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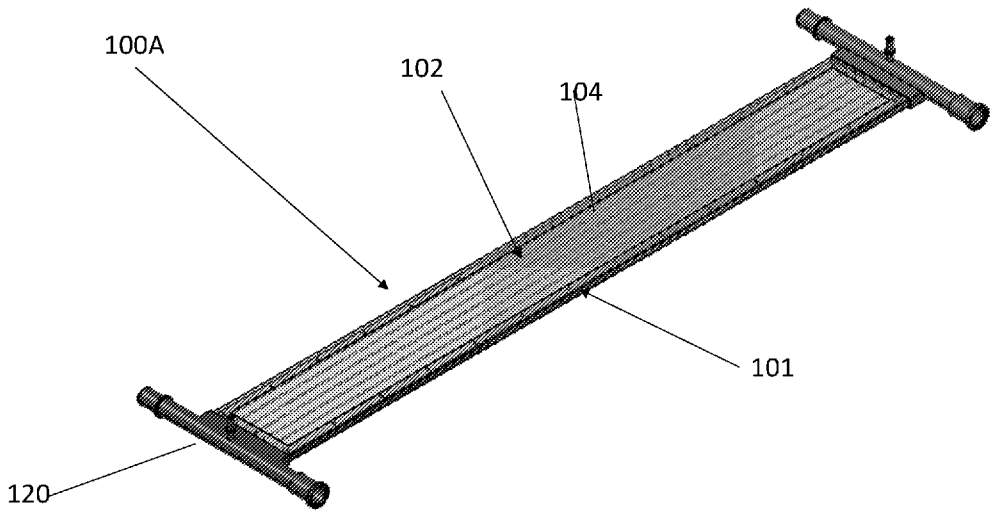


FIG. 1

(57) Abstract: The present disclosure provides a battery cooling assembly. The battery cooling assembly includes a metallic platform comprising opposed first and second major surfaces. The battery cooling assembly further includes a thermoplastic resin platform including opposed third and fourth major surfaces. At least a portion of the second major surface of the metallic platform is contacting at least a portion of the third major surface of the thermoplastic resin platform.

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HYBRID COOLING PLATE FOR MODULAR ARRAY

CROSS REFERNCE TO RELATED APPLICATIONS

[0001] This application claims priority to CN Application No. 202011251140.8 filed on November 10, 2020, which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] Electric vehicles require batteries to provide power to motors which propel them. Batteries produce heat during operation. If the batteries are disposed in an environment where the heat is allowed to build, the increased temperature can negatively impact the battery's performance.

SUMMARY OF THE INVENTION

[0003] The present disclosure provides a battery cooling assembly. The battery cooling assembly includes a metallic platform comprising opposed first and second major surfaces. The battery cooling assembly further includes a thermoplastic resin platform including opposed third and fourth major surfaces. At least a portion of the second major surface of the metallic platform is contacting at least a portion of the third major surface of the thermoplastic resin platform.

[0004] The present disclosure further provides a battery cooling assembly. The battery cooling assembly includes a metallic platform including aluminum and extending between opposed first and second major surfaces. The battery cooling assembly further includes a thermoplastic resin platform comprising a polyamide such as PA6, PA66, PA66/6T copolymer, PA612, or any combination thereof, and extending between opposed third and fourth major surfaces. At least a portion of the second major surface of the metallic platform is contacting at least a portion of the third major surface of the thermoplastic resin platform. The third major surface of the thermoplastic resin platform, the fourth major surface of the thermoplastic resin platform, or both, include a projection extending in a direction substantially perpendicular to the third major surface. The battery cooling assembly further

includes a channel formed between the second major surface of the metallic platform and the third major surface of the thermoplastic resin platform.

[0005] The present disclosure further provides a method of making a battery cooling assembly. The battery cooling assembly includes a metallic platform comprising opposed first and second major surfaces. The battery cooling assembly further includes a thermoplastic resin platform including opposed third and fourth major surfaces. At least a portion of the second major surface of the metallic platform is contacting at least a portion of the third major surface of the thermoplastic resin platform. The method includes contacting the metallic platform and the thermoplastic resin platform.

[0006] The present disclosure further provides an electric vehicle. The electric vehicle includes a battery cooling assembly. The battery cooling assembly includes a metallic platform comprising opposed first and second major surfaces. The battery cooling assembly further includes a thermoplastic resin platform including opposed third and fourth major surfaces. At least a portion of the second major surface of the metallic platform is contacting at least a portion of the third major surface of the thermoplastic resin platform.

[0007] There are many reasons to use the battery cooling assembly of the present disclosure including the following non-limiting reasons. For example, according to various examples, the battery cooling assembly is able to efficiently and effectively conduct heat from a battery cell so that the battery cell can be operated under optimal temperatures. According to various embodiments, operating the battery cell at optimal temperatures can improve the efficiency of the battery cell and therefore improve the performance of the electric vehicle which the battery cells operate. Additionally, according to various examples, the battery cooling assemblies provide sufficient strength to be used in an electric vehicle, while being lightweight enough to avoid negatively impacting the performance of the electric vehicle. This is in contrast to other battery cooling assemblies that use a tubular design with a foam component to decrease weight because the foam decreases the mechanical strength of the battery cooling assembly.

BRIEF DESCRIPTION OF THE FIGURES

[0008] The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments of the present inventive subject matter.

[0009] FIG. 1 is a perspective view of a battery cooling assembly, in accordance with various examples of the present disclosure.

[0010] FIG. 2 is an exploded view of the battery cooling assembly of FIG. 1, in accordance with various examples of the present disclosure.

[0011] FIG. 3 is a sectional end view of the battery cooling assembly of FIGs. 1 and 2, in accordance with various examples of the present disclosure.

[0012] FIG. 4 is a perspective view of another battery cooling assembly, in accordance with various examples of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Reference will now be made in detail to certain embodiments of the disclosed subject matter, examples of which are illustrated in part in the accompanying drawings. While the disclosed subject matter will be described in conjunction with the enumerated claims, it will be understood that the exemplified subject matter is not intended to limit the claims to the disclosed subject matter.

[0014] Throughout this document, values expressed in a range format should be interpreted in a flexible manner to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. For example, a range of "about 0.1% to about 5%" or "about 0.1% to 5%" should be interpreted to include not just about 0.1% to about 5%, but also the individual values (e.g., 1%, 2%, 3%, and 4%) and the sub-ranges (e.g., 0.1% to 0.5%, 1.1% to 2.2%, 3.3% to 4.4%) within the indicated range. The statement "about X to Y" has the same meaning as "about X to about Y," unless indicated otherwise. Likewise, the statement "about X, Y, or about

Z" has the same meaning as "about X, about Y, or about Z," unless indicated otherwise.

[0015] In this document, the terms "a," "an," or "the" are used to include one or more than one unless the context clearly dictates otherwise. The term "or" is used to refer to a nonexclusive "or" unless otherwise indicated. The statement "at least one of A and B" has the same meaning as "A, B, or A and B." In addition, it is to be understood that the phraseology or terminology employed herein, and not otherwise defined, is for the purpose of description only and not of limitation. Any use of section headings is intended to aid reading of the document and is not to be interpreted as limiting; information that is relevant to a section heading may occur within or outside of that particular section.

[0016] In the methods described herein, the acts can be carried out in any order without departing from the principles of the disclosure, except when a temporal or operational sequence is explicitly recited. Furthermore, specified acts can be carried out concurrently unless explicit claim language recites that they be carried out separately. For example, a claimed act of doing X and a claimed act of doing Y can be conducted simultaneously within a single operation, and the resulting process will fall within the literal scope of the claimed process.

[0017] The term "about" as used herein can allow for a degree of variability in a value or range, for example, within 10%, within 5%, or within 1% of a stated value or of a stated limit of a range, and includes the exact stated value or range.

[0018] The term "substantially" as used herein refers to a majority of, or mostly, as in at least about 50%, 60%, 70%, 80%, 90%, 95%, 96%, 97%, 98%, 99%, 99.5%, 99.9%, 99.99%, or at least about 99.999% or more, or 100%.

[0019] The term "polyamide" as used herein refers to a polymer having repeating units linked by amide bonds. Polyamides may arise from monomers comprising aliphatic, semi-aromatic or aromatic groups. Polyamides include nylons, e.g., nylon-6,6 or nylon-6, and may refer to polyamides arising from a single monomer, two different monomers, or three or more different monomers. The term polyamide thus includes dimonomeric polyamides. The polyamide may be a nylon

having as monomer units a dicarboxylic acid monomer unit and a diamine monomer unit. For example, if the dicarboxylic acid monomer unit is adipic acid and the diamine is hexamethylene diamine, the resulting polyamide can be nylon-6,6. Nylon-6 is a polyamide having a caprolactam monomer. The polyamide may be a copolymer which may be prepared from aqueous solutions or blends of aqueous solutions that contain more than two monomers. In various embodiments, polyamides can be manufactured by polymerization of dicarboxylic acid monomers and diamine monomers. In some cases, polyamides can be produced via polymerization of aminocarboxylic acids, aminonitriles, or lactams. Suitable polyamides include, but are not limited to, those polymerized from the monomer units described herein. The term "polyamide" includes polyamides such as PA6, PA66, PA11, PA12, PA612, Nylon-66/6T. However, this term can be modified, when done so expressly, to exclude particular polyamides. For example, in some embodiments, the polyamide can be a polyamide other than PA11, PA12, and PA612; or the polyamide can be a polyamide other than nylon-66/6T.

[0020] The term "N6," "nylon-6," or "PA6" as used herein, refers to a polymer synthesized by polycondensation of caprolactam. The polymer is also known as polyamide 6, nylon-6, and poly(caprolactam).

[0021] The term "N66," "nylon-6,6," or "PA66," as used herein, refers to a polymer synthesized by polycondensation of hexamethylenediamine (HMD) and adipic acid. The polymer is also known as Polyamide 66, nylon-66, nylon-6-6, and nylon-6/6.

[0022] The polymers described herein can terminate in any suitable way. In some embodiments, the polymers can terminate with an end group that is independently chosen from a suitable polymerization initiator, -H, -OH, a substituted or unsubstituted (C_1-C_{20})hydrocarbyl (e.g., (C_1-C_{10})alkyl or (C_6-C_{20})aryl) interrupted with 0, 1, 2, or 3 groups independently selected from -O-, substituted or unsubstituted -NH-, and -S-, a poly(substituted or unsubstituted (C_1-C_{20})hydrocarbyloxy), and a poly(substituted or unsubstituted (C_1-C_{20})hydrocarbylamino).

[0023] The present disclosure is directed towards an assembly used for cooling a battery cell including one or more batteries or battery systems. The assembly can be a component of an electric vehicle. The electric vehicle, for example, can be an automobile, an airplane, a two- or three-wheeler or a watercraft. FIGs. 1-4 show various views of battery cooling assembly 100A. FIGs. 1-4 show many of the same features and are discussed concurrently. FIG. 1 is a perspective view of battery cooling assembly 100A. FIG. 2 is an exploded view of battery cooling assembly 100A. FIG. 3 is a sectional end view of battery cooling assembly 100A. As shown in FIGs. 1-3, battery cooling assembly 100A includes hybrid structure 101 including metallic platform 102 and thermoplastic resin platform 108. Metallic platform 102 includes first major surface 104 and opposed second major surface 106. Battery cooling assembly 100A further includes thermoplastic resin platform 108. Thermoplastic resin platform 108 extends between third major surface 110 and fourth major surface 112 (FIG. 2). Thermoplastic resin platform 108 further includes a series of projections 114 extending from third major surface 110. Projections 114 form a series of channels 116 (FIG. 3) between second major surface 106 and third major surface 110. Battery cooling assembly 100A further includes end caps 120 (FIG. 4), which are joined to the ends of metallic platform 102 and thermoplastic resin platform 108.

[0024] As shown in FIGs. 1-4, metallic platform 102 has a substantially planar profile. However, in some examples, metallic platform 102 can have a non-planar profile. For example, metallic platform 102 can have a curved or faceted profile. Metallic platform 102 includes a metal. The metal can be any elemental metal or alloy that is capable of conducting a sufficient amount of heat. An example of such a metal is aluminum. Metallic platform 102 can include elemental aluminum, an alloy of aluminum, or a combination thereof. The metal used in metallic platform 102 can range from about 90 wt% to about 100 wt% of metallic platform 102, about 95 wt% to about 100 wt%, less than, equal to, or greater than about 90 wt%, 91, 92, 93, 94, 95, 96, 97, 98, 99, or about 100 wt% of metallic platform 102.

[0025] In one embodiment and as schematically shown in FIG. 2, Metallic platform 102 can be composed of a central metallic region 104 and a boundary plastic frame 155. The boundary plastic frame 155 may have extended structure joints 135A and 135B at either end to facilitate connections to end caps 120. The boundary plastic frame 155 may have a plurality of holes 125 at the periphery of metallic region 104. These holes 125 may offer better connection to the boundary plastic frame 155 by over-molding or equivalent joining process.

[0026] Metallic platform 102 is joined to thermoplastic resin platform 108 to form hybrid structure 101. Specifically, at least a portion of second major surface 106 is joined to at least a portion of third major surface 110. Platforms 102 and 108 can be joined by a welding procedure, an adhesive, or through thermoplastic resin platform 108 being directly extruded to metallic platform 102. In examples where an adhesive is used, the adhesive can include a pressure-sensitive adhesive. Specific examples of adhesives can include an epoxy-based adhesive or a liquid silicone adhesive.

[0027] In some examples, a weld between metallic platform 102 and thermoplastic resin platform 108 can be strengthened by coating at least a portion of the second surface 106 or metallic platform 102 with a thermoplastic resin. This is because thermoplastic resin platform 108 includes a thermoplastic resin and a weld between like materials tends to be strongest. In some examples, the entirety of the second surface 106 can be coated with the thermoplastic resin. However, in further examples, only the portion of the second surface 106 that contacts the third surface 110 of thermoplastic resin platform 108 is coated with the thermoplastic resin. This can help to facilitate welding because similar materials tend to weld together better than dissimilar materials. In some examples the thermoplastic resin can be joined to the second surface 106 using a tie layer. The thermoplastic resin coated to the second major surface 106 or a portion thereof can include a polyamide, such as PA6, PA66, PA66/6T copolymer, PA612, or any combination thereof.

[0028] As described herein, thermoplastic resin platform 108 is joined to metallic platform 102. Specifically, second major surface 106 of metallic platform

102 is joined to third major surface 110 of thermoplastic resin platform 108. As shown, thermoplastic resin platform 108 has a generally planar profile that is generally commensurate with that of metallic platform 102. In some examples, however, thermoplastic resin platform 108 can have a non-planar profile. For example, thermoplastic resin platform 108 can be curved or faceted. Even though thermoplastic resin platform 108 is shown as being generally planar, third major surface 110 includes a plurality of projections 114, which are discussed further herein.

[0029] Thermoplastic resin platform 108 is formed at least in part by a polyamide component. The polyamide component can be present in a range of from about 50 wt% to about 100 wt% of thermoplastic resin platform 108, about 70 wt% to about 95 wt%, less than, equal to, or greater than about 50 wt%, 55, 60, 65, 70, 75, 80, 85, 90, 95, or about 100 wt%. The polyamide of the polyamide component can include any suitable polyamide. Examples of suitable polyamides include PA6, PA66, PA66/6T copolymer, PA612, or any combination thereof. In some examples the polyamide of the polyamide component can be the same as any polyamide that is coated to second major surface 106 of metallic platform 102.

[0030] In some examples, the polyamide component can include constituents in addition to the polyamide. For example, the polyamide component can include a reinforcing component. Suitable examples of reinforcing components include glass fibers. Glass fibers can be dispersed internally within polyamide platform 108 or adhered to third major surface 110, fourth major surface 112, or both. Where present, glass fibers can be randomly oriented. Alternatively, glass fibers can be arranged according to a predetermined pattern. For example, glass fibers can be oriented in a substantially longitudinal direction of thermoplastic resin platform 108. Alternatively, glass fibers can be oriented in a substantially transverse direction relative to the longitudinal direction. In still further examples, glass fibers can be arranged in a cross-hatch pattern with a portion of the total number of glass fibers oriented longitudinally and another portion of the total number of glass fibers oriented transversely, relative to the longitudinally direction of thermoplastic resin

platform 108. Where present, the reinforcing component can be present in a range of from about 5 wt% to about 50 wt% of the polyamide component, about 10 wt% to about 50 wt%, about 12 wt% to about 50 wt% of the polyamide component.

[0031] In some examples, the polyamide component can include an additive. For example, the polyamide component can include flame retardancy additives, anti-static additives, impact modifiers, color additives (e.g., pigments), heat stabilizer additives, and moisture repellency additives. Examples of suitable impact modifying additives can include a maleated polyolefin. Examples of suitable maleated polyolefins include maleated polyolefins available under the trade designation AMPLIFY™ GR, which are commercially available from Dow Chemical Co., Midland MI, USA (examples include Amplify™ GR 202, Amplify™ GR 208, Amplify™ GR 216, and Amplify™ GR380), maleated polyolefins available under the trade designation EXXELOR™ available from ExxonMobil, Irving TX, USA (examples include Exxelor™ VA 1803, Exxelor™ VA 1840, Exxelor™ VA1202, Exxelor™ PO 1020, and Exxelor™ PO 1015), maleated polyolefins available under the trade designation ENGAGE™ 8100 available from Dow Elastomer Midland MI, USA, and maleated polyolefins available under the trade designation BONDYRAM® 7103 available from Ram-On Industries LP.

[0032] Examples of suitable flame retardants include, for example, organophosphorous compounds such as organic phosphates (including trialkyl phosphates such as triethyl phosphate, tris(2-chloropropyl)phosphate, and triaryl phosphates such as triphenyl phosphate and diphenyl cresyl phosphate, resorcinol bis-diphenylphosphate, resorcinol diphosphate, and aryl phosphate), phosphites (including trialkyl phosphites, triaryl phosphites, and mixed alkyl-aryl phosphites), phosphonates (including diethyl ethyl phosphonate, dimethyl methyl phosphonate), polyphosphates (including melamine polyphosphate, ammonium polyphosphates), polyphosphites, polyphosphonates, phosphinates (including aluminum tris(diethyl phosphinate); halogenated fire retardants such as chlorendic acid derivatives and chlorinated paraffins; organobromines, such as decabromodiphenyl ether (decaBDE), decabromodiphenyl ethane, polymeric brominated compounds such as

brominated polystyrenes, brominated carbonate oligomers (BCOs), brominated epoxy oligomers (BEOs), tetrabromophthalic anyhydride, tetrabromobisphenol A (TBBPA) and hexabromocyclododecane (HBCD); metal hydroxides such as magnesium hydroxide, aluminum hydroxide, cobalt hydroxide, and hydrates of the foregoing metal hydroxide; and combinations thereof. The flame retardant can be a reactive type flame-retardant (including polyols which contain phosphorus groups, 10-(2,5-dihydroxyphenyl)-10H-9-oxa-10-phospha-phenanthrene-10-oxide, phosphorus-containing lactone-modified polyesters, ethylene glycol bis(diphenyl phosphate), neopentylglycol bis(diphenyl phosphate), amine- and hydroxyl-functionalized siloxane oligomers). These flame retardants can be used alone or in conjunction with other flame retardants. Any of the additives or combinations of additives can be present in a range of from about 0.01 wt% to about 30 wt% of the thermoplastic resin platform.

[0033] As shown, thermoplastic resin platform 108 includes a plurality of projections 114. Projections 114 extend from third major surface 110 in a direction that is substantially perpendicular to third major surface 110. In some examples, any of projections 114 can be oriented in a non-perpendicular direction. For example, any of projections 114 can extend at an angle in a range of from about 5 degrees to about 89 degrees, relative to third major surface 110; about 45 degree to about 80 degrees; less than, equal to, or greater than about 5 degrees; 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, or about 89 degrees. In addition to extending from third major surface 110 towards second major surface 106, projections 114 extend longitudinally in a direction substantially aligned with the major dimension of thermoplastic resin platform 108. As shown, each of projections 114 is aligned in substantially the same direction. However, in some examples a subset of projections 114 or each projection 114 can be oriented in different directions. As shown, the length, width, and height of each projection 114 is substantially the same. However, in some examples it is possible for a subset of projections 114 or each projection 114 to differ in their respective length, width, height, or combination thereof.

[0034] Projections 114, along with second major surface 106 of metallic platform 102 and third major surface 110 of thermoplastic resin platform 108 form channels 116. Channels 116 are hollow through which a heat transfer fluid can flow or be present. As shown in FIG. 3, each of channels 116 has a quadrilateral cross-sectional shape generally conforming to a rectangle. In further examples, however, any individual channel can have any suitable circular cross-sectional shape or a polygonal cross-sectional shape. Examples of suitable polygonal cross-sectional shapes include a triangular shape, a quadrilateral shape, a pentagonal shape, a hexagonal shape, a heptagonal shape, or an octahedral shape. As shown in the figure, the dimensions and cross-sectional shape of each channel 116 is substantially the same. However, in further examples, it is possible for a subset of channels 116 or for each channel 116 to have different dimensions or cross-sectional shapes. In FIGs. 1-4, channels 116 are shown in a straight-line (linear) pattern that is oriented in the longitudinal direction of the battery cooling assembly 100A. It is also possible for channels 116 to run non-linear along the longitudinal direction of the battery cooling assembly 100A. For example, channels 116 may run in a curvilinear pattern, S-shape pattern, sinusoidal wave pattern, serpentine pattern, and combinations thereof.

[0035] End cap 120 is attached to opposed ends of metallic platform 102 and thermoplastic resin platform 108. End cap 120 is shown in FIG. 4 as a hollow-tube structure. Although shown as a hollow-tube, it is possible for end cap 120 to have a non-tubular shape (e.g., a polygonal shape). End cap 120 can serve several functions. As described further herein, end caps 120 can be used to join several hybrid structures together for modular arrangement. Additionally, end caps 120 can serve as a manifold and/or header used to deliver/collect heat transfer fluid (e.g.: coolant) to/from channels 116.

[0036] End cap 120 may be an injection molded part from a thermoplastic resin. For example, End cap 120 may be prepared using 30 wt% glass-fiber reinforced nylon-6,6.

[0037] The coolant can be any suitable coolant. For example, the coolant can include gas, a liquid, or both. The gas coolant can be ambient air or compressed air. Examples of liquid coolants include water, a refrigerant, a heat transfer fluid, or a mixture thereof. Specific examples of liquid coolants include aqueous solution comprising sodium chloride (NaCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), lithium bromide (LiBr), zinc chloride ($ZnCl_2$), sulfuric acid (H_2SO_4), sodium hydroxide (NaOH), sodium sulfate (Na_2SO_4), potassium chloride (KCl), calcium nitrate ($Ca[NO_3]_2$), potassium carbonate (K_2CO_3), ammonium nitrate (NH_4NO_3), diethylene glycol, triethylene glycol, dipropylene glycol, or any mixture thereof. The coolant disposed in any channel 116 can be static. In some examples, however, the coolant can be circulated within channel 116 and continuously supplied to channel 116. In some examples any of projections 114 can include a port where coolant from one channel 116 can be supplied to an adjacent channel 116.

[0038] In various examples, assembly 100 includes only one hybrid structure 101 as described herein with respect to assembly 100A. However, in further examples, assembly 100A can include a plurality of hybrid structures 101. For example, as shown in FIG. 4, assembly 100B includes three hybrid structures 101A, 101B, and 101C. The structure, composition, or both of hybrid structures 101A, 101B, and 101C can be substantially identical. For example, the compositions and dimensions of all metallic platforms 102, thermoplastic resin platforms 108 can be substantially similar. However, in other examples any one of the compositions and dimensions of all or some metallic platforms 102, thermoplastic resin platforms 108 can be substantially different. Additionally, the coolant disposed in each hybrid structure 101A, 101B, and 101C can be the same or different.

[0039] Adjacent hybrid structures 101A, 101B, and 101C can be joined by end caps 120. Adjacent end caps 120 can be joined by a welding procedure or an adhesive. In examples where an adhesive is used, the adhesive can include a pressure-sensitive adhesive. Specific examples of adhesives can include an epoxy-

based adhesive or a liquid silicone adhesive. The welding procedure may include laser welding to join parts.

[0040] As shown in FIG. 4, each of hybrid structures 101A, 101B, and 101C are arranged such that they are substantially parallel (e.g., at about 180 degrees) to each other. However, in further examples, assembly 100B can be arranged differently. For example, hybrid structures 101A, 101C, or both can be angled relative to hybrid structure 101B. In some examples, hybrid structures 101A, 101C, or both can be angled at about 5 degrees to about 170 degrees, about 70 degrees to about 110 degrees, less than, equal to, or greater than about 5 degrees, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105, 110, 115, 120, 125, 130, 135, 140, 145, 150, 155, 160, 165, or about 170 degrees relative to hybrid structure 101B. By arranging adjacent hybrid structures 101A, 101B, and 101C, it is possible for assembly 100B to form a partial enclosure. Although FIG. 4 shows three hybrid structures 101A–C, it is possible for any further assemblies to have any higher plural number of hybrid structures (e.g., a fourth hybrid structure, fifth hybrid structure, or sixth hybrid structure).

[0041] In operation, assembly 100A can be used as a battery cooling assembly in an electric vehicle. Examples of suitable electric vehicles include automobiles, aircraft, and watercraft. The one or more battery cells of batteries used in an electric vehicle generally have an optimal operating temperature in a range of from about 25 °C to about 35 °C. If the temperature of the battery cell exceeds this range, their performance and thus the performance of the electric vehicle can be compromised. However, the combination of metallic platform 102 and thermoplastic resin platform 108 can help to efficiently and effectively remove heat from the battery cell. Specifically, metallic platform 102 can provide good thermal conductivity to quickly transfer heat from the battery cell to the coolant. Additionally, metallic platform 102 is lightweight and provides good strength to assembly 100A. Thermoplastic resin platform 108 is lightweight and resistant to degradation by heat or the coolant. The combined ability of assembly 100A to remove heat from the battery cell, while providing adequate strength while being

lightweight, make assembly 100A a desirable component of an electric vehicle. The strength of assembly 100A can be particularly improved by comparison to a battery cell cooling assembly that includes a lightweight foam.

[0042] Additionally, as described herein, it is possible for assembly 100 (e.g., assembly 100B) to form at least a partial enclosure. This can further improve a battery cell's performance. This is because it is not uncommon for a temperature difference to exist across the height of a battery cell. For example, if only the bottom of a battery cell is in contact with assembly 100B, the bottom may be within the operating temperature in a range of from about 25 °C to about 35 °C. However, the sides of the battery cell may be at a higher temperature (e.g., about 37 °C to about 38 °C). Additionally, the top of the battery cell can be at an even higher temperature (e.g., about 40 °C to about 42 °C). To mitigate this, a battery cell can be placed in an example of assembly 100B that forms an at least partial enclosure. This can allow for heat to be conducted from the sides and tops of the batteries as well so that more zones of the battery cell run at an optimal temperature. In some examples, multiple battery cells can be disposed on assembly 100B and separated by vertical hybrid structures 101.

[0043] Manufacturing assembly 100 can be accomplished simply by contacting metallic platform 102 and thermoplastic resin platform 108. Platforms 102 and 108 can be joined using any of the adhesives described herein or via welding. In some examples, a better weld between metallic platform 102 and thermoplastic resin platform 108 can be accomplished by coating at least a portion of metallic platform 102 with the same thermoplastic resin that is found in thermoplastic resin platform 108.

[0044] Metallic platform 102 can be formed through any suitable technique. For example, metallic platform 102 can be machined. Thermoplastic resin platform 108 can be formed through extrusion. In some examples, thermoplastic resin platform 108 is extruded to metallic platform 102.

Exemplary Examples.

[0045] The following exemplary examples are provided, the numbering of which is not to be construed as designating levels of importance.
In the following examples, static heat transfer is shown for illustrative purposes. In real systems, it will be understood that dynamic heat flow would occur between the hot and cold sides and in the presence or absence of heat exchange medium.

Example A –

[0046] A single unit of the battery cooling assembly, according to the present disclosure and as shown in FIGs. 1 through 4, has 0.1 m^2 total surface area that is perpendicular to the heat flow. The thermal conductivity index, K, for the 1-mm thick metallic (aluminum) platform is 234. The thermal conductivity index for the 2-mm polyamide platform is 0.3. The temperature gradient across the cooling assembly is about 20 °C from 45 °C hot battery side and 25 °C ambient cold side. The heat flow from the hot-side to the cold-side of the cooling assembly is about 468 KW. Compared to that, the heat flow from the hot-side to the cold-side in the absence of cooling assembly is about 0.3 W. A significant improvement to thermal/heat management for an electric vehicle battery system is thus achieved by integrating the battery cooling assembly of the present disclosure. By doing so, the battery operating temperature is maintained in the 25-35 °C environment resulting in efficient operation at normal as well as battery charge/discharge modes.

Example B -

[0047] A single unit of the battery cooling assembly, as described in Example A and FIGs. 1-4, may be 50 to 130 cm long, 5 to 20 cm wide and 3 to 10mm thick. The total surface area for heat transfer is between 0.025 m^2 to 0.26 m^2. For the temperature gradient of about 10 °C across the hot- and cold-side, the total heat flow across the cooling assembly is between about 5-60 KW for 10mm thick assembly and 20-200 KW for 3mm thick assembly.

Example C –

[0048] Depending on the overall size of the battery cell compartment, multiple units of the battery cooling assembly are connected together using repeating units of End caps 120 and as shown in FIG. 4. Such connected cooling

assemblies form an array that covers most of the battery cell compartment. A cooling fluid or coolant is passed through the cooling assembly equipped with an inlet and an outlet port. The coolant is distributed across End cap 120, flows through channels 116 [see FIG. 3] and further exchanges heat from hot battery cells.

[0049] This combination of the metallic platform with the polyamide platform having coolant-filled channels efficiently and effectively cools the battery cell compartment and maintains the 25-35 °C optimum temperature.

Example D -

[0050] In a similar setup as described in Example C, battery cell compartment heat maintenance is possible during the winter season. In this case, the heat flow occurs towards the battery cell compartment. Heat flow is effective to heat up battery cell to a suitable temperature in the 25-35°C range.

[0051] Example 1 provides a battery cooling assembly comprising:

a metallic platform comprising opposed first and second major surfaces; and

a thermoplastic resin platform comprising opposed third and fourth major surfaces, wherein at least a portion of the second major surface of the metallic platform is contacting at least a portion of the third major surface of the thermoplastic resin platform.

[0052] Example 2 provides the battery cooling assembly of Example 1, wherein the metallic platform comprises elemental aluminum, an alloy of aluminum, or a combination thereof.

[0053] Example 3 provides the battery cooling assembly of any one of Examples 1 or 2, wherein the portion of the second major surface of the metallic platform joined to the thermoplastic resin platform, a portion of the first major surface of the metallic platform, or a combination thereof, comprises a thermoplastic resin coating.

[0054] Example 4 provides the battery cooling assembly of Example 3, wherein the thermoplastic resin coated to the second major surface of the metallic platform is in contact with the thermoplastic resin platform.

[0055] Example 5 provides the battery cooling assembly of any one of Examples 1-4, wherein the first major surface of the metallic platform, the second major surface of the metallic platform, or both, are substantially planar.

[0056] Example 6 provides the battery cooling assembly of any one of Examples 1-5, wherein the first major surface of the metallic platform, the second major surface of the metallic platform, or both, comprise a projection extending in a direction substantially perpendicular to the respective first major surface or second major surface.

[0057] Example 7 provides the battery cooling assembly of any one of Examples 1-6, wherein the thermoplastic resin platform comprises a polyamide component comprising PA6, PA66, PA66/6T copolymer, PA612, or any combination thereof.

[0058] Example 8 provides the battery cooling assembly of Example 7, wherein the polyamide component is in a range of from about 50 wt% to about 100 wt% of the thermoplastic resin platform.

[0059] Example 9 provides the battery cooling assembly of any one of Examples 7 or 8, wherein the polyamide component is in a range of from about 70 wt% to about 95 wt% of the thermoplastic resin platform.

[0060] Example 10 provides the battery cooling assembly of any one of Examples 1-9, wherein the thermoplastic resin platform comprises a polyamide component comprising a reinforcing component.

[0061] Example 11 provides the battery cooling assembly of Example 10, wherein the reinforcing component comprises a glass fiber.

[0062] Example 12 provides the battery cooling assembly of any one of Examples 10 or 11, wherein the reinforcing component is in a range of from about 5 wt% to about 50 wt% of the polyamide component.

[0063] Example 13 provides the battery cooling assembly of any one of Examples 10-12, wherein the reinforcing component is in a range of from about 25 wt% to about 35 wt% of the polyamide component.

[0064] Example 14 provides the battery cooling assembly of any one of Examples 1-13, wherein the thermoplastic resin platform further comprises an additive.

[0065] Example 15 provides the battery cooling assembly of Example 14, wherein the additive comprises a flame retardant, an antistatic additive, a toughner, or a mixture thereof.

[0066] Example 16 provides the battery cooling assembly of any one of Examples 14 or 15, wherein the additive comprises a flame retardant.

[0067] Example 17 provides the battery cooling assembly of any one of Examples 14-16, wherein the additive is in a range of from about 0.01 wt% to about 30 wt% of the thermoplastic resin platform.

[0068] Example 18 provides the battery cooling assembly of any one of Examples 14-17, wherein the additive is in a range of from about 0.10 wt% to about 25 wt% of the thermoplastic resin platform.

[0069] Example 19 provides the battery cooling assembly of any one of Examples 3-18, wherein the thermoplastic resin coated to the portion of the second major surface of the metallic platform joined to the thermoplastic resin platform, a portion of the first major surface of the metallic platform, or a combination thereof is the same polyamide as a polyamide of the thermoplastic resin platform.

[0070] Example 20 provides the battery cooling assembly of any one of Examples 1-19, wherein the third major surface of the thermoplastic resin platform, the fourth major surface of the thermoplastic resin platform, or both, is substantially planar.

[0071] Example 21 provides the battery cooling assembly of any one of Examples 1-20, wherein the third major surface of the thermoplastic resin platform comprises a projection extending in a direction substantially perpendicular to the third major surface and contacting the second major surface of the metallic platform.

[0072] Example 22 provides the battery cooling assembly of Example 21, wherein the projection is a first projection, and the assembly further comprises a

second projection extending a direction substantially perpendicular to the third major surface and contacting the second major surface of the metallic platform.

[0073] Example 23 provides the battery cooling assembly of Example 22, wherein the first projection, second projection or both extend in a longitudinal direction substantially aligned with a longitudinal direction of the thermoplastic resin platform.

[0074] Example 24 provides the battery cooling assembly of any one of Examples 22 or 23, wherein a length, width, height, or a combination thereof of the first projection and the second projection are substantially the same.

[0075] Example 25 provides the battery cooling assembly of any one of Examples 1-24, wherein the second major surface of the metallic platform comprises a third projection extending in a direction substantially perpendicular to the second major surface and contacting the third major surface of the thermoplastic resin platform.

[0076] Example 26 provides the battery cooling assembly of Example 21, further comprising a fourth projection extending a direction substantially perpendicular to the second major surface and contacting the third major surface of the thermoplastic resin platform.

[0077] Example 27 provides the battery cooling assembly of Example 26, wherein the third projection, fourth projection or both extend in a longitudinal direction substantially aligned with a longitudinal direction of the metallic platform.

[0078] Example 28 provides the battery cooling assembly of any one of Examples 26 or 27, wherein a length, width, height, or a combination thereof of the third projection and the fourth projection are substantially the same.

[0079] Example 29 provides the battery cooling assembly of any one of Examples 1-28, further comprising a channel formed between the second major surface of the metallic platform and the third major surface of the thermoplastic resin platform.

[0080] Example 30 provides the battery cooling assembly of Example 29, wherein the channel is a hollow channel.

[0081] Example 31 provides the battery cooling assembly of any one of Examples 1-30, wherein a cross-sectional shape of the channel comprises a circular shape or a polygonal shape.

[0082] Example 32 provides the battery cooling assembly of Example 31, wherein the polygonal shape comprises a triangular shape, a quadrilateral shape, a pentagonal shape, a hexagonal shape, a heptagonal shape, or an octahedral shape.

[0083] Example 33 provides the battery cooling assembly of any one of Examples 29-32, further comprising an end cap attached to an end of the thermoplastic resin platform.

[0084] Example 34 provides the battery cooling assembly of Example 33, wherein the end cap is for delivery of coolant to the channel.

[0085] Example 35 provides the battery cooling assembly of any one of Examples 29-34, further comprising a coolant disposed in the channel.

[0086] Example 36 provides the battery cooling assembly of Example 35, wherein the coolant comprises gas, a liquid, or both.

[0087] Example 37 provides the battery cooling assembly of Example 36, wherein the liquid coolant comprises water, a refrigerant, a heat transfer fluid, or a mixture thereof.

[0088] Example 38 provides the battery cooling assembly of any one of Examples 1-37, wherein the metallic platform is a first metallic platform, the thermoplastic resin platform is a first thermoplastic resin platform, and a first hybrid structure comprises the first metallic platform and the thermoplastic resin platform, wherein the assembly further comprises:

a second hybrid structure contacting the first hybrid structure, the second hybrid structure comprising:

a second metallic platform; and

a second thermoplastic resin platform contacting the second metallic platform.

[0089] Example 39 provides the battery cooling assembly of Example 38, wherein the first metallic platform comprises the same material or combination of

material as the second metallic platform and/or the first thermoplastic resin platform comprises the same material or combination of materials as the second thermoplastic resin platform.

[0090] Example 40 provides the battery cooling assembly of any one of Examples 38 or 39, wherein the second hybrid structure is arranged substantially parallel to the first hybrid structure.

[0091] Example 41 provides the battery cooling assembly of any one of Examples 38 or 40, wherein the second hybrid structure is arranged substantially at a 90 degree angle relative to the first hybrid structure.

[0092] Example 42 provides the battery cooling assembly of any one of Examples 38-41, wherein the first hybrid structure and the second hybrid structure are attached by end caps.

[0093] Example 43 provides the battery cooling assembly of any one of Examples 38-42, wherein the first hybrid structure and the second hybrid structure are spaced relative to each other.

[0094] Example 44 provides the battery cooling assembly of any one of Examples 38-43, further comprising a third hybrid structure contacting the first hybrid structure, the second hybrid structure, or both, the third hybrid structure comprising:

a third metallic platform; and

a third thermoplastic resin platform contacting the second metallic platform.

[0095] Example 45 provides the battery cooling assembly of any one of Examples 38-44, further comprising a fourth hybrid structure contacting the first hybrid structure, the second hybrid structure, the third hybrid structure, or a combination thereof, the fourth hybrid structure comprising:

a fourth metallic platform; and

a fourth thermoplastic resin platform contacting the second metallic platform.

[0096] Example 46 provides a battery cooling assembly comprising:

a metallic platform comprising aluminum and extending between opposed first and second major surfaces; and

a thermoplastic resin platform comprising PA6, PA66, PA66/6T copolymer, PA612, or any combination thereof, and extending between opposed third and fourth major surfaces, wherein

at least a portion of the second major surface of the metallic platform is contacting at least a portion of the third major surface of the thermoplastic resin platform,

the third major surface of the thermoplastic resin platform, the fourth major surface of the thermoplastic resin platform, or both, comprise a projection extending in a direction substantially perpendicular to the third major surface, and

a channel formed between the second major surface of the metallic platform and the third major surface of the thermoplastic resin platform.

[0097] Example 47 provides the battery cooling assembly of any one of Examples 1-46, further comprising a battery cell in contact with the hybrid structure.

[0098] Example 48 provides the battery cooling assembly of Example 47, wherein the battery cell is in contact with the metallic platform.

[0099] Example 49 provides a method of making the battery cooling assembly of any one of Examples 1-48, the method comprising:

contacting the metallic platform and the thermoplastic resin platform.

[0100] Example 50 provides the method of making the battery cooling assembly of Example 49, further comprising:

forming the metallic platform; and

forming the thermoplastic resin platform.

[0101] Example 51 provides the method of Example 50, wherein forming the thermoplastic resin platform comprises extruding the thermoplastic resin platform.

[0102] Example 52 provides the method of making the battery cooling assembly of Example 49, comprising extruding the thermoplastic resin platform directly to the metallic platform.

[0103] Example 53 provides the method of making the battery cooling assembly of Example 49, wherein the thermoplastic resin platform is welded to metallic platform.

[0104] Example 54 provides the method of making the battery cooling assembly of Example 53, wherein a portion of the metallic platform comprises a thermoplastic resin coating and the portion comprising the thermoplastic resin coating is welded to the thermoplastic resin platform.

[0105] Example 55 provides the method of making the battery cooling assembly of any one of Examples 49-54, wherein the thermoplastic resin platform and the metallic platform are joined by an adhesive.

[0106] Example 56 provides the method of Example 55, wherein the adhesive comprises a liquid silicone.

[0107] Example 57 provides a vehicle comprising the battery cooling assembly according to any one of Examples 1-56.

[0108] Example 58 provides the vehicle of Example 57, wherein the vehicle is an electric vehicle.

[0109] Example 59 provides the vehicle of any one of Examples 57 or 58, wherein the vehicle is an automobile.

CLAIMS

What is claimed is:

1. A battery cooling assembly comprising:

a metallic platform comprising opposed first and second major surfaces; and

a thermoplastic resin platform comprising opposed third and fourth major surfaces, wherein at least a portion of the second major surface of the metallic platform is contacting at least a portion of the third major surface of the thermoplastic resin platform.

2. The battery cooling assembly of claim 1, wherein the metallic platform comprises elemental aluminum, an alloy of aluminum, or a combination thereof.

3. The battery cooling assembly of any one of claims 1 or 2, wherein the portion of the second major surface of the metallic platform joined to the thermoplastic resin platform, a portion of the first major surface of the metallic platform, or a combination thereof, comprises a thermoplastic resin coating.

4. The battery cooling assembly of any one of claims 1-3, wherein the first major surface of the metallic platform, the second major surface of the metallic platform, or both, are substantially planar.

5. The battery cooling assembly of any one of claims 1-4, wherein the thermoplastic resin platform comprises a polyamide component comprising PA6, PA66, PA66/6T copolymer, PA612, or any combination thereof.

6. The battery cooling assembly of claim 5, wherein the polyamide component is in a range of from about 50 wt% to about 100 wt% of the thermoplastic resin platform.

7. The battery cooling assembly of any one of claims 1-6, wherein the thermoplastic resin platform comprises a polyamide component comprising a glass fiber reinforcing component.

8. The battery cooling assembly of claim 7, wherein the glass fiber is in a range of from about 5 wt% to about 50 wt% of the polyamide component.

9. The battery cooling assembly of any one of claims 1-8, wherein the third major surface of the thermoplastic resin platform comprises a projection extending in a direction substantially perpendicular to the third major surface and contacting the second major surface of the metallic platform.

10. The battery cooling assembly of claim 9, wherein the projection is a first projection, and the assembly further comprises a second projection extending a direction substantially perpendicular to the third major surface and contacting the second major surface of the metallic platform.

11. The battery cooling assembly of any one of claims 1-10, further comprising a channel formed between the second major surface of the metallic platform and the third major surface of the thermoplastic resin platform.

12. The battery cooling assembly of claim 11, wherein the channel is a hollow channel.

13. The battery cooling assembly of any one of claims 11 or 12, further comprising an end cap attached to an end of the thermoplastic resin platform.

14. The battery cooling assembly of any one of claims 1-13, wherein the metallic platform is a first metallic platform, the thermoplastic resin platform is a first thermoplastic resin platform, and a first hybrid structure comprises the first

metallic platform and the thermoplastic resin platform, wherein the assembly further comprises:

a second hybrid structure contacting the first hybrid structure, the second hybrid structure comprising:

a second metallic platform; and

a second thermoplastic resin platform contacting the second metallic platform.

15. A battery cooling assembly comprising:

a metallic platform comprising aluminum and extending between opposed first and second major surfaces; and

a polyamide platform comprising PA6, PA66, PA66/6T copolymer, PA612, or any combination thereof, and extending between opposed third and fourth major surfaces, wherein

at least a portion of the second major surface of the metallic platform is contacting at least a portion of the third major surface of the polyamide platform,

the third major surface of the polyamide platform, the fourth major surface of the polyamide platform, or both, comprise a projection extending in a direction substantially perpendicular to the third major surface, and

a channel formed between the second major surface of the metallic platform and the third major surface of the polyamide platform.

16. The battery cooling assembly of any one of claims 1-15, further comprising a battery in contact with the hybrid structure.

17. A method of making the battery cooling assembly of any one of claims 1-16, the assembly comprising:

a metallic platform comprising opposed first and second major surfaces; and

a polyamide platform comprising opposed third and fourth major surfaces, wherein at least a portion of the second major surface of the metallic platform is

contacting at least a portion of the third major surface of the polyamide platform, the method comprising:

contacting the metallic platform and the polyamide platform.

18. The method of making the battery cooling assembly of claim 17, further comprising:

forming the metallic platform; and

forming the polyamide platform.

19. The method of claim 18, wherein forming the polyamide platform comprises extruding the polyamide platform.

20. The method of making the battery cooling assembly of claim 19, comprising extruding the polyamide platform directly to the metallic platform.

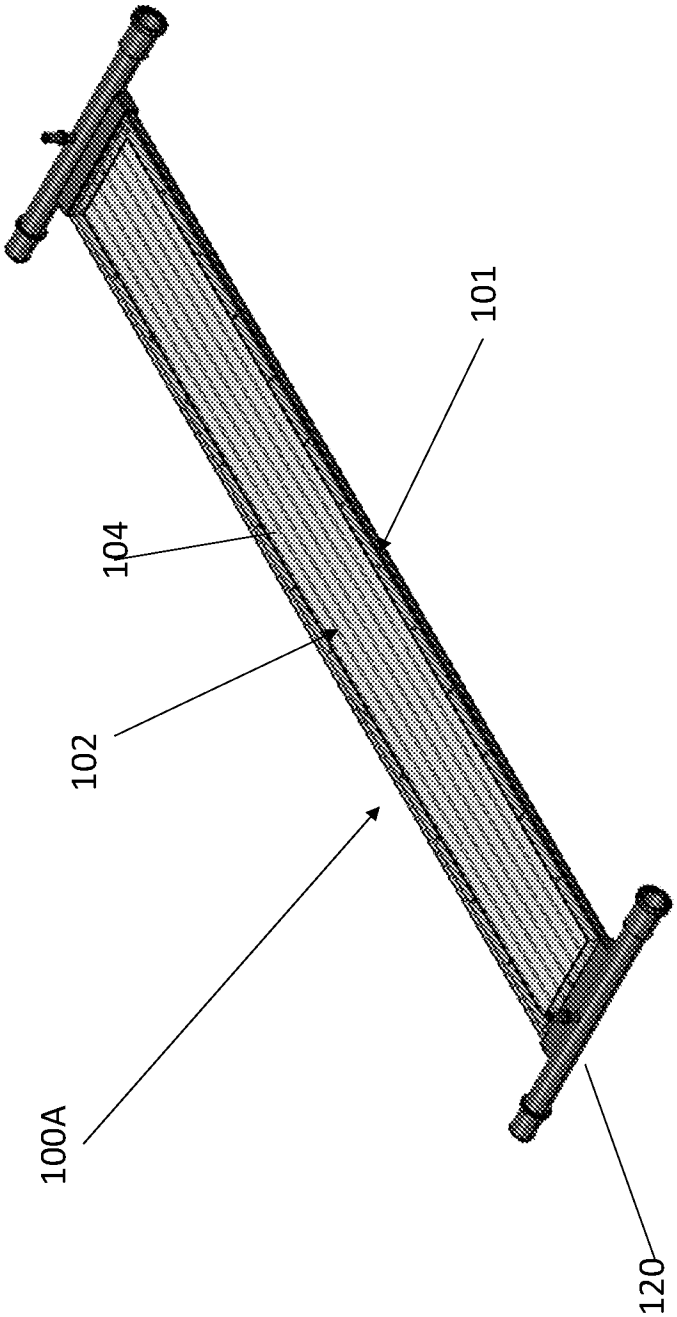


FIG. 1

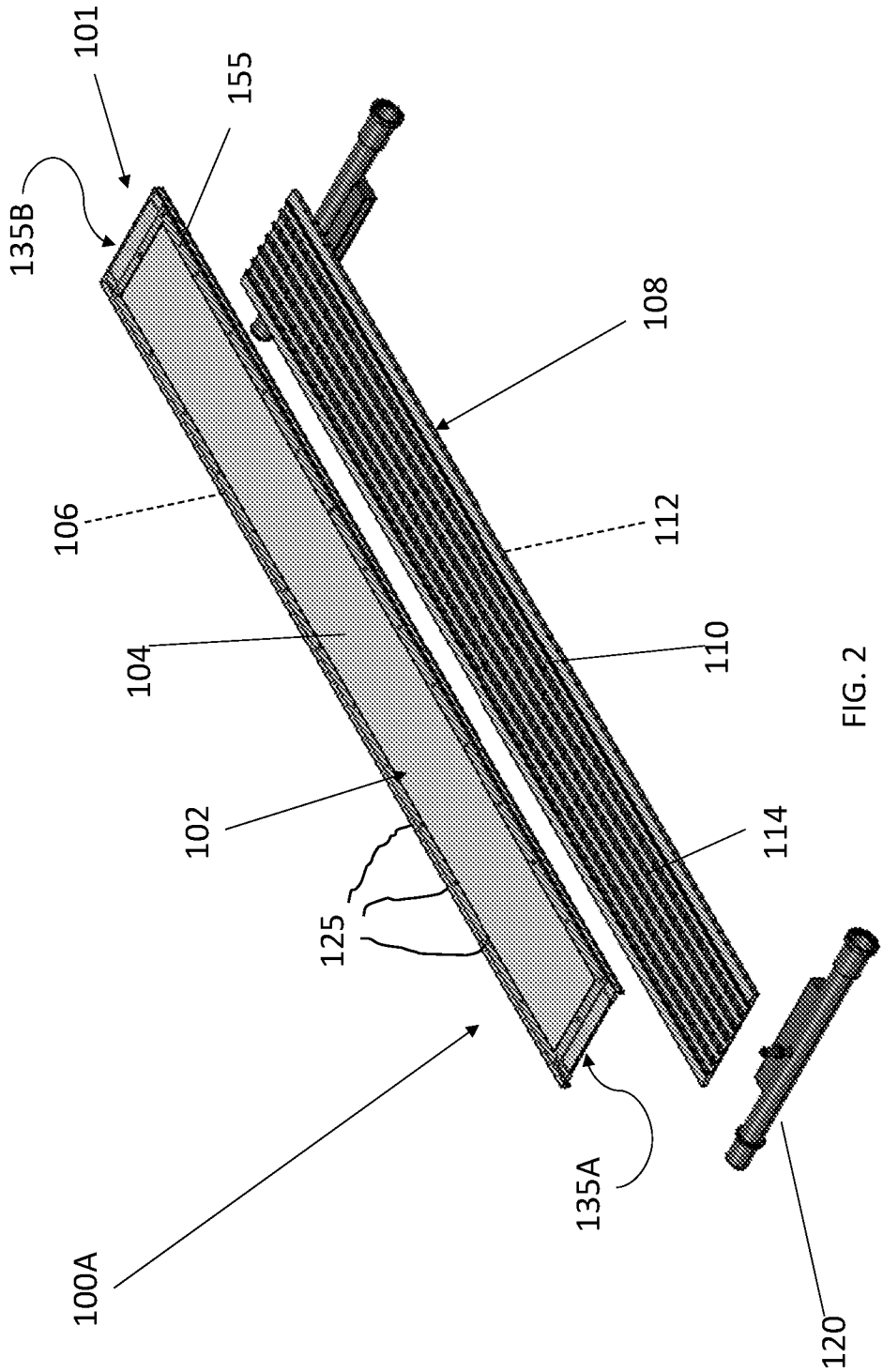


FIG. 2

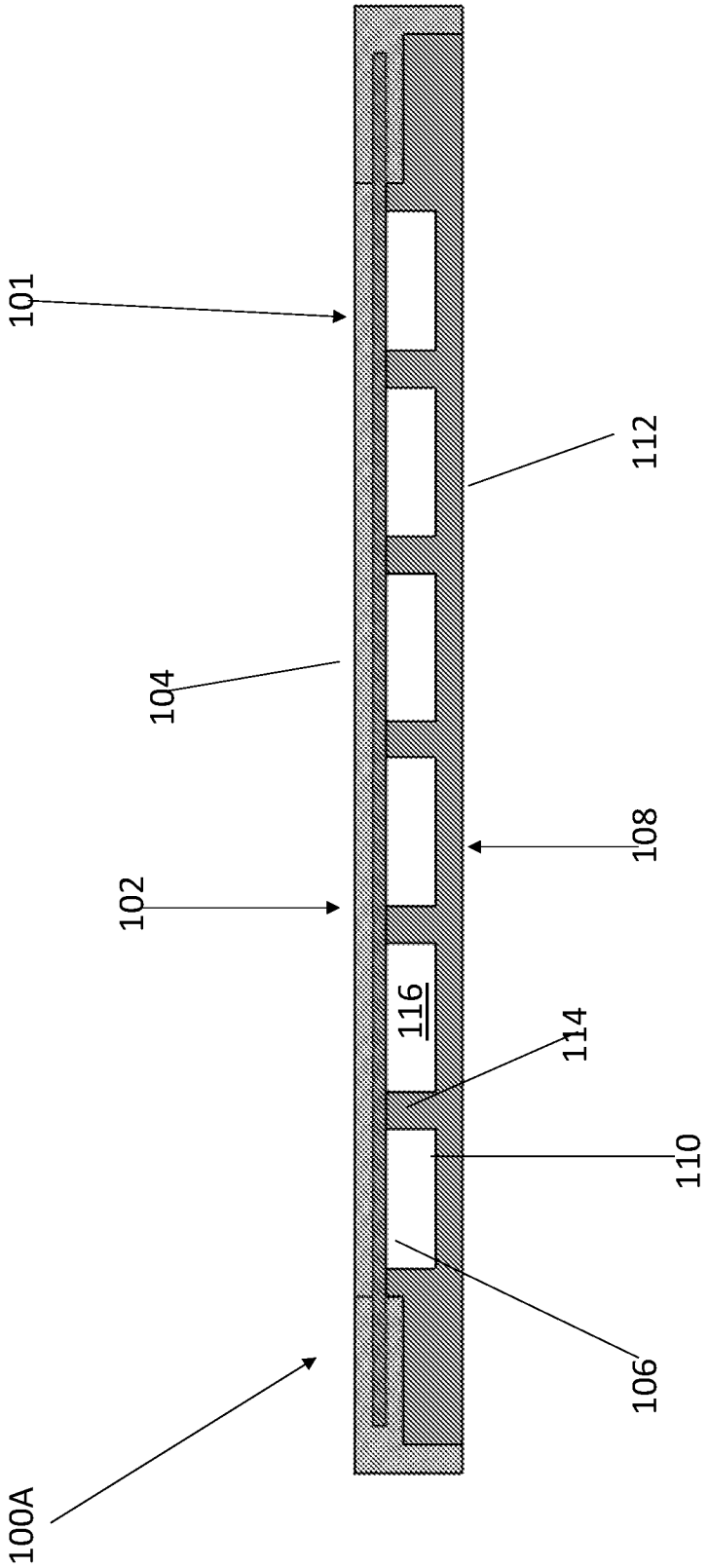


FIG. 3

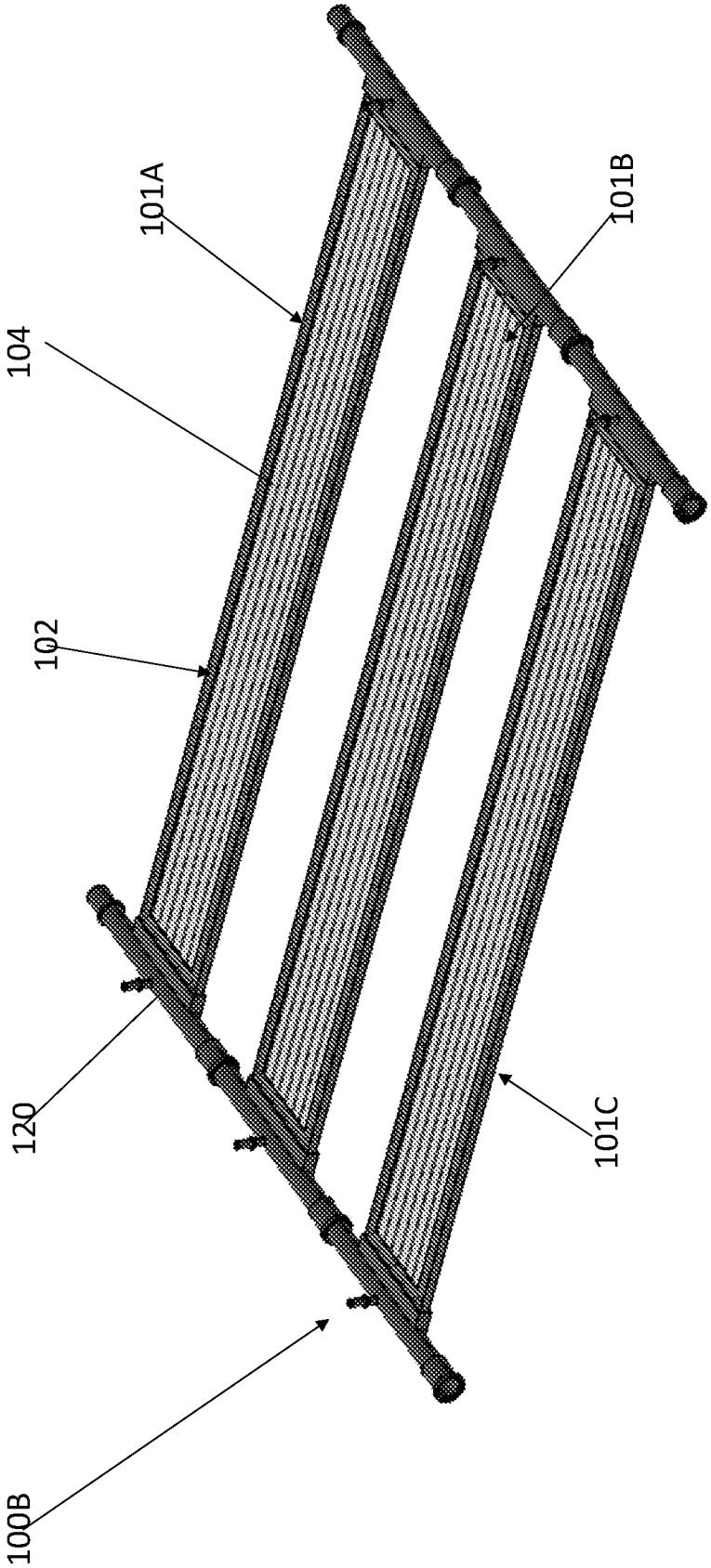


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2021/060365

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M10/613 H01M10/625 H01M10/656 H01M10/6556
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01M

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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2020/027299 A1 (MITSUI CHEMICALS INC [JP]) 6 February 2020 (2020-02-06) paragraphs [0007], [0010], [0015], [0017], [0020], [0022], [0031] paragraph [0037] - paragraph [0040] figures 1-4	1-20
X	CN 109 921 144 A (WEICHAI POWER CO LTD) 21 June 2019 (2019-06-21) abstract; figure 1	1-20
A	JP 2019 129236 A (MITSUI CHEMICALS INC; UACJ CORP) 1 August 2019 (2019-08-01) paragraph [0027]	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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
5 January 2022	14/01/2022

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2021/060365

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2020027299 A1	06-02-2020	CN 112514141 A	16-03-2021
		EP 3832786 A1	09-06-2021
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		KR 20210025653 A	09-03-2021
		US 2021249710 A1	12-08-2021
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