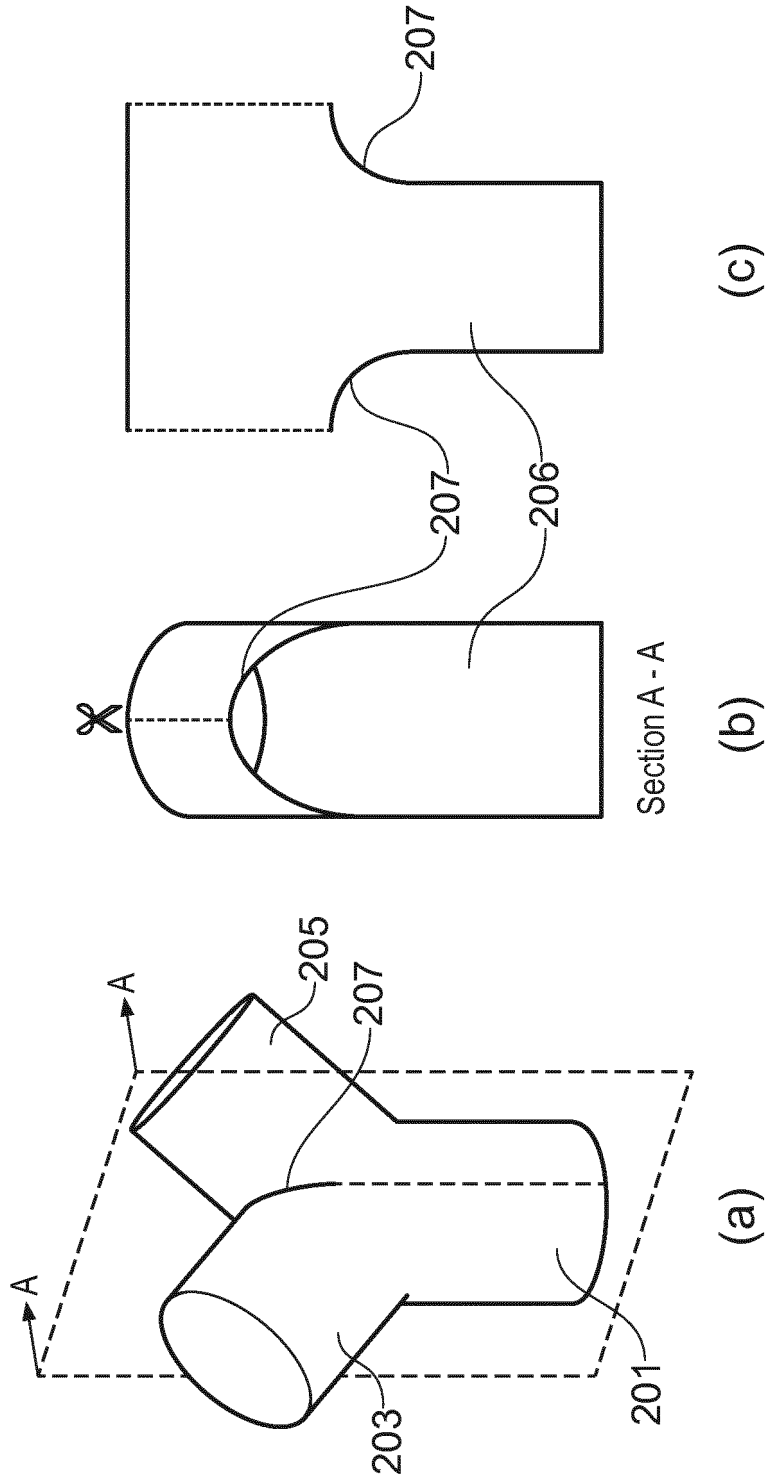


FIG. 1



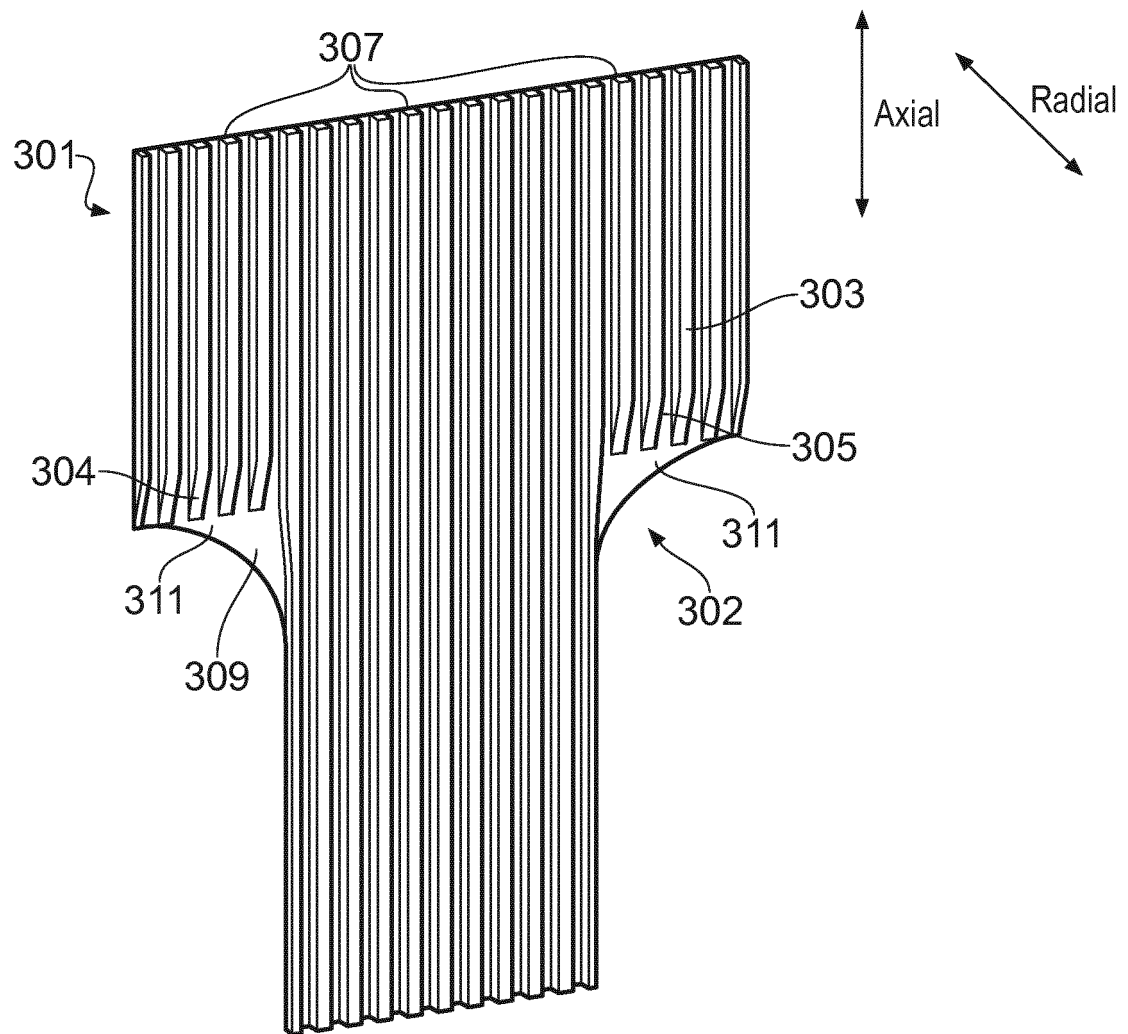
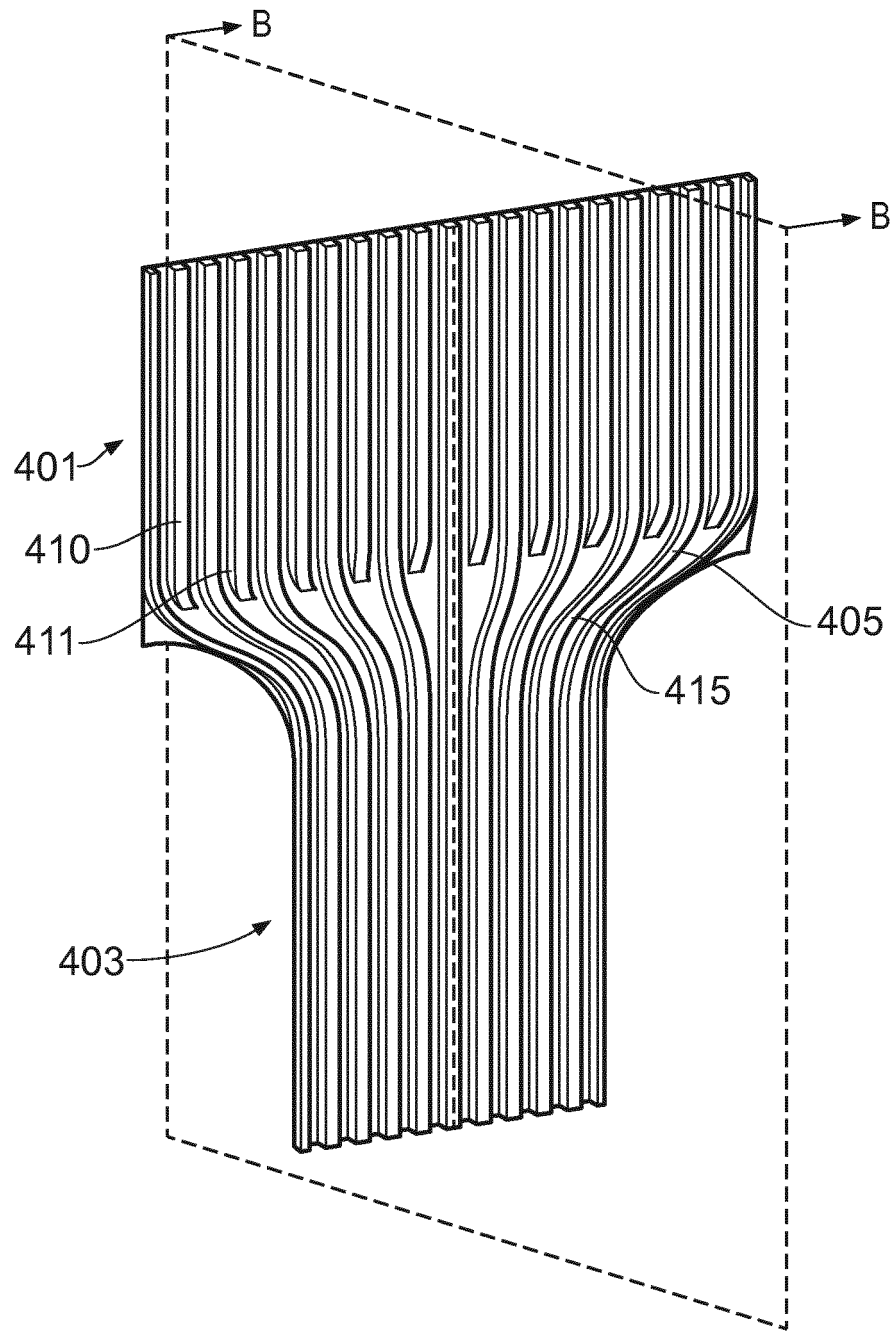
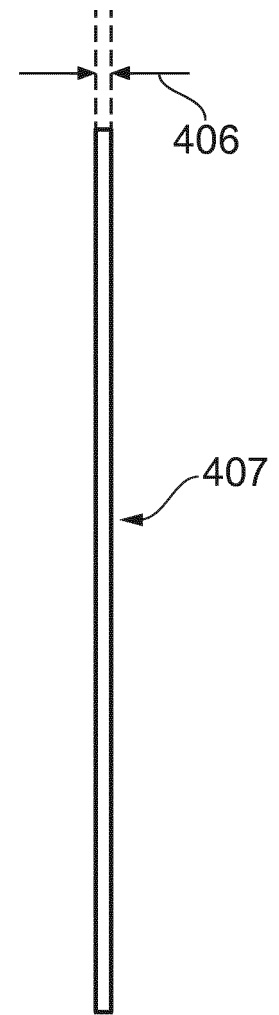


FIG. 3



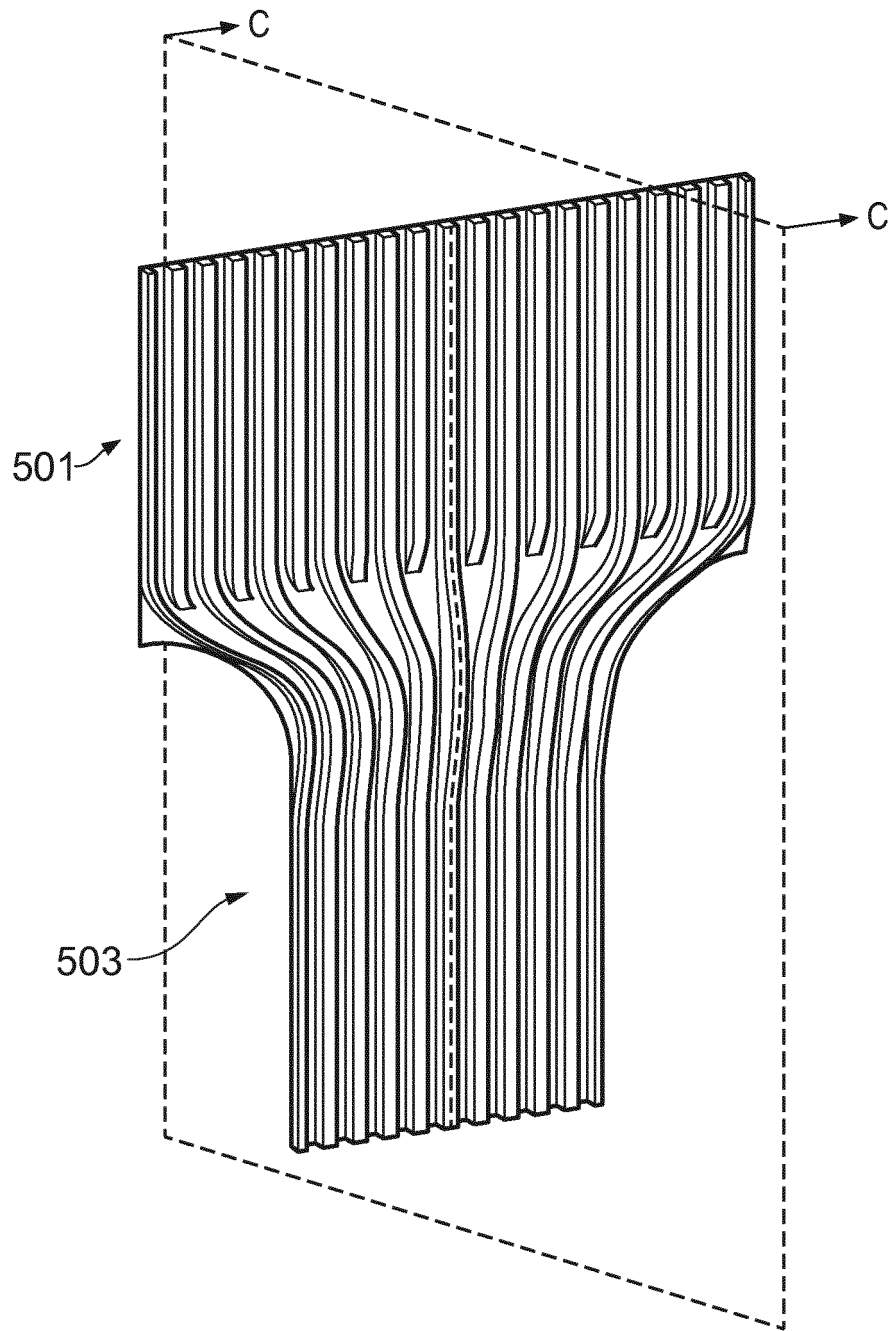
(a)



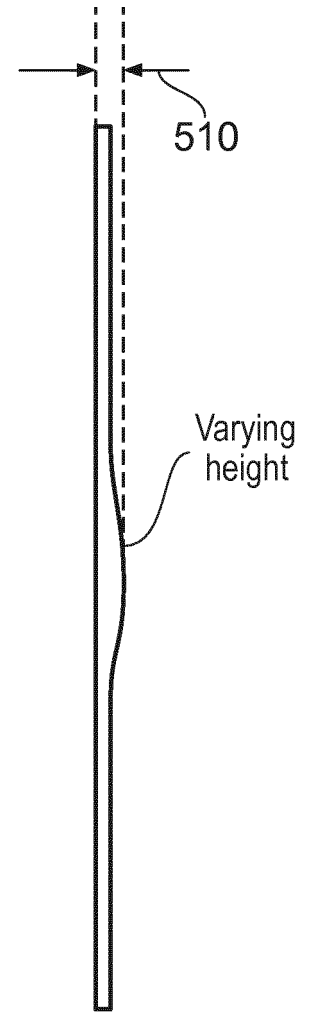
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(b)

FIG. 4



(a)



(b)

FIG. 5

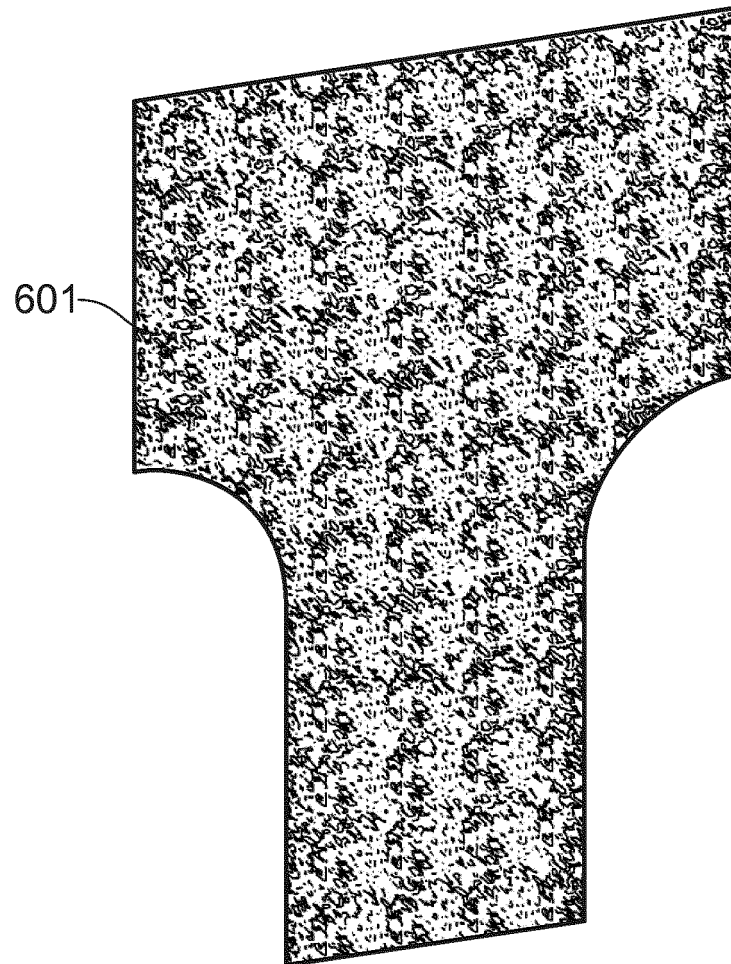


FIG. 6

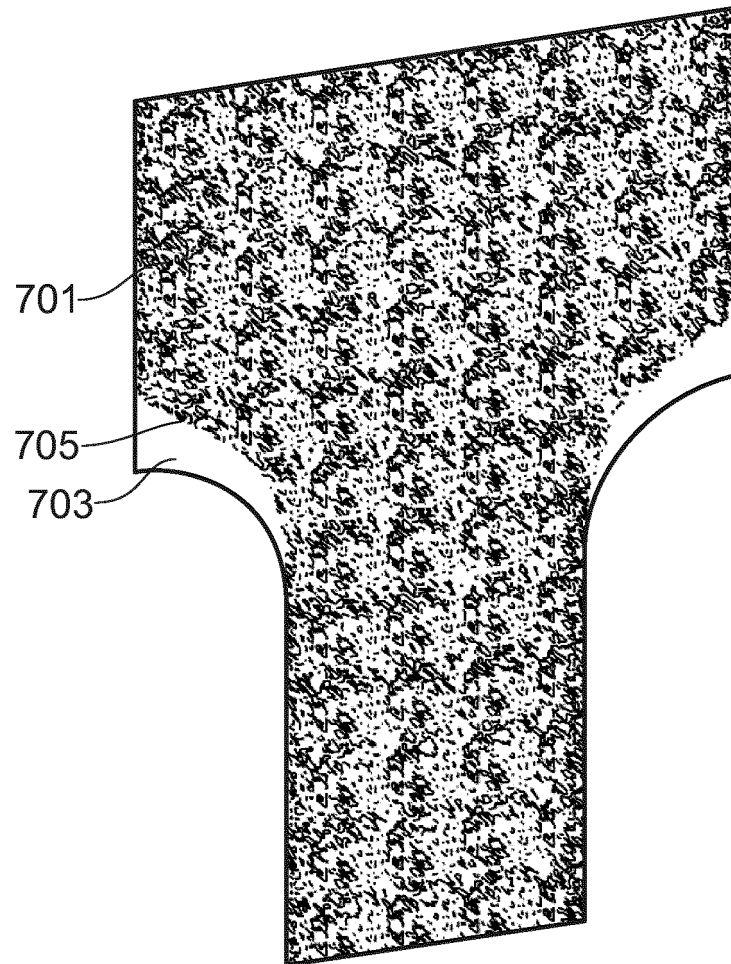


FIG. 7

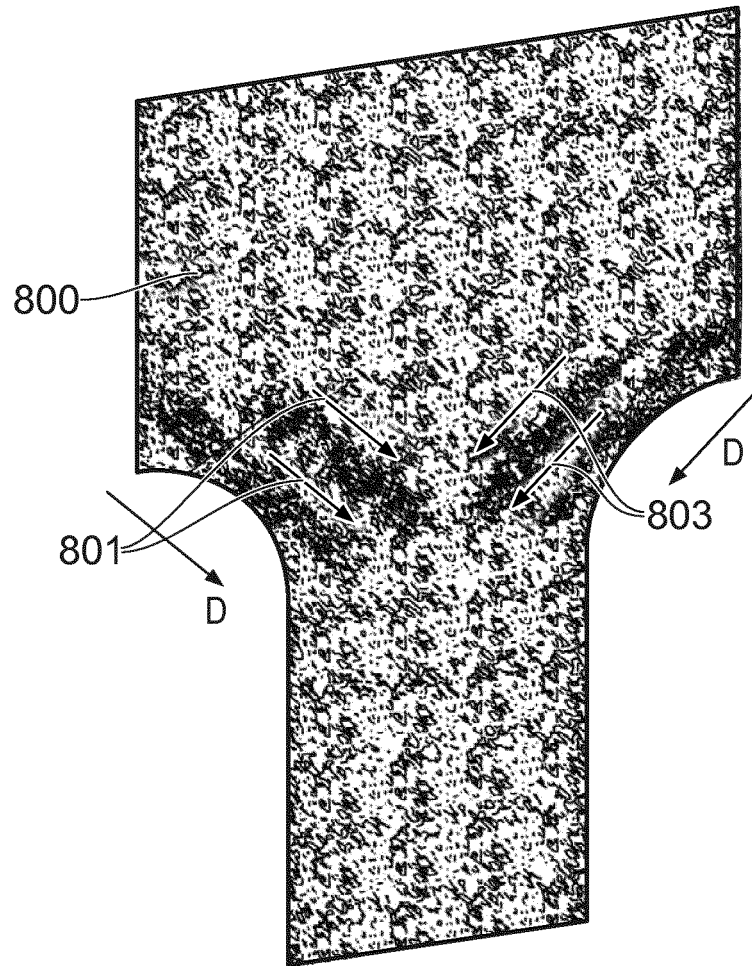


FIG. 8



EUROPEAN SEARCH REPORT

 Application Number
EP 17 17 9184

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 20 December 2017	Examiner Beltzung, Francis
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EP 17 17 9184

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