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(54) A sheet for exchange of heat or mass transfer between fluid flows, a device comprising such a sheet, and a method of manufacturing the sheet

(57) The present disclosure relates to a sheet (1) for exchange of heat and/or mass transfer between fluid flows, to a device comprising such a sheet, and to a method of manufacturing the sheet (1). The sheet (1) is provided with corrugations defining open channels (3, 5), wherein a cross-section of every other open channel (3) has two channel end points (3a, 3b), and two peaks (3c, 3d) and a valley floor (3e) between the two channel end points (3a, 3b)

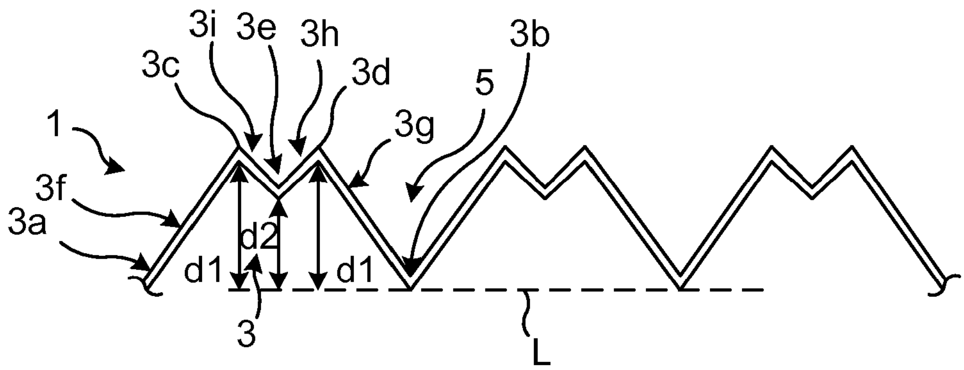

Fig. 1b

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Description

TECHNICAL FIELD

[0001] The present disclosure generally relates to the exchange of heat or mass transfer between fluid flows, and in particular to a sheet for heat and/or mass transfer, a device comprising such a sheet, and to a method of manufacturing such a sheet.

BACKGROUND

[0002] As in most fields of technology, manufacturers of heat exchangers and devices for mass transfer between fluid flows strive to find cost efficient and simple production methods.

[0003] JP2004132589 discloses a heat exchanger which comprises corrugated sheets. The corrugations form flow channels of the heat exchanger. Every second channel of a sheet is an open channel and the remaining channels are closed channels. The closed channels are obtained by adhering lids to originally open channels of the sheet. Two such sheets are then stacked and laminated to form a plurality of closed channels.

[0004] A disadvantage with the heat exchanger disclosed in JP2004132589 is that the lamination of the sheets requires additional process steps. In addition to the lamination step, a process step of surface activation of the sheets to enable lamination may also be necessary. Moreover, adhesives are expensive and may be hazardous to the environment. Furthermore, the lamination step also complicates changes in the production line. Different applications may require different sheet material which in turn may need to be laminated with different types of adhesives. Thus, if the sheet material is changed, considerations concerning a suitable adhesive and surface activator for that material will also need to be taken into account.

SUMMARY

[0005] In view of the above, a general objective of the present disclosure is to provide a sheet for exchange of heat and/or mass transfer which at least mitigate the problems of the prior art.

[0006] Another objective is to provide a device for exchange of heat or mass transfer.

[0007] A third objective is to provide a method of manufacturing a sheet for exchange of heat or mass transfer.

[0008] Hence, according to a first aspect of the present disclosure there is provided a sheet for exchange of heat or mass transfer between fluid flows, which sheet is provided with corrugations defining open channels, wherein a cross-section of every other open channel has two channel end points, and two peaks and a valley floor between the two channel end points.

[0009] An effect which may be obtainable thereby is that these sheets do not require any adhesive for stacking them to produce a heat exchanger or a device for mass transfer between fluid flows. Every other channel has two peaks and a valley floor which define a corrugation of each such channel, in a sense a sub-corrugation relative to the main corrugations defining the channels of the sheet. By means of this structure, sheets may be stacked in a manner in which every open channel with two peaks and a valley floor of one sheet engages an intermediate channel, i.e. a channel between two open channels each having two peaks and a valley floor, of another sheet. In particular the cross-sectional shape of each open channel having two peaks and a valley prevents relative lateral movement of two adjacent stacked sheets. Moreover, this structure also prevents sheets to move towards each other. Stacked sheet are hence fixed with regards to relative movement to the sides and towards each other. Consequently, adhesives are therefore not necessary for stacking a plurality of sheets to form a device for the exchange of heat and/or mass transfer between fluid flows.

[0010] According to one embodiment the two peaks are located at a first distance from a straight line extending between the channel end points and the valley floor is located at a second distance from the straight line.

[0011] According to one embodiment the valley floor is arranged between the two peaks. The geometry of two peaks with a valley floor therebetween provides a locking mechanism of two stacked sheets. Two stacked sheets can thereby interlock such that relative lateral movement and towards movement may be restricted.

[0012] According to one embodiment the cross-sectional shape of that section which connects the two peaks is congruent with the cross-sectional shape of any of the open channels which are arranged between said every other open channel. The cross-sectional shape of an intermediate open channel, i.e. of an open channel between two channels each having two peaks and a valley floor, thus enables the engagement or interlocking of two stacked sheets. Every pair of stacked sheets is hence displaced, for example by one half of a channel width, such that a portion of an intermediate open channel is aligned with and arranged within the section that connects two peaks.

[0013] According to one embodiment the entire section connecting a first of the channel end points with a first of the peaks is parallel with the entire section connecting the valley floor with a second of the peaks.

[0014] According to one embodiment the entire section connecting a second of the channel end points and the second of the peaks is parallel with the entire section connecting the valley floor with the first of the peaks. The section connecting a channel end point with a peak also defines the side wall of an intermediate open channel. Two such sections facing each other, i.e. of two adjacent open channels having two peaks and a valley floor, thus define the side walls of an intermediate channel. By the provision of parallel sections as defined above, congruence of the cross-section of an intermediate channel with a section which connects the two peaks may be obtained.

[0015] According to one embodiment each of said every other channel has an essentially M-shaped cross-section.

[0016] According to one embodiment the sheet is a heat exchanger sheet.

[0017] According to a second aspect of the present disclosure there is provided a device for exchange of heat or mass transfer between fluid flows, comprising a plurality of sheets according to the first aspect, which plurality of sheets are stacked such that the open channels of each pair of adjacent sheets define fluid flow channels.

[0018] According to one embodiment the channel end points of a sheet engage a respective valley floor of an adjacent sheet.

[0019] One embodiment comprises fluid inlets and fluid outlets, wherein each fluid inlet is arranged to direct fluid into fluid flow channels of two adjacent sheets and each fluid outlet is arranged to direct fluid out from fluid flow channels of two adjacent sheets, wherein each fluid inlet and fluid outlet has a tapering shape.

[0020] According to one embodiment each fluid inlet has an inlet mouth parallel to the longitudinal extension of the fluid flow channels, wherein each inlet mouth is arranged in level with a lateral end of a sheet, wherein each fluid inlet extends from said lateral end towards the other lateral end of the sheet, and wherein each fluid inlet is tapering from the said lateral end to the other lateral end towards channel inlet mouths of fluid flow channels. Thereby, the Venturi effect that may affect flow in channels closest to the inlet mouth may be reduced such that essentially uniform fluid distribution in each fluid flow channel may be obtained. As a consequence the fluid throughput of the device may be increased, thus increasing the efficiency of the device.

[0021] According to one embodiment each fluid outlet has an outlet mouth parallel to the longitudinal extension of the fluid flow channels, wherein each outlet mouth is arranged in level with a lateral end of a sheet, wherein each fluid outlet extends from said lateral end towards the other lateral end of the sheet, and wherein each fluid outlet is tapering from said lateral end to the other lateral end towards channel outlet mouths of the fluid flow channels. Thereby, the total pressure drop is balanced between all fluid flow channels of a specific layer of fluid flow channels. As a consequence the fluid throughput of the device may be increased, thus increasing the efficiency of the device.

[0022] According to a third aspect of the present disclosure there is provided a method of manufacturing a sheet for exchange of heat or mass transfer between fluid flows, wherein the method comprises:

a) providing a sheet blank,

b) corrugating the sheet blank to form open channels such that every other channel has a cross-section with two channel end points, and two peaks and a valley floor between the two channel end points.

[0023] According to one embodiment step a) of corrugating is performed by 1) thermoforming or 2) by folding along fold lines. Thus, a production method may be provided in which each sheet blank may be corrugated in a simple manner, without having to utilise any adhesive or additional parts to obtain a robust structure when assembling a device for exchange of heat and/or mass transfer comprising a plurality of stacked sheets.

[0024] Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, etc. are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, etc., unless explicitly stated otherwise.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The specific embodiments of the inventive concept will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1a depicts a schematic perspective view of an example of a sheet for exchange of heat or mass transfer;

Fig. 1b depicts a portion of a cross-section of the sheet in Fig. 1a;

Fig. 1c depicts a cross-sectional view of another example of a sheet for exchange of heat or mass transfer;

Fig. 2 shows a perspective view of a cross-section stacked sheets for exchange of heat or mass transfer;

Figs 3a-b schematically depicts elevated views of examples of sheet with fluid inlets and fluid outlets;

Fig. 3c depicts a perspective view of two stacked sheets which comprises a fluid inlet and a fluid outlet;

Fig. 4 depicts a device for exchange of heat or mass transfer, which device comprises a plurality of sheets;

Fig. 5a depicts a variation of the device in Fig. 4, comprising channel dividing sheets;

Fig. 5b depicts a variation of the device in Fig. 5a;

Fig. 6 depicts a flowchart of a method of producing a sheet for exchange of heat and/or mass transfer; and

Fig. 7 depicts a top view of an example of a sheet blank.

DETAILED DESCRIPTION

[0026] The inventive concept will now be described more fully hereinafter with reference to the accompanying drawings, in which exemplifying embodiments are shown. The inventive concept may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the inventive concept to those skilled in the art. Like numbers refer to like elements throughout the description.

[0027] Fig. 1 depicts an example of a sheet 1 for exchange of heat and/or mass transfer. The sheet 1 has a plurality of corrugations forming a plurality of open channels 3, 5. A pair of sheets 1 may be stacked such that closed fluid flow channels are formed by the open channels 3, 5 of the stacked sheets 1. A plurality of sheets 1 may be stacked to form a heat exchanger or a device for mass transfer between fluid flows, or a device which has both of said functionalities. The particular application of the sheet 1 is dependent of the properties of the material of the sheet 1. To this end, the sheet 1 may be made of a material that is impermeable, permeable or semipermeable for a fluid such as water, air or any other fluid which may be utilised in heat exchange or mass transfer applications.

[0028] Adjacent open channels 3 and 5 of the sheet 1 have mouths in opposite directions. Every other open channel, open channels 3, has a corrugation. Open channels 3 will in the following be referred to as corrugated open channels 3. The corrugation of each corrugated open channel 3 is less prominent than the corrugations which form the open channels 3 and 5 of the sheet 1 and may thus be seen as a sub-corrugation relative to the open channel-defining corrugations. The remaining open channels, i.e. open channels 5 that are intermediate each pair of corrugated open channel 3, will in the following be referred to as intermediate open channels 5. Intermediate open channels 5 have a cross-sectional shape which allows them to engage the corrugation of a corrugated open channel 5 of another sheet 1 when two sheets 1 are stacked in a manner in which each intermediate open channel 5 of one sheet 1 is arranged in an aligned manner with a respective sub corrugation of the other sheet 1. Thus, the corrugation of each corrugated open channel 3 defines means for engagement with an intermediate open channel 5 of another sheet 1.

[0029] Fig. 1b shows a cross-sectional view of a portion of the sheet 1 in Fig. 1a. Each corrugated open channel 3 has two channel end points 3a and 3b defining the mouth of open channel 3. Between the channel end points 3a, 3b of a corrugated open channel 3 are two peaks 3c and 3d, and a valley having a valley floor 3e. The two peaks 3c and 3d and the valley floor 3e of a corrugated open channel 3 define the corrugation or sub-corrugation of that corrugated open channel 3.

[0030] It should be noted that when referring to peaks and valleys throughout this disclosure, these features obtain their intended meaning when the sheet 1 is in the horizontal position such that the open channels 3 and 5 extend horizontally with the mouths of the corrugated open channels 3 facing downwards.

[0031] The two peaks 3c, 3d are located at a first distance d1 from a straight line L extending between the channel end points 3a. The valley floor 3c is located at a second distance d2 from the line L. The first distance d1 differs from the second distance d2. In particular, the first distance d1 is greater than the second distance d2.

[0032] The entire section 3f connecting one of the channel end points 3a with the first peak 3c of the two peaks 3c, 3d of a corrugated open channel 3 is parallel with the entire section 3h connecting the valley floor 3e with the second peak 3d of the peaks 3c, 3d. The entire section 3g connecting the other channel end point 3b with the second peak 3d is parallel with entire section 3i connecting the valley floor 3e with the first peak 3c. In particular, every other section connecting two inclination-changing points of a cross-section of a corrugated open channel 3 are parallel. Each corrugated open channel 3 thus has an essentially M-shaped cross-section when the open channels 3, 5 are arranged horizontally with the mouths of the corrugated open channels 3 facing downwards. The corrugated open channels 3 have this cross-sectional shape along their entire longitudinal extension.

[0033] The valley floor 3e is arranged between the two peaks 3c and 3d. In a cross-section the structure of a valley floor 3e between the two peaks 3c and 3d may be seen as a cutout, in the sense that this specific geometry functions as a means for receiving an intermediate channel 5 of another sheet 1. In particular, the cross-sectional shape of that section 3g, 3h of a corrugated open channel 3 which connects the two peaks 3c and 3d is congruent with the cross-sectional shape of any intermediate open channel 5.

[0034] Fig. 1c shows a cross-sectional view of a portion of a variation of the sheet 1 in Fig. 1a. Fig. 1c illustrates one of a plurality of possibilities for alternative channel shape design. Sheet 1' depicted in Fig. 1c has a plurality of corrugations forming open channels 3' and 5'. Every other open channel is corrugated and is a corrugated open channel 3'. The remaining open channels, i.e. those adjacent to a corrugated open channel 3' are, as above, referred to as intermediate open channels 5'. As can be seen, the general cross-sectional structure of sheet 1' is identical to that of Figs 1a and 1b. The cross-section of each corrugated open channel 3' includes two channel end points 3a' and 3b', and two peaks 3c', 3d' and a valley floor 3e' arranged between the two channel end points 3a' and 3b'. A difference between sheet 1 and sheet 1' is that the valley floors 3e' are plane and that the intermediate open channels 5' have a plane portion. The cross sectional shape of the intermediate open channels 5' is congruent with the section connecting the two peaks 3c' and 3d' of a corrugated open channel 3'.

[0035] Other variations include arrangements where sections interconnecting a channel end point and a peak have a staircase formation. Moreover, the corrugated open channels, as well as the intermediate channels, could be asymmetrical.

[0036] Fig. 2 shows a perspective view of a portion of two sheets 1 that have been stacked. The intermediate open channel 5 of the upper sheet 1 has been arranged in the valley and rests on the valley floor 3e defined between the two peaks 3c and 3d of the lower sheet 1. Fluid flow channels 11 are thus formed by pairs of intermediate open channels 5 facing corrugated open channels 3 of the two sheets 1. The two sheets 1 are shifted to the side such that each intermediate open channel 5 of one sheet is arranged between two peaks of a respective corrugated open channel 3 of the other sheet. Each pair of adjacent sheet 1 are thus staggered relative to each other such that the intermediate channels 5 of one of the sheet 1 engage respective valley floors between two peaks of the other sheet. The corrugations of stacked sheets may thus be identical, simplifying the manufacturing process.

[0037] Fig. 3a schematically depicts an elevated view of two or more stacked sheets 1. Each sheet 1 may have end portions, either integrated with the sheet 1, or end parts attached to the sheet 1.These end portions or parts are typically not corrugated but they could however be corrugated. The end portions or parts are arranged at each end of the open channels 3, 5, i.e. at the inlet and outlet to the open channels 3, 5.

[0038] When two sheets 1 are stacked, the end portions or parts of both sheets 1 are joined, for example by means of welding, or by means of an adhesive. When joining two end portions or parts, a portion thereof is left unsealed, forming a mouth, such that fluid may enter the thus created fluid inlet or exit the thus created fluid outlet. The sealed end portions or end parts of such a pair of sheets 1 thereby form a fluid inlet 7 and a fluid outlet 9 for that pair of sheets 1. When two pairs of such stacked sheet 1, each pair having a fluid inlet and a fluid outlet, in turn are stacked, the already joined end portions or parts of a pair will not be joined with the already joined end portions or parts of the other pair. Instead, the fluid flow channels defined between the two pairs of stacked sheets 1 may function as a counter-current layer. Each fluid inlet and each fluid outlet hence serves only one layer of fluid flow channels, i.e. one pair of sheets.

[0039] The fluid inlet 7 is arranged to direct fluid into the fluid flow channels 11 of two stacked sheets 1 and the fluid outlet 9 is arranged to direct fluid exiting from the fluid flow channels 11 of the same two stacked sheets 1. Fluid inlet 7 is thus arranged at one end of the fluid flow channels 11 and fluid outlet 9 is arranged at the other end of the fluid flow channels 11. The fluid inlet 7 and the fluid outlet 9 both have a tapering shape.

[0040] The fluid inlet 7 has an inlet mouth 7a for receiving a fluid flow. The fluid inlet 7 is arranged to direct fluid received via the inlet mouth 7a into the fluid flow channels 11.

[0041] The fluid inlet 7 has a distal end 7b relative to channel inlet mouths 1a. The inlet mouth 7a is parallel to the longitudinal extension of the fluid flow channels 11. The inlet mouth 7a may be aligned with a lateral end 1c of the sheet 1. The fluid inlet 7 extends from the lateral end 1c to the other lateral end of the sheet 1d. The fluid inlet 7 is tapering from the lateral end 1c aligned with the inlet mouth 7a to the other lateral end 1d towards channel inlet mouths 1a of the fluid flow channels 11.

[0042] The fluid outlet 9 has an outlet mouth 9a for dispensing fluid which has flowed through the fluid flow channels 11. The fluid outlet 9 has a distal end 9b relative to channel outlet mouths 1b. The outlet mouth 9a is parallel to the longitudinal extension of the fluid flow channels 11. The outlet mouth 7a may be aligned with a lateral end 1d of the sheet 1. The fluid outlet 9 extends from said lateral end to the other lateral end 1c of the sheet 1, wherein the fluid outlet 9 is tapering from the lateral end 1d aligned with the outlet mouth 9a to the other lateral end 1c towards channel outlet mouths 1b of the fluid flow channels 11.

[0043] In general, the fluid inlet should have an extension so as to be able to guide fluid into all fluid flow channels 11 of a pair of adjoined sheets 1, and the fluid outlet part should have an extension to be able to guide fluid out from all the fluid flow channels 11 of a pair of adjoined sheets 1. The fluid inlets and fluid outlets must thus not necessarily have to extend along the entire distance between the lateral edges of a sheet. It is sufficient that their extension in this direction is such that each fluid inlet extends along the channel inlet mouths and that each the fluid outlet extends along the channel outlet mouths of all fluid flow channels 11 in a layer of fluid flow channels.

[0044] The height dimension of the fluid inlet 7 and the fluid outlet 9 is preferably less than the height dimension of the fluid flow channels 11. The height dimension of the fluid inlet and the fluid outlet may for example be half the height dimension of the fluid flow channels. Other variations of this ratio are of course also possible. A ratio where the fluid inlet and fluid outlet have smaller height dimension than the fluid flow channels facilitates the flow distribution in different directions, i.e. it facilitates counter-current flow in a device comprising a plurality of stacked sheet. In particular, different height dimension ratios provide different pressure drops in the two flow directions.

[0045] According to the example in Fig. 3a, the inlet mouth 7a and the outlet mouth 7b are diagonally arranged. The inlet mouth 7a and the outlet mouth 9a are thus arranged in opposite directions. Another example of arrangement of the fluid inlet 7 and fluid outlet 9 relative to the sheet 1 is depicted in Fig. 3b. According to this variation, the inlet mouth 7a and the outlet mouth 9a are facing the same direction. The particular orientation of the inlet mouth relative to the outlet mouth normally depends on the application and the particular device for exchange of heat or mass transfer that is to be assembled from the sheets.

[0046] Fig. 4 depicts a cross-section of a device 13 for exchange of heat and/or mass transfer. The device comprises a plurality of stacked sheets 1, arranged as described hereabove. According to the example, all sheets 1 are stacked with the same orientation, i.e. the two peaks of all corrugated open channels of all sheets face the same direction. The device 13 may further comprise a structure such as a mount or a frame in which the plurality of stacked sheet may be arranged, not shown in Fig. 4. Their mutual positions may thereby be maintained in all directions.

[0047] The pairs of sheets 1 of the device 13 may comprise fluid inlets and fluid outlets as described above, such that fluid that is to be subjected to heat exchange and/or mass transfer can flow through the device 13. The device 13 may beneficially be used as a counter-current fluid flow exchange device. The device 13 may thus be arranged such that every other layer of fluid flow channels 11 of the device 13 may receive fluid flow in a first direction, and the fluid flow channels 11 of the remaining layers may receive fluid flow in a second direction opposite the first direction.

[0048] Fig. 5a depicts a portion of a cross-section of a plurality of stacked sheets that may be arranged in a device for heat exchange and/or mass transfer. Between each adjacent sheet 1 is a channel dividing sheet 14. The channel dividing sheet 14 has corrugated open channels 3" similar to those described above, and intermediate channels 5", which according to the example also have corrugations. All open channels 3", 5" of the channel dividing sheet 14 hence have corrugations. Each intermediate open channel 5" has two valley floors and a peak, and the corrugations are thus inverted relative to the two peaks and one valley floor configuration of the corrugated open channels 3". A channel dividing sheet 14 is adapted to be arranged between each pair of adjacent sheets 1. The channel dividing sheets 14 act as dividing elements of the fluid flow channels created between two adjacent sheets 1. As can be seen in Fig. 5a, each channel C1 defined by intermediate open channels 5 and 5" of a sheet 1 and a channel dividing sheet 14 is smaller in cross-sectional dimension compared to the cross-sectional dimension of the remaining channels C2 defined between an intermediate channel 5" of a channel dividing sheet 14 and a corrugated open channel 3 of a sheet 1. Moreover, each channel C1 is surrounded by channels C2 having greater cross-sectional dimension than channel C1.

[0049] Fig. 5b depicts a variation of the arrangement in Fig. 5b. In the variation in Fig. 5b, the arrangement comprises another type of channel dividing sheet than in Fig. 5a. Moreover, the channel dividing sheet 14 in Fig. 5b has an undulating profile with each open channel having equal height, instead of having an M-W profile as in Fig. 5a. Any combination of channel dividing sheets could however be used in a device for heat exchange and/or mass transfer, depending on the particular application and the desired fluid flow characteristics.

[0050] Channel dividing sheet 14' comprises planar sections 14'a and corrugated sections 14'b. A corrugated section 14'b is provided between each pair of planar section 14'a. The channel dividing sheet 14' is arranged to be sandwiched between two adjacent sheets 1. Each corrugated section 14'a is congruent with an intermediate open channel 5 and with a valley of a sheet 1. The width of each planar section 14'a is dimensioned such that each corrugated section 14'a can be arranged sandwiched between an intermediate open channel 5 of one sheet 1 and a valley of another sheet 1. The planar sections 14'a provide the channel dividing property of the channel dividing sheet 14', and each planar section 14'a is arranged to divide a fluid flow channel formed by two adjacent sheets 1, in particular between an intermediate open channel 5 and a corrugated open channel 3. The planar sections 14'a divide the fluid flow channels into channels C3 and C4. The cross-sectional dimension of channels C3 and C4 are determined by dimensioning the planar sections 14'a and the corrugated sections 14'b in a suitable manner depending on the particular application and desired specifications of the heat exchange and/or mass transfer. As an alternative to the arrangement shown in Fig. 5b a device for exchange of heat and/or mass transfer may for example comprise channel dividing sheets 14' only in combination with sheets 1.

[0051] According to one variation the channel dividing sheet may be a sheet blank or a deformable sheet. When the sheet blank or deformable sheet is arranged between two sheets 1, the sheet blank or deformable sheet is shaped by the two sheets. In particular, the sheet blank or deformable sheet, which initially may be essentially shapeless or it may not have an intentionally shaped design, can obtain a similar shape as for example channel dividing sheet 14', i.e. the material of the channel dividing sheet folds where an intermediate channel of a sheet 1 is arranged between two peaks of another sheet 1 with the channel dividing sheet being arranged therebetween. The sheet blank or deformable sheet may thus in production of a device for heat exchange and/or mass transfer be placed on top of a sheet 1, wherein another sheet 1 is placed on top of the sheet blank or deformable sheet such that the sheet blank or deformable sheet folds in those locations where an intermediate channel of one sheet are arranged between two peaks of the other sheet. The sheet blank or deformable sheet is thereby stretched or tightened to form planar sections between the folded or corrugated sections. A channel dividing sheet is thereby created.

[0052] An example of suitable material for a sheet blank or deformable sheet may be a membrane material, for example Gore-Tex® or a cellulose-based material.

[0053] The configurations illustrated in Figs 5a and 5b are advantageous in for example heat exchange systems utilising liquids as heat transfer medium for influencing the temperature of a gas. A liquid generally has a greater heat capacity than gas, and the amount of liquid may thus in general be smaller than the amount of gas to obtain a heat equilibrium condition between the two fluids. By means of the configurations shown in Fig. 5a and Fig. 5b, and any variation thereof, a more efficient heat exchanger may be obtained. A device comprising a configuration as shown in Figs 5a and 5b may thus utilise a greater amount of its fluid transfer capacity for the gas which is to have its temperature altered. Moreover, the size of the device utilising this arrangement may be reduced.

[0054] An example of an application for the arrangement shown in Fig. 5a is an oil cooling device, where the device comprising the configuration of sheets 1 and 14 may be adapted such that oil may flow through channels C1 and a gas may flow through channels C2.

[0055] With reference to Figs 6 and 7, a method of manufacturing a sheet such as sheet 1 will be described in more detail. In a step a) a sheet blank is provided. In a step b) the sheet blank is corrugated to form open channels 3, 5 such that every other channel has a cross-section with two channel end points, and two peaks and a valley floor between the two channel end points.

[0056] In Fig. 7 one example of a sheet blank 15 is shown. The sheet blank 15 comprises a plurality of fold lines 17 and 19. Fold lines 17 create the two peaks and the valley floor of a corrugated open channel 3 when the fold lines 17 have been folded. Fold lines 19 create intermediate channels 5 when the fold lines 19 have been folded. Step b) of corrugating may for this variation thus involve folding the sheet blank 15 along the fold lines 17 and 19. The fold lines 17 and 19 may for example be created by creasing.

[0057] As an alternative to providing fold lines to create a sheet blank, the step of corrugating may be performed by for example thermoforming or any other method of corrugating a sheet blank. Another alternative is to extrude the shape of a corrugated sheet directly, or to extrude the entire device comprising a plurality of sheets.

[0058] In a further optional step, a plurality of sheets may be stacked in a staggered manner. The distal ends of each pair of adjacent fluid inlet and fluid outlet may be attached to each other to thereby form distal end walls for both the fluid inlet and fluid outlet to thereby create fluid flow guides. In case the fluid inlet and fluid outlet are integrated with the sheet blank, the fluid inlet and the fluid outlet may be corrugated in step b). Typically, the corrugations of the fluid inlet and fluid outlet differ from that of the open channels 3 and 5. The cross-sectional shape of the fluid inlet and fluid outlet thus normally differs from that of the open channels 3 and 5.

[0059] The sheet 1 and its variations presented herein may be rigid or flexible. According to one variation, the sheet is flexible along the corrugation lines, e.g. fold lines in case the corrugations have been folded during manufacturing. Device 13 may thereby be flexible in the sense that it may be deformed when a pressure is applied from any side along its periphery. This is beneficial in that the volume of the device may be reduced during transportation. The device may thus be deformed for transportation, and thereafter receive its original shape for installation.

[0060] As previously noted, the sheet, including the channel dividing sheet, may be made of impermeable, permeable, or semi-permeable material. The device may be formed of sheets all having the same properties. All sheets may thus be impermeable, permeable or semi-permeable. Alternatively, the device may comprise a combination of sheets with different permeability properties. For example a subset of sheets may be permeable and another subset of sheets may be impermeable. Every other sheet may for example be permeable and the remaining sheets may be impermeable.

[0061] The sheets, including the channel dividing sheets, may for example be made of metal, for example stainless steel, aluminium, copper or any other metal suitable for heat transfer, plastic such as PE, PP, PET, PS, PPS, Polycarbonate, nylon, semi-permeable membranes, for example PEMs like Nafion, or any other suitable material for heat exchange or mass transfer applications, for example carbon foam and porous sheets. It is also envisaged that the sheet may comprise a mixture of different materials.

[0062] The inventive concept has mainly been described above with reference to a few examples. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the inventive concept, as defined by the appended claims.

Claims

1. A sheet (1; 1’) for exchange of heat and/or mass transfer between fluid flows, which sheet (1; 1’) is provided with corrugations defining open channels (3, 5), wherein a cross-section of every other open channel (3) has two channel end points (3a, 3b), and two peaks (3c, 3d) and a valley floor (3e) between the two channel end points (3a, 3b).

2. The sheet (1; 1’) as claimed in claim 1, wherein the two peaks (3c, 3d) are located at a first distance (d1) from a straight line (L) extending between the channel end points (3a, 3b) and the valley floor (3e) is located at a second distance (d2) from the straight line (L).

3. The sheet (1; 1’) as claimed in claim 1 or 2, wherein the valley floor (3e) is arranged between the two peaks (3c, 3d).

4. The sheet (1; 1’) as claimed in any of the preceding claims, wherein the cross-sectional shape of that section (3g, 3i) which connects the two peaks (3a, 3b) is congruent with the cross-sectional shape of

any of the open channels (5) which are arranged between said every other open channel (3).

5. The sheet (1; 1') as claimed in any of the preceding claims, wherein the entire section (3f) connecting a first of the channel end points (3a) with a first of the peaks (3c) is parallel with the entire section (3h) connecting the valley floor (3e) with a second of the peaks (3d).

6. The sheet (1; 1') as claimed in any of the preceding claims, wherein the entire section (3g) connecting a second of the channel end points (3b) and the second of the peaks (3d) is parallel with the entire section (3i) connecting the valley floor (3e) with the first of the peaks (3c).

7. The sheet (1; 1') as claimed in any of the preceding claims, wherein each of said every other channel (3) has an essentially M-shaped cross-section.

8. The sheet (1; 1') as claimed in any of the preceding claims, wherein the sheet (1; 1') is a heat exchanger sheet.

9. A device (13) for exchange of heat and/or mass transfer between fluid flows, comprising a plurality of sheets (1; 1') as claimed in any of claims 1-11, which plurality of sheets (1; 1') are stacked such that the open channels (3) of each pair of adjacent sheets (1; 1') define fluid flow channels (11).

10. The device (13) as claimed in claim 9, wherein the channel end points (3a, 3b) of a sheet (1; 1') engage a respective valley floor (3e) of an adjacent sheet (1; 1').

11. The device (13) as claimed in claim 9 or 10, comprising fluid inlets (7) and fluid outlets (9), wherein each fluid inlet (7) is arranged to direct fluid into fluid flow channels (11) of two adjacent sheets (1) and each fluid outlet (9) is arranged to direct fluid out from fluid flow channels (11) of two adjacent sheets (1), wherein each fluid inlet (7) and fluid outlet (9) has a tapering shape.

12. The device (13) as claimed in claim 11, wherein each fluid inlet (7) has an inlet mouth (7a) parallel to the longitudinal extension of the fluid flow channels (11), wherein each inlet mouth (7a) is arranged in level with a lateral end of a sheet (1; 1'), wherein each fluid inlet (7) extends from said lateral end towards the other lateral end of the sheet (1; 1'), and wherein each fluid inlet (7) is tapering from the said lateral end to the other lateral end towards channel inlet mouths (1a) of fluid flow channels (11).

13. The device (13) as claimed in claim 11 or 12, wherein each fluid outlet (9) has an outlet mouth (9a) parallel to the longitudinal extension of the fluid flow channels (11), wherein each outlet mouth (9a) is arranged in level with a lateral end of a sheet (1; 1'), wherein each fluid outlet (9) extends from said lateral end towards the other lateral end of the sheet (1; 1'), and wherein each fluid outlet (9) is tapering from said lateral end to the other lateral end towards channel outlet mouths (1b) of the fluid flow channels (11).

14. A method of manufacturing a sheet (1; 1') for exchange of heat and/or mass transfer between fluid flows, wherein the method comprises:

a) providing a sheet blank (15),
b) corrugating the sheet blank (15) to form open channels (3, 5) such that every other channel (3) has a cross-section with two channel end points(3a, 3b), and two peaks (3c, 3d) and a valley floor (3e) between the two channel end points (3a, 3b).

15. The method as claimed in claim 14, wherein step a) of corrugating is performed by 1) thermoforming or 2) by folding along fold lines (17,19).

Amended claims in accordance with Rule 137(2) EPC.

1. A sheet (1; 1') for exchange of heat and/or mass transfer between fluid flows, which sheet (1; 1') is provided with corrugations defining open channels (3, 5), wherein every other open channel (3) is a corrugated open channel (3), wherein a cross-section of every corrugated open channel (3) has two channel end points (3a, 3b), and two peaks (3c, 3d) and a valley floor (3e) between the two channel end points (3a, 3b),
wherein the two channel end points (3a, 3b) of a corrugated open channel (3) define the mouth of that corrugated open channel (3), wherein the remaining open channels that are intermediate each pair of corrugated open channel (3) are intermediate open channels (5), wherein corrugated open channels (3) and intermediate open channels (5) have mouths in opposite directions.

2. The sheet (1; 1') as claimed in claim 1, wherein the two peaks (3c, 3d) are located at a first distance (d1) from a straight line (L) extending between the channel end points (3a, 3b) and the valley floor (3e) is located at a second distance (d2) from the straight line (L).

3. The sheet (1; 1') as claimed in claim 1 or 2, wherein the valley floor (3e) is arranged between the two peaks (3c, 3d).

4. The sheet (1; 1') as claimed in any of the preceding claims, wherein the cross-sectional shape of that section (3g, 3i) which connects the two peaks (3a, 3b) is congruent with the cross-sectional shape of any of the open channels (5) which are arranged between said every other open channel (3).

5. The sheet (1; 1') as claimed in any of the preceding claims, wherein the entire section (3f) connecting a first of the channel end points (3a) with a first of the peaks (3c) is parallel with the entire section (3h) connecting the valley floor (3e) with a second of the peaks (3d).

6. The sheet (1; 1') as claimed in any of the preceding claims, wherein the entire section (3g) connecting a second of the channel end points (3b) and the second of the peaks (3d) is parallel with the entire section (3i) connecting the valley floor (3e) with the first of the peaks (3c).

7. The sheet (1; 1') as claimed in any of the preceding claims, wherein each of said every other channel (3) has an essentially M-shaped cross-section.

8. The sheet (1; 1') as claimed in any of the preceding claims, wherein the sheet (1; 1') is a heat exchanger sheet.

9. A device (13) for exchange of heat and/or mass transfer between fluid flows, comprising a plurality of sheets (1; 1') as claimed in any of claims 1-11, which plurality of sheets (1; 1') are stacked such that the open channels (3) of each pair of adjacent sheets (1; 1') define fluid flow channels (11).

10. The device (13) as claimed in claim 9, wherein the channel end points (3a, 3b) of a sheet (1; 1') engage a respective valley floor (3e) of an adjacent sheet (1; i').

11. The device (13) as claimed in claim 9 or 10, comprising fluid inlets (7) and fluid outlets (9), wherein each fluid inlet (7) is arranged to direct fluid into fluid flow channels (11) of two adjacent sheets (1) and each fluid outlet (9) is arranged to direct fluid out from fluid flow channels (11) of two adjacent sheets (1), wherein each fluid inlet (7) and fluid outlet (9) has a tapering shape.

12. The device (13) as claimed in claim 11, wherein each fluid inlet (7) has an inlet mouth (7a) parallel to the longitudinal extension of the fluid flow channels (11), wherein each inlet mouth (7a) is arranged in level with a lateral end of a sheet (1; 1'), wherein each fluid inlet (7) extends from said lateral end towards the other lateral end of the sheet (1; 1'), and wherein each fluid inlet (7) is tapering from the said lateral end to the other lateral end towards channel inlet mouths (1a) of fluid flow channels (11).

13. The device (13) as claimed in claim 11 or 12, wherein each fluid outlet (9) has an outlet mouth (9a) parallel to the longitudinal extension of the fluid flow channels (11), wherein each outlet mouth (9a) is arranged in level with a lateral end of a sheet (1; 1'), wherein each fluid outlet (9) extends from said lateral end towards the other lateral end of the sheet (1; 1'), and wherein each fluid outlet (9) is tapering from said lateral end to the other lateral end towards channel outlet mouths (1b) of the fluid flow channels (11).

14. A method of manufacturing a sheet (1; 1') for exchange of heat and/or mass transfer between fluid flows, wherein the method comprises:

   a) providing a sheet blank (15),
   b) corrugating the sheet blank (15) to form open channels (3, 5) such that every other channel (3) has a cross-section with two channel end points (3a, 3b), and two peaks (3c, 3d) and a valley floor (3e) between the two channel end points (3a, 3b),

   wherein the two channel end points (3a, 3b) of a corrugated open channel (3) define the mouth of that corrugated open channel (3), wherein the remaining open channels that are intermediate each pair of corrugated open channel (3) are intermediate open channels (5), wherein corrugated open channels (3) and intermediate open channels (5) have mouths in opposite directions.

15. The method as claimed in claim 14, wherein step a) of corrugating is performed by 1) thermoforming or 2) by folding along fold lines (17, 19).

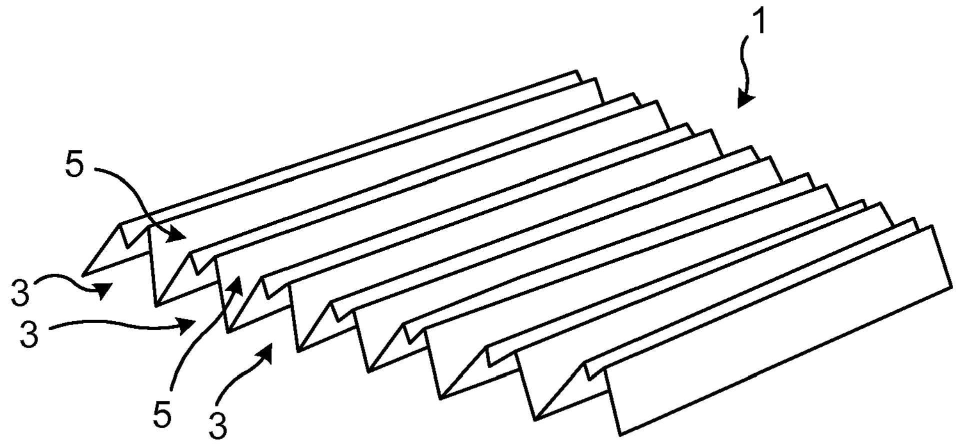

Fig. 1a

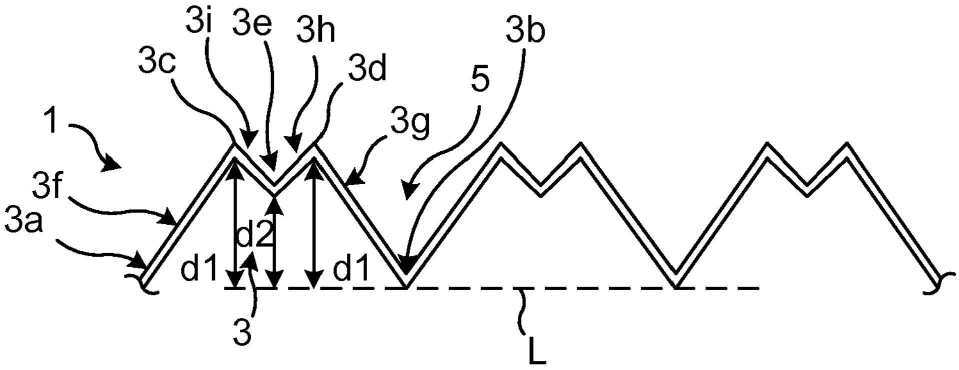

Fig. 1b

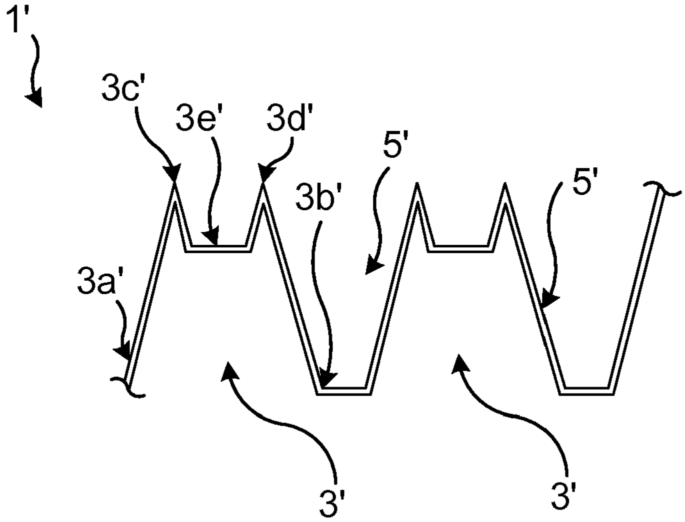

Fig. 1c

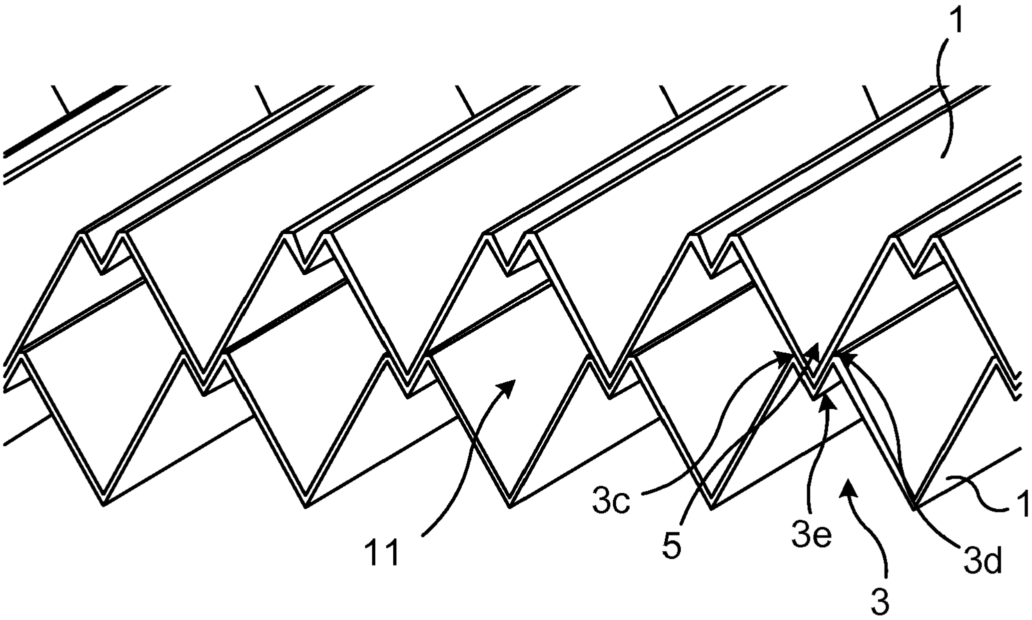

Fig. 2

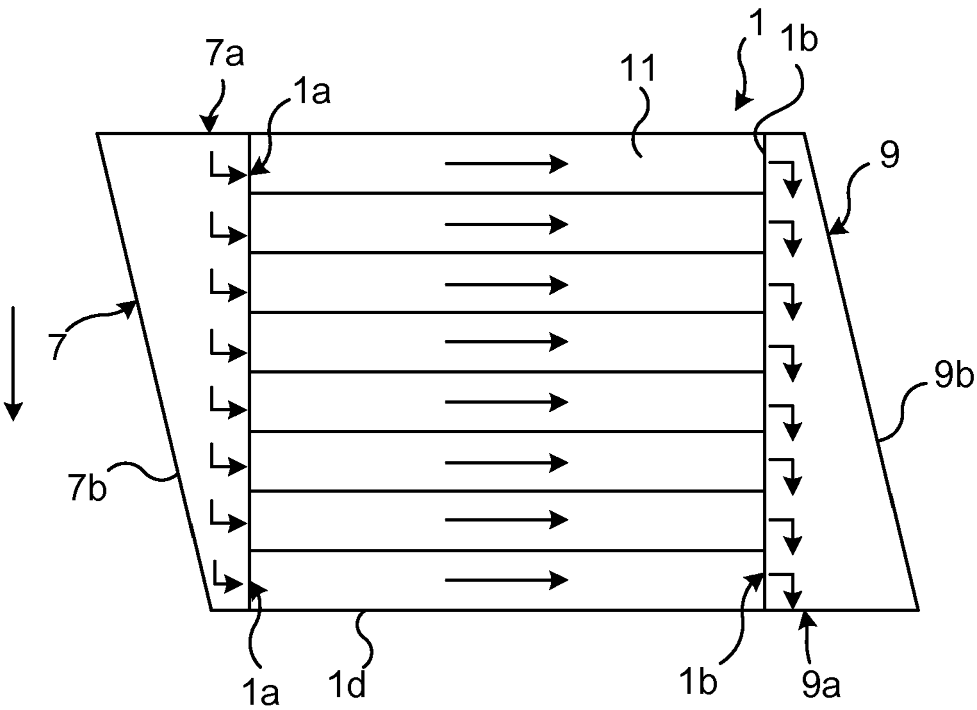

Fig. 3a

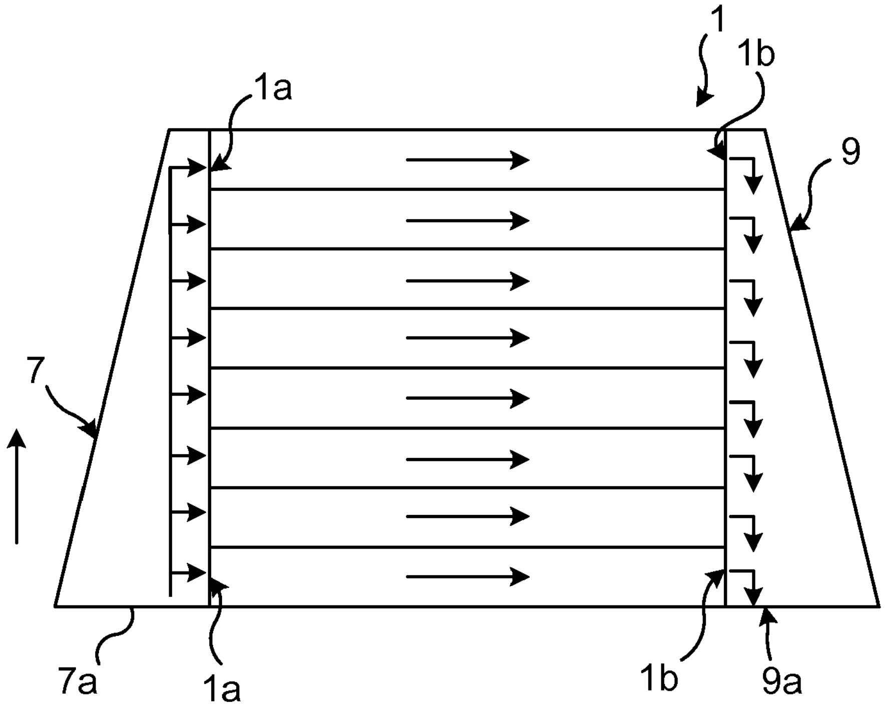

Fig. 3b

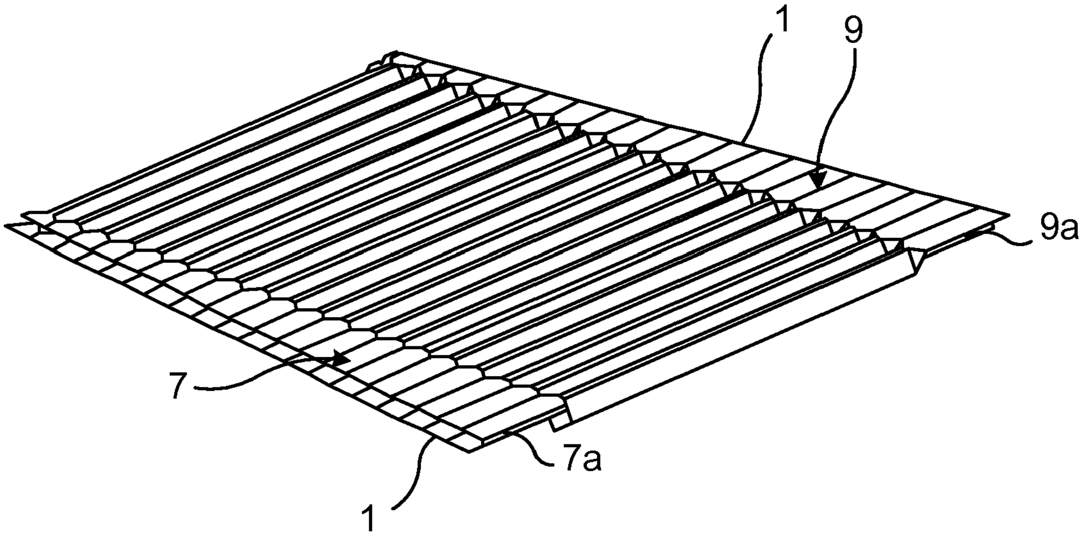

Fig. 3c

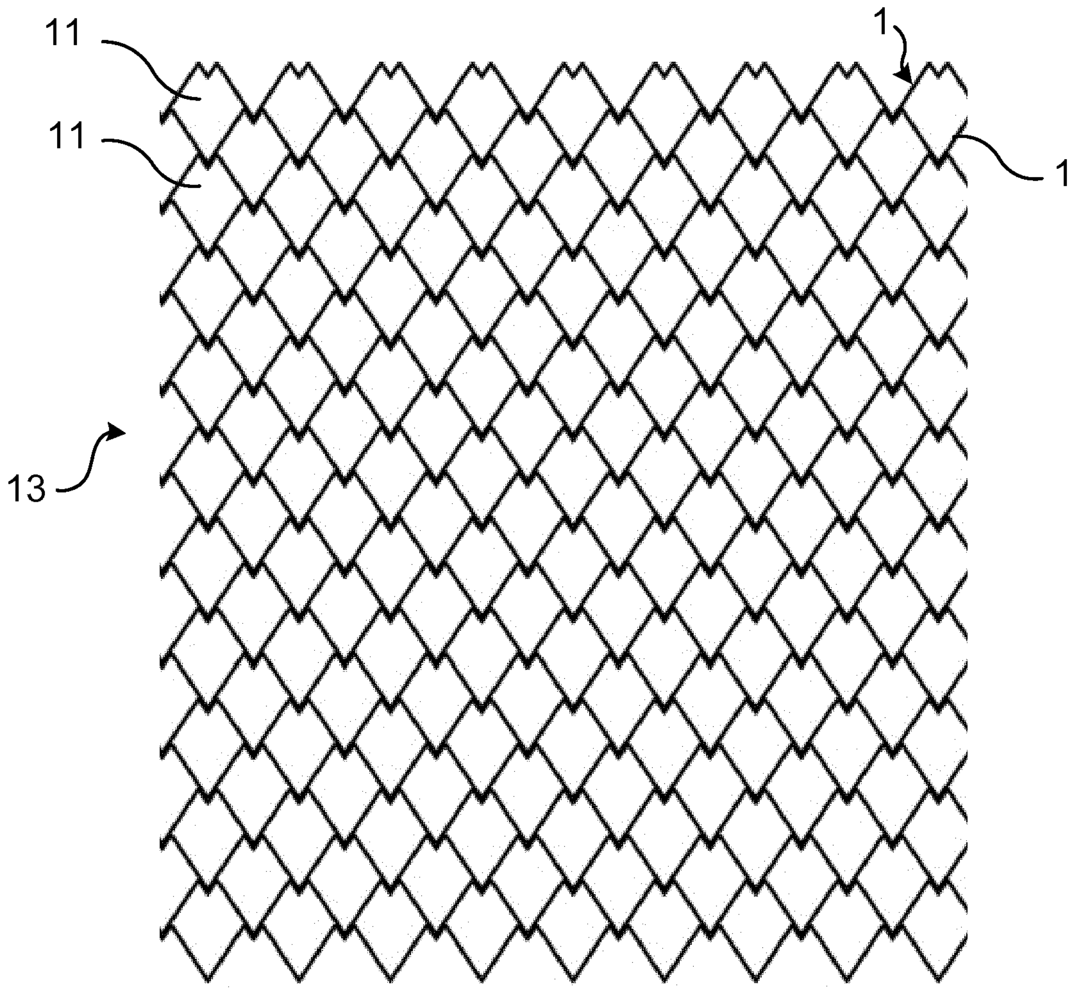

Fig. 4

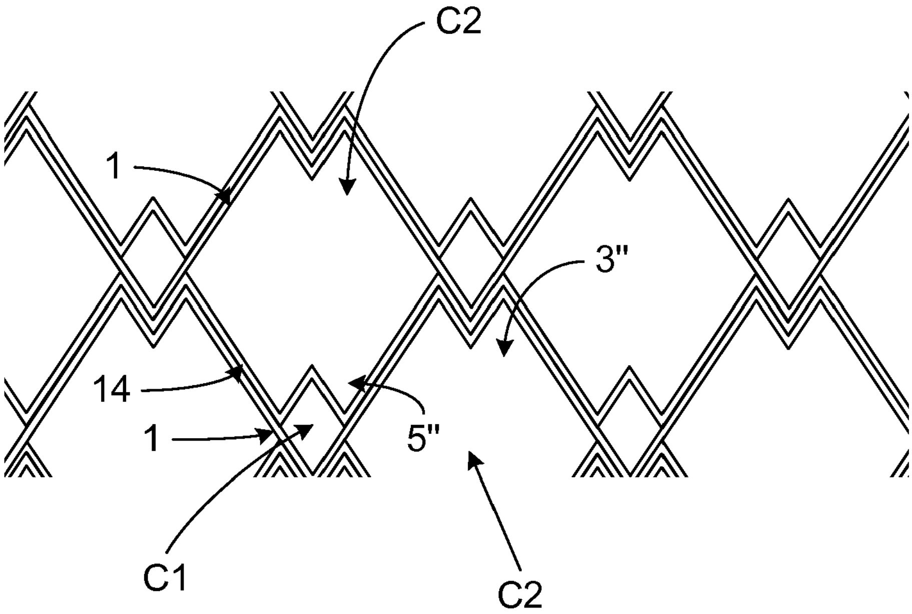

Fig. 5a

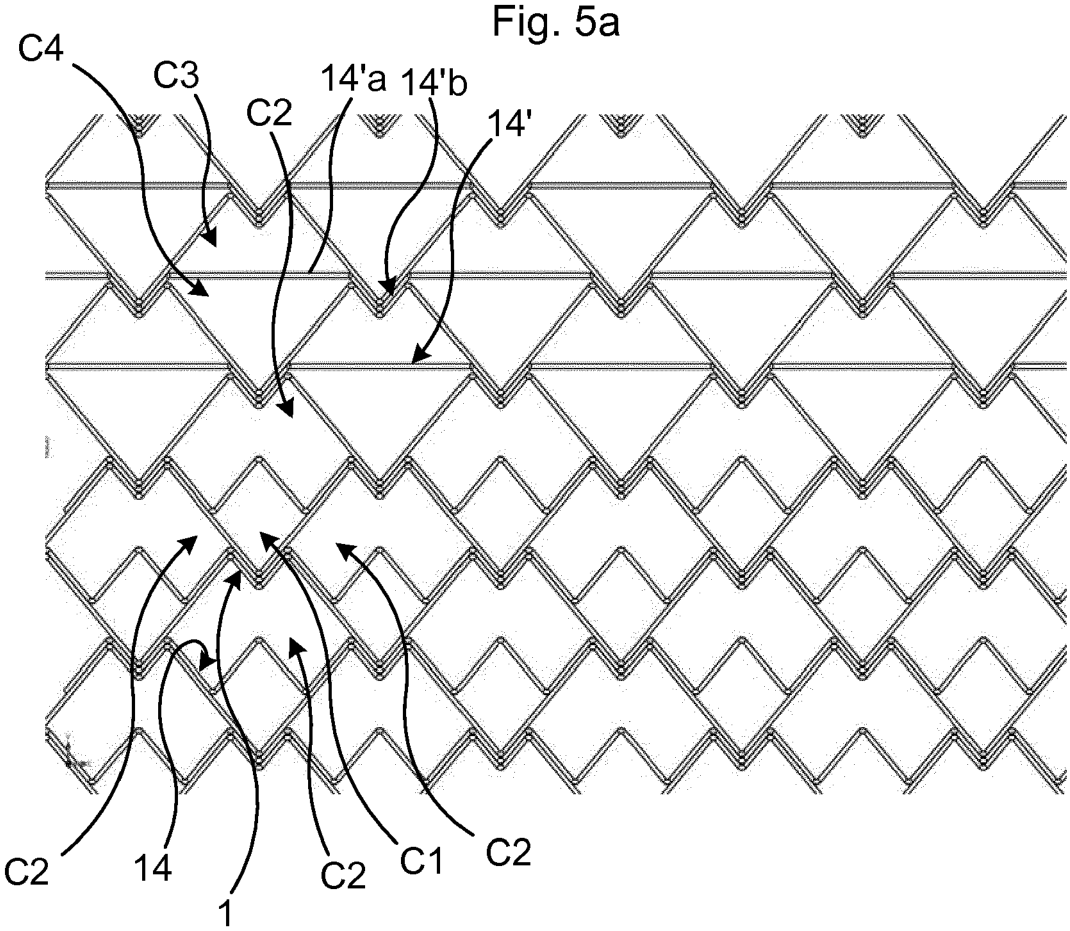

Fig. 5b

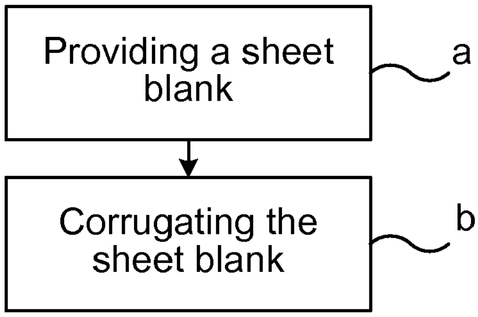
Providing a sheet blank
a
Corrugating the sheet blank
b

Fig. 6

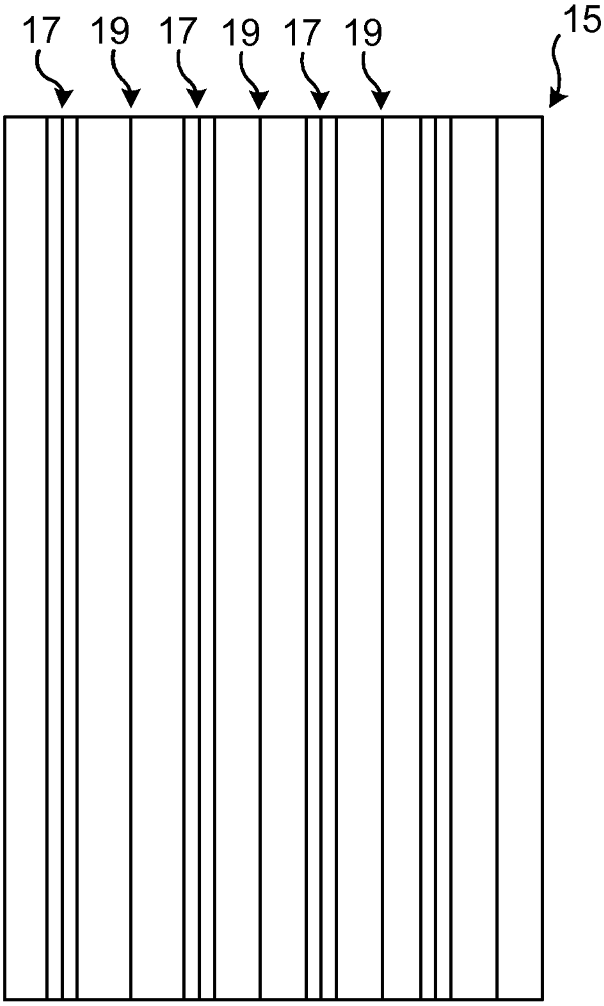
17
19
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Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 13 19 1909

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Y	WO 2013/091099 A1 (DPOINT TECHNOLOGIES INC [CA]) 27 June 2013 (2013-06-27) * paragraph [0069]; figures 7a,7b * -----	11	
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			F28F F28D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	3 April 2014	Delval, Stéphane

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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