



(51) International Patent Classification:

H01M 10/617 (2014.01) H01M 50/509 (2021.01)
H01M 10/643 (2014.01) H01M 50/55 (2021.01)
H01M 50/213 (2021.01) H01M 50/559 (2021.01)
H01M 50/249 (2021.01) H01M 50/526 (2021.01)
H01M 50/503 (2021.01)

(21) International Application Number:

PCT/EP2021/073206

(22) International Filing Date:

20 August 2021 (20.08.2021)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2013433.4 27 August 2020 (27.08.2020) GB

(71) Applicant: JAGUAR LAND ROVER LIMITED

[GB/GB]; Abbey Road, Whitley, Coventry Warwickshire CV3 4LF (GB).

(72) Inventors: HANEY, Paul; Patents Department W/1/073,

Abbey Road, Whitley, Coventry Warwickshire CV3 4lf (GB). GONG, Shuai; Patents Department W/1/073, Abbey Road, Whitley, Coventry Warwickshire CV3 4lf (GB). NI-

CHOLLS, Stephen; Patents Department W/1/073, Abbey Road, Whitley, Coventry Warwickshire CV3 4lf (GB).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: BATTERY INTERCONNECTOR

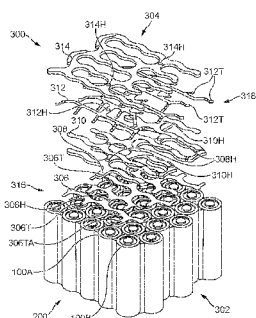


FIG. 3

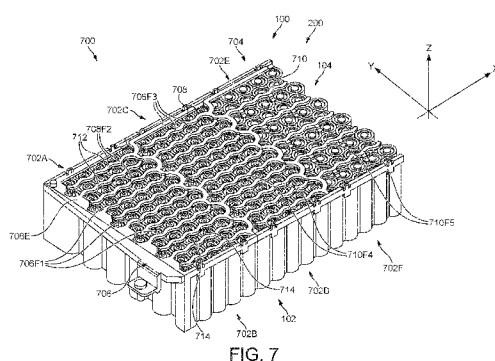


FIG. 7

(57) Abstract: Embodiments of the present invention provide components for batteries, and methods of manufacture of batteries or battery modules. In some embodiments, the methods comprise producing a plurality of sub-assemblies (300) comprising a group of mechanically-connected cells (100A, 100B) and an associated busbar assembly (304), and subsequently assembling the sub-assemblies within a housing and electrically connecting the busbar assemblies to produce a battery module.

Published:

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

BATTERY INTERCONNECTOR

TECHNICAL FIELD

The present invention relates generally to components for batteries. In particular, but not exclusively, the invention relates to components for vehicle traction batteries. Aspects of the invention relate to a battery module, to a method
5 of manufacture of a battery, to a sub-assembly arranged to form part of a battery module, to a busbar assembly and to a vehicle.

BACKGROUND

There has recently been increased interest in providing battery-powered vehicles, which has led to developments in vehicle battery, in particular vehicle traction battery technology. It is generally desirable for vehicle batteries to
10 provide high energy capacity and peak current output, whilst minimising the size and weight of the battery module and thus the vehicle.

Vehicle traction batteries often comprise one or more modules each containing a plurality of cells. It is generally desirable to package the cells into a battery module as densely as can safely be achieved, so as to maximise the energy and current capacity that can be provided within a given packaging volume.

15 Electrical connections between cells are typically provided by a busbar assembly. It is generally desirable to reduce the size and weight of the busbar assembly, whilst also reducing the electrical resistance introduced by the busbar assembly.

It is also desirable to provide manufacturing processes that are highly repeatable and that avoid faulty electrical connections. A single battery module will typically comprise a large number of electrical connections between cells
20 and the busbar assembly, and any faulty connections may lead to the entire module malfunctioning, potentially requiring an entire module failing quality control and having to be reworked where possible or otherwise scrapped.

It is an object of embodiments of the invention to at least mitigate one or more of the problems of the prior art.

SUMMARY OF THE INVENTION

According to an aspect of the invention for which protection is sought, there is provided a method of manufacture of
25 a battery module comprising a plurality of cylindrical cells, each of the cells comprising a first end surface, a second end surface a cylindrical surface between the first and second end surfaces, a first terminal and a second terminal, the first terminal being located in a central region of the first end surface and at least a part of a second terminal being located in an peripheral region of the first end surface, the method comprising:

- a. joining the plurality of cells together with an adhesive on the cylindrical surfaces such that the
30 first ends of the cells are substantially coplanar;
- b. electrically connecting the plurality of cells to a busbar assembly, wherein the busbar assembly is located proximate the first ends of the cells and is arranged to electrically connect the plurality of cells in parallel, thereby to create a first sub-assembly;
- c. repeating steps a and b to produce a second sub-assembly;
- 35 d. positioning the first and second sub-assemblies within a housing; and

e. electrically connecting the busbar assemblies of the first and second sub-assemblies, such that the cells in the first sub-assembly are electrically connected to the cells in the second sub-assembly in series.

According to another aspect of the invention for which protection is sought there is provided a method of manufacture of a battery module comprising a plurality of cylindrical cells, each of the cells comprising a first end surface, a second end surface a cylindrical surface between the first and second end surfaces, a first terminal and a second terminal, the first terminal being located in a central region of the first end surface and at least a part of a second terminal being located in an peripheral region of the first end surface, the method comprising:

a. joining the plurality of cells together with an adhesive on the cylindrical surfaces, such that the first ends of the cells are substantially coplanar;

b. electrically connecting the plurality of cells to a busbar assembly, wherein the busbar assembly is located proximate the first ends of the cells and is arranged to electrically connect the plurality of cells in parallel, thereby to create a first sub-assembly;

c. repeating steps a and b to produce a second sub-assembly;

d. electrically connecting the busbar assemblies of the first and second sub-assemblies, such that the cells in the first sub-assembly are electrically connected to the cells in the second sub-assembly in series; and

e. sealing the first and second sub-assemblies within a housing.

It will be understood that the provision of letters to identify the steps of the above methods is merely for convenience and is not intended to, and does not, imply that the steps must be performed in the precise order specified above. It will also be understood that the sealing of the housing need not necessarily prevent ingress or egress of gases and/or moisture. Instead, the housing may be considered to be sealed once a closure is in place that prevents removal of the sub-assemblies from the housing.

Advantageously, the above methods allow a battery module to be constructed from a plurality of sub-assemblies, which sub-assemblies already include the connections between the cells and the busbar assemblies. Accordingly, the reliability of the process is improved, because the connections on the sub-assemblies can be readily tested before the overall module is assembled. Furthermore, the process is flexible, as different combinations of sub-assemblies can be used for different battery modules.

In an embodiment, the method further comprises providing an insulating wrap around the plurality of cells in each sub-assembly. Provision of such an insulating wrap helps to prevent undesired electrical connections from occurring between adjacent sub-assemblies.

In an embodiment, the adhesive joining adjacent cells has a thickness of 0.5mm or less, preferably 0.3mm or less. The thickness of the adhesive may be considered to be the distance between the cell cylindrical surfaces at their closest point. It will be understood that this gap will generally be filled by the adhesive.

In an embodiment, each of the busbar assemblies comprises:

a first busbar component comprising a first terminal collection plate connected to the first terminals of each cell in the respective sub-assembly and comprising a first series connection portion located at a first longitudinal end of the sub-assembly; and

a second busbar component comprising a second terminal collection plate connected to the second terminals of each cell in the respective sub-assembly and comprising a second series connection portion located at a second longitudinal end of the sub-assembly,

5 wherein electrically connecting the busbar assemblies of the first and second sub-assemblies comprises electrically connecting the first series connection portion on the first sub-assembly to the second series connection portion on the second sub-assembly. For example, electrically connecting the first series connection portion on the first sub-assembly to the second series connection portion on the second sub-assembly may comprise welding the first series connection portion on the first sub-assembly to the second series connection portion on the second sub-assembly. This provides a simple and reliable method of connecting adjacent sub-assemblies in series.

10 In an embodiment, the first and second sub-assemblies are positioned within the housing in a longitudinal end-to-end arrangement.

Optionally, step a. is performed within a jig. Such a jig may help to retain the relative positions of the cells in the desired relative positions.

15 According to a further aspect of the invention for which protection is sought, there is provided a sub-assembly arranged to form part of a battery module, the sub-assembly comprising:

a plurality of cylindrical cells, wherein each cylindrical cell comprises a first end surface, a second end surface and a cylindrical surface between the first and second end surfaces, a first terminal and a second terminal, the first terminal of each of the cylindrical cells being located in a central region of the first end surface and at least a part of a second terminal of each of the cylindrical cells being located in an peripheral region of the first end surface, wherein the cylindrical cells are arranged in a common orientation, such that the first end surfaces of all of the cylindrical cells in the set are substantially coplanar, and wherein the cells are joined together by an adhesive on the cylindrical surfaces of the cells;

20

a first busbar component comprising a first terminal collection plate connected to the first terminals of each cell in the set of cells and being located proximate the first end surface of the cells; and

25 a second busbar component comprising a second terminal collection plate connected to the second terminals of each cell in the set of cells and being located proximate the first end surface of the cells; wherein:

the first busbar component comprises a first series connection portion located at a first longitudinal end of the sub-assembly;

30 the second busbar component comprises a second series connection portion located at a second longitudinal end of the sub-assembly; and

the second series connection portion is arranged to contact the first series connection portion of a similar sub-assembly positioned adjacent to the sub-assembly in a longitudinal end-to-end arrangement. Advantageously, such a sub-assembly may be used in conjunction with one or more similar sub-assemblies to form a battery module having a higher voltage output than the individual cells.

35

In an embodiment, the first busbar component further comprises at least one parallel connection portion located at a first transverse end of the busbar assembly. Advantageously, such a parallel connection portion provides the

option of connecting the sub-assembly in parallel with another sub-assembly placed in a transverse end-to-end arrangement with the sub-assembly.

In an embodiment, the second series connection portion is arranged to overlie the first series connection portion of a similar busbar assembly positioned adjacent to the busbar assembly in a longitudinal end-to-end arrangement.

5 This provides a simple arrangement for ensuring reliable series electrical connections can be made between adjacent busbar assemblies. Optionally, the second series connection portion is configured to form a lap joint with the first series connection portion of a similar busbar assembly positioned adjacent to the busbar assembly in a longitudinal end-to-end arrangement.

10 In an embodiment, the busbar assembly further comprises an insulating layer disposed between the first and second terminal connection plates, and wherein the first terminal collection plate is located in a first plane, and the second terminal collection plate is located in a second plane, the second plane being offset from the first plane in a direction normal to the first plane. The insulating layer is preferably heat-resistant and non-combustible, so that it is not destroyed in the event of a cell in the sub-assembly undergoing a venting event.

15 According to a further aspect of the invention for which protection is sought, there is provided a battery module comprising at least two sub-assemblies as described above, and a housing, wherein the wherein the first series connection portion of a first one of the sub-assemblies is electrically connected to the second series connection portion of a second one of the sub-assemblies.

20 According to another aspect of the invention for which protection is sought, there is provided a busbar assembly for electrically connecting a set of cylindrical cells in a battery module, wherein each cylindrical cell comprises a first terminal and a second terminal, the busbar assembly comprising:

- a first component comprising a first terminal collection plate;
- a second component comprising a second terminal collection plate; and
- an insulating layer disposed between the first and second terminal connection plates,

wherein:

25 the first terminal collection plate is located in a first plane, and the second terminal collection plate is located in a second plane, the second plane being offset from the first plane in a direction normal to the first plane. Advantageously, such a busbar assembly may be easier to assemble onto a set of cylindrical cells than prior art busbar assemblies.

30 In an embodiment, a plurality of first terminal connection tabs are electrically connected to the first terminal collection plate and a plurality of second terminal connection tabs are electrically connected to the second terminal connection plate, and wherein the first terminal collection plate comprises at least one void space, wherein at least some of the second terminal connection tabs are operable to connect to the second terminals of the cells via the void space.

35 In an embodiment, the first terminal connection plate comprises a plurality of first terminal connection tabs and the second terminal connection plate comprises a plurality of second terminal connection tabs. Optionally, the first terminal connection tabs are provided on a metallic sheet that is electrically and mechanically connected to the first terminal connection plate, and the second terminal connection tabs are provided on a metallic sheet that is electrically and mechanically connected to the second terminal connection plate. Advantageously, provision of the

connection tabs on separate sheets allows different materials to be used for the bodies of the collection plates and the tabs. For example, the first and second terminal connection tabs may be at least partly formed from copper. The first and second terminal connection tabs may be coated with a material to prevent oxidation such as nickel.

5 Optionally, the first and second components may be connected to the insulating layer by electrically insulating fixings passed through aligned holes in the first and second components and the electrically insulating layer. However, it will be understood that other methods of connecting the first and second components to the insulating layer are also useful, for example ultrasonic or other welding techniques, by injection moulding a fixing directly into aligned holes, or by using a suitable adhesive.

10 In an embodiment each of the first and second terminal collection plates are at least partly formed from aluminium. For example, the first and second terminal collection plates may be formed substantially or entirely from aluminium.

According to a further aspect of the invention for which protection is sought, there is provided a battery module comprising a busbar assembly as claimed in any preceding claim and a plurality of cylindrical cells.

15 According to another aspect of the invention for which protection is sought, there is provided a battery module comprising a busbar assembly and a plurality of cylindrical cells, each of the cylindrical cells comprising a first end surface, wherein:

a first terminal of each of the cylindrical cells is located in a substantially central region of the first end surface;

at least a part of a second terminal of each of the cylindrical cells is located in an peripheral region of the first end surface;

20 each of the cylindrical cells is arranged to circumferentially abut at least two other cylindrical cells and the cylindrical cells are arranged within the battery module in a common orientation, such that the first end surfaces of all of the cylindrical cells are substantially coplanar;

the busbar assembly is located proximate to the first end surfaces of the plurality of cylindrical cells and comprises a first component electrically connected to the first terminals via a plurality of first terminal connection tabs and a second component electrically connected to the second terminals via a plurality of second terminal connection tabs; and

25

at least some of the second terminal connection tabs are electrically connected to the second terminal of at least two of the cylindrical cells. Advantageously, each cell abutting at least two other cells may help to prevent individual cells from overheating, as adjacent cells will act as heat sinks. Furthermore, the second terminal connection tabs may connect to the shoulder regions of two adjacent cylindrical cells, which allows for fewer connection tabs to be used.

30

In an embodiment the first component comprises a first group of fingers and the second component comprises a second group of fingers, and wherein at least some of the first terminal connection tabs extend from the first group of fingers and at least some of the second terminal connection tabs extend from the second group of fingers.

35 The first terminals may comprise positive terminals and the second terminals may comprise negative terminals. It will be understood that it is conventional for the positive terminal of a cylindrical cell to be defined on a cap at a first end, and for the negative terminal to be defined on a cell casing which covers a second end opposite the first end,

the entire cylindrical surface between the first and second ends, and a peripheral or "shoulder" region of the first end. Accordingly, the negative terminal of each cell may comprise a casing of the cell.

In an embodiment, the second terminal connection tabs are connected to the peripheral regions of two adjacent cells.

- 5 In an embodiment, each of the first and second busbar components are formed from aluminium.

Optionally, the first and second terminal connection tabs are formed from copper. The first and second terminal connection tabs may be coated with a material to prevent oxidation such as nickel.

According to a further aspect of the invention for which protection is sought, there is provided a vehicle comprising a battery module as described above.

- 10 According to a further aspect of the invention for which protection is sought, there is provided a component of a busbar assembly for electrically connecting a plurality of cylindrical cells in a battery module, wherein each cylindrical cell comprises a positive terminal and a negative terminal, the component comprising:

an end bar and a first group of fingers extending from the end bar, each of the fingers in the first group comprising a plurality of connection tabs,

- 15 wherein at least some of the fingers are tapered such that a cross sectional area of each tapered finger is greater in a proximal portion of the finger than a distal portion of the finger. Advantageously, this may provide a better optimised distribution of current as compared to prior art busbar components.

In an embodiment, at least some of the fingers are serpentine. Advantageously, this may help to ensure that a path with minimal obstruction is provided for any vent gases that may be ejected by a malfunctioning cell.

- 20 In an embodiment, the fingers are formed from aluminium. The connection tabs may be formed from copper and may be provided with a metallic coating to prevent oxidation. For example the metallic coating may be a nickel coating.

According to a further aspect of the invention for which protection is sought, there is provided a busbar assembly comprising a plurality of components as described above.

- 25 According to a further aspect of the invention for which protection is sought, there is provided a battery module comprising a plurality of cells and a busbar assembly or one or more components as described above.

In an embodiment, the battery module further comprises a housing and a cell carrier arranged to position the cells within the housing, the cell carrier being made from an electrically insulating material. Optionally, the cell carrier is also configured to position the components of the busbar assembly. Advantageously, the cell carrier may help to ensure that adequate separation is always maintained between components that are not intended to be electrically connected to one another.

30

According to a further aspect of the invention for which protection is sought, there is provided a vehicle comprising a battery module as described above.

According to another aspect of the invention for which protection is sought, there is provided a busbar assembly for electrically connecting a plurality of cylindrical cells in a battery module, wherein each cylindrical cell comprises a positive terminal and a negative terminal, the busbar assembly comprising:

5 a first component comprising a positive end bar and a first group of fingers extending from the positive end bar, each of the fingers in the first group comprising a plurality of positive connection tabs;

a second component comprising a negative end bar and a second group of fingers extending from the negative end bar, each of the fingers in the second group comprising a plurality of negative connection tabs; and

10 an intermediate component comprising a third group of fingers and a fourth group of fingers electrically connected to the third group of fingers, each of the fingers in the third group of fingers comprising a plurality of negative connection tabs and each of the fingers in the fourth group of fingers comprising a plurality of positive connection tabs, wherein the first group of fingers are arranged to interleave with the third group of fingers and the second group of fingers are arranged to interleave with the fourth group of fingers. Advantageously, this provides a single-sided busbar assembly with a reduced height as compared to prior art busbar assemblies.

15 Optionally, the busbar assembly comprises at least one additional intermediate component. In an embodiment, the additional intermediate component comprises a fifth group of fingers and a sixth groups of fingers electrically connected to the fifth group of fingers, each of the fingers in the fifth group of fingers comprising a plurality of negative connection tabs and each of the fingers in the sixth group of fingers comprising a plurality of positive connection tabs, wherein the fifth group of fingers are arranged to interleave with the fourth group of fingers or the first group of fingers, and wherein the sixth group of fingers are arranged to interleave with the third group of fingers or the second
20 group of fingers. The intermediate component and the additional intermediate component may be substantially identical to one another. In some embodiments, several additional intermediate components may be provided.

In an embodiment, each of the positive connection tabs is arranged to connect to a positive terminal of a respective one of the cylindrical cells. Each of the negative connection tabs may be arranged to connect to a negative terminal of one or more of the cylindrical cells.

25 In an embodiment, each of the negative connection tabs is arranged to connect to a negative terminal of two of the cylindrical cells.

In an embodiment at least some of the fingers in the first, second, third and fourth groups are tapered such that a cross sectional area of each tapered finger is greater in a proximal portion of the finger than a distal portion of the finger. Advantageously, this may provide a better optimised current distribution as compared to prior art busbar
30 assemblies.

At least some of the fingers in the first, second, third and fourth groups may be serpentine.

In an embodiment the fingers of each of the first, second and intermediate busbar components are at least partly formed from aluminium. The fingers may be formed substantially from aluminium or entirely from aluminium.

35 Optionally, the positive and negative connection tabs are at least partly formed from copper. The positive and negative connection tabs may be coated with a material to prevent oxidation. For example, the positive and negative connection tabs may be coated with nickel.

According to another aspect of the invention for which protection is sought there is provided a battery module comprising a busbar assembly as claimed in any preceding claim and a plurality of cylindrical cells.

The battery module may comprise a cell carrier arranged to position the cells within a housing of the battery module, the cell carrier being made from an electrically insulating material.

5 Optionally, the cell carrier is configured to position one or more components of the busbar assembly.

In an embodiment, a plurality of upwardly extending tabs for positioning the one or more components of the busbar assembly are provided on the cell carrier.

In an embodiment, the plurality of cylindrical cells comprises a first group of cells and a second group of cells, wherein:

10 the positive terminal of each cell in the first group of cells is electrically connected to a finger in the first group of fingers via a positive connection tab;

the negative terminal of each cell in the first group of cells is electrically connected to a finger in the third group of fingers via a negative connection tab;

15 the negative terminal of each cell in the second group of cells is electrically connected to a finger in the second group of fingers via a negative connection tab;

the positive terminal of each cell in the second group of cells is electrically connected to a finger in the fourth group of fingers via a positive connection tab,

20 whereby the cells in the first group of cells are electrically connected to one another in parallel, the cells in the second group of cells are electrically connected to one another in parallel, and the first and second groups of cells are electrically connected in series.

In an embodiment, each of the cylindrical cells circumferentially abuts at least one, preferably at least two, other cylindrical cells.

The negative terminal of each cell may comprise a casing of the cell.

25 In an embodiment, casing of each cell covers a peripheral region of the first end surface, and wherein the negative connection tabs are connected to the peripheral regions of the first end surfaces of two adjacent cells.

According to a further aspect of the invention for which protection is sought there is provided a vehicle comprising a battery module as described above.

30 Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

35 BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described by way of example only, with reference to the accompanying figures, in which:

Figures 1A-C show different views of a cylindrical cell that may be used in a vehicle battery module (PRIOR ART);

5 Figure 2 shows a group of cylindrical cells mechanically bonded together according to an embodiment of the present invention;

Figure 3 shows an exploded view of a sub-assembly comprising a busbar assembly and a group of cylindrical cells according to an embodiment of the present invention;

10 Figure 4A shows a plurality of groups of cells electrically connected together by a plurality of busbar assemblies as shown in figure 3;

Figure 4B shows a cross section through the groups of cells shown in figure 4A;

Figure 5 shows an exploded view of a battery module in an embodiment of the present invention;

Figure 6 shows a flow chart illustrating a method of assembling a battery module according to an embodiment of the present invention;

15 Figure 7 shows a plurality of groups of cells electrically connected together by a busbar assembly in another embodiment of the present invention;

Figure 8 shows a busbar assembly in another embodiment of the present invention; and

Figure 9 shows a vehicle in an embodiment of the present invention.

DETAILED DESCRIPTION

20 Figures 1A-C show different views of a conventional cylindrical cell 100. Cylindrical cells 100 are widely available in a variety of different sizes. For example, in traction batteries for vehicles cells having a diameter D of 21mm and a length L of 70mm are often used. Such cells are typically referred to as 21700 cells (the first two numbers referring to the diameter D, in mm, and the last three numbers referring to the length L, in tenths of mm). However, it will be understood that other sizes of cell may also be used in embodiments of the present invention.

25 As will be well understood by the skilled person, the cell 100 comprises a positive terminal 100P, a negative terminal 100N, and vent means 100V. The positive terminal is provided by a steel end cap 106 in a central region of the first end 104 of the cell, and the negative terminal is provided by a steel cylindrical case 108. The steel cylindrical case 108 covers the second end 102, the entire cylindrical surface between the first and second ends, and a peripheral region 100S of the first end surface. The peripheral region of the first end surface may also be referred to as a
30 "shoulder" region 100S of the first end surface 104. In commercially-available cells, it is sometimes the case that the end cap that defines the positive terminal 100P on the first end surface 104 protrudes beyond the shoulder region of the first end surface, although this is not the case in the cell shown in figure 1. This allows a substantially planar connector to be connected to the positive terminal and not the negative terminal. As will be well understood by the skilled person, it is important to avoid direct electrical connections between the positive and negative terminals, as
35 such connections create a short circuit which may damage the cell.

As shown in figure 1, the cell 100 comprises three vent means 100V in the first end surface 104, between the steel end cap 106 that defines the positive terminal 100P and the shoulder region 100S of the steel cylindrical case 108. The vent means 100V are gaps that are covered by a material that will rupture to allow hot gases to escape through

the gap between the end cap 106 and steel cylindrical case 108 in the event of excessive pressure occurring inside the cell, thereby mitigate against the risk of the cell exploding.

Figure 2 shows a block 200 comprising a plurality of cylindrical cells 100 mechanically joined together via an adhesive on the cylindrical surfaces of the cells 100. At its narrowest point, the adhesive has a thickness of 0-0.5mm, preferably 0.2-0.4mm. It will be understood that the diameter of the cells is not controlled to a very high dimensional tolerance. Accordingly, the thickness of the layer of adhesive between adjacent cells may vary depending upon the actual dimensions of the cells, and this variation may help to mitigate the effects of the dimensional tolerance of the cells 100 on the overall dimensional tolerance of the block 200.

The block 200 shown in figure 2 comprises 30 cylindrical cells arranged in a common orientation and in a side-to-side configuration. The block comprises six rows of five cells, each row being offset from the adjacent rows by a distance approximately equal to the radius of one of the cylindrical cells, thereby improving the efficiency with which the cells can be packaged into a given volume. It will be understood that other configurations of the block 200 are also useful, and that the block may comprise more or fewer cells in different embodiments.

The adhesive layer between the cells 100 in the block 200 has a relatively high electrical resistance. As such, whilst the cells 100 in the block 200 are mechanically joined together, the cylindrical surfaces (which form part of the negative terminal of the cells) are not likely to be electrically connected to one another. However, as will be explained in more detail below, when the blocks 200 are assembled to form part of a battery module, the cells within each block will all be electrically connected together in parallel. Accordingly, it is perfectly acceptable for electrical connections to be present between the cylindrical surfaces of some or all of the cells within the block 200.

As will be understood by the skilled person, a block of cells 200 may be manufactured in a suitable jig, which may hold the cells 100 in the correct relative positions whilst the adhesive is applied and during curing of the adhesive.

Figure 3 shows an exploded view of a sub-assembly 300 for incorporation into a battery module. The sub-assembly 300 comprises the group of cells 200 shown in figure 2, with an electrically-insulating wrap 302 disposed around the group of cells, such that the outer-facing cylindrical surfaces of the cells in the group 200 are all covered by the wrap 302. A single-sided busbar assembly 304 is provided adjacent to the first ends of the cells within the group of cells 200. The busbar assembly 304 is arranged to electrically connect all of the cells within the group 200 in parallel with one another.

Busbar assembly 304 comprises a negative collection plate 308 arranged to be electrically connected to the negative terminals of all of the cells within the group of cells 200. The connection between the negative collection plate 308 and the negative terminals of the cells is facilitated by thin metallic sheet 306. In the illustrated embodiment, the negative collection plate 308 is formed from Aluminium and the metallic sheet 306 is formed from Copper plated with Nickel. The electrical and mechanical connections between the negative terminals, the metallic sheet 306 and the negative collection plate 308 will be discussed in more detail below.

Busbar assembly 304 further comprises a positive collection plate 314 arranged to be electrically connected to the positive terminals of all of the cells within the group of cells 200. The connections between the positive collection plate 314 and the positive terminals of the cells is facilitated by a further thin metallic sheet 312. An insulating layer

310 is positioned between the negative collection plate 308 and the thin metallic sheet 312, to ensure that the positive and negative collection plates are electrically isolated from one another.

Before the busbar assembly 304 is connected to the group of cells 200, each of the thin metallic sheets 306, 312 are electrically and mechanically connected to the respective collection plate 308, 314, by welding a portion of the metallic sheet to the respective collection plate. Although this can be achieved by any suitable welding method, laser welding through the thin metallic sheets is particularly effective. Once the metallic sheet 306 is welded to the negative collection plate 308, a negative busbar component 316 is formed having a plurality of negative tabs 306T extending away from the body of the negative collection plate 308. As will be explained in more detail below, the negative tabs 306T can be welded to the negative terminals of the cells in the group of cells 200, and the positioning of the tabs is such that each cell 100 can be connected to a respective tab 306T when the negative busbar component 316 is correctly positioned relative to the group of cells 200. Similarly, when the thin metallic sheet 312 is welded to the positive collection plate 314, a positive busbar component 318 is formed. The positive busbar component comprises a plurality of positive tabs 312T that can be welded to respective positive terminals of the cells in the group of cells 200, and the positioning of the tabs is such that each cell 100 can be connected to a respective tab 312T when the positive busbar component 318 is correctly positioned relative to the group of cells 200. As can be seen from figure 3, the negative tabs 306T are coplanar with the rest of the metallic sheet 306, whereas the positive tabs 312T extend outwardly and downwardly from the portions of the metallic sheet 312 that are welded to the positive collection plate 314. This allows the positive tabs to pass through void spaces in the negative busbar component 316 and the insulating layer 310 and to connect to the positive terminals of the cells 100, without contacting any part of the negative busbar component. It will be appreciated that the extent to which the tabs 312T extend downwardly will depend, at least in part, on the shape of the cells used in the group, in particular, the extent to which the steel end cap 106 extends above-, or is recessed below the shoulder region 100S.

Once the positive and negative busbar components 316, 318 are formed by welding the metallic sheets to the respective collection plates, the busbar assembly 304 may be formed by mechanically joining the positive and negative busbar components, with the insulating layer 310 disposed between the two busbar components. This may be achieved by passing electrically-insulating fixings through the aligned holes 314H, 312H, 310H, 308H, 306H in the collection plates, the metallic sheets and the insulating layer. Additionally or alternatively, the insulating layer 310 may have integrally formed fixings arranged to locate into and cooperate with through holes in the busbar components, these fixings may then be heat staked or ultrasonically welded once the busbar components have been correctly placed either side of the insulating layer. Additionally or alternatively, the two busbar components may be secured to the insulating layer 310 by a suitably electrically insulating adhesive.

Once the busbar assembly 304 is formed, it is positioned adjacent to the group of cells 200 such that the positive and negative tabs 306T, 312T are in contact with the positive and negative terminals of the cells 100 within the group of cells 200. The tabs are then electrically and mechanically connected to the respective terminals by laser welding. It will be understood that other methods of electrically and mechanically connecting the tabs to the terminals, including but not limited to other welding techniques, are also useful.

Each of the positive connection tabs 312T is positioned adjacent to a respective positive terminal of a single cell 100 within the group of cells 200, and a planar portion of the tab is laser welded to the positive terminal 100P. The

negative tabs 306T are each positioned adjacent to the shoulder regions 100S of respective cells 100, which regions form part of the negative terminal of the cells. However, unlike the positive tabs 312T, several of the negative tabs 306T are positioned adjacent to the shoulder regions 100S of two adjacent cells 100 within the group of cells 200. For example, it can readily be seen that tab 306TA will be positioned adjacent to the shoulder regions of both of cells 100A, 100B, and that tab 306TA can be used to electrically and mechanically connect both of the cells 100A, 100B to the negative busbar component 316. As will be understood by the skilled person, several of the other tabs 306T are also connectable to the shoulder regions of two adjacent cells 100 within the group of cells 200.

When laser welding the tabs 306T, 312T to the respective terminals, it is important to control the amount of energy used in the weld to ensure that the internal components of the cells are not damaged by the heat generated during the welding process. Accordingly, laser welding may be a particularly suitable technique, as it enables precise control of the amount of energy applied during each weld operation.

Once all of the terminals are welded to the tabs, all of the positive terminals within the group of cells 200 are electrically connected together, and all of the negative terminals within the group of cells 200 are electrically connected together. Accordingly, the cells 100 within the group 200 are electrically connected together in parallel. The sub-assembly 300 may therefore be referred to as a "parallel set" or a "P set". A battery module may comprise a plurality of assemblies 300 electrically connected together in series or in parallel, or a combination of assemblies connected in series and assemblies connected in parallel as may be required in order to achieve the desired battery voltage and current capacity.

Figure 4A shows a plurality of assemblies 300A-D as illustrated in figure 3, with parallel and series connections made between adjacent assemblies, so as to provide an arrangement having increased voltage and current capacity as compared to a single sub-assembly 300. Figure 4A also shows a coordinate system. In the following description, the X axis shown in figure 4A may be referred to as a "longitudinal" axis, and the Y axis may be referred to as a "transverse" axis. However, it will be understood that this notation is merely for convenience. In particular, the use of "longitudinal" and "transverse" does not imply that the sub-assemblies must have a greater length along the longitudinal or transverse axis. Accordingly, in some embodiments the sub-assemblies may have a greater length along their transverse axis than along their longitudinal axis, in some embodiments the sub-assemblies may have a greater length along their longitudinal axis than along their transverse axis, and in other embodiments the lengths along the longitudinal and transverse axes may be equal.

In figure 4A, the positive collection plate of the sub-assembly 300A is electrically connected to the negative collection plate of the sub-assembly 300C, thereby providing a series connection between the assemblies 300A and 300C. Similarly, the positive collection plate of the sub-assembly 300B is electrically connected to the negative collection plate to the sub-assembly 300D, thereby providing a series connection between the assemblies 300B and 300D. As will be well understood by the skilled person, provision of series connections between assemblies 300 allows a battery module comprising a plurality of assemblies to output a substantially higher voltage than the individual cells within the housing.

The series connections between assemblies that are adjacent along the X axis shown in figure 4A are facilitated by the series connection portion 320 on each of the positive collection plates 314 and the corresponding first series

connection portion 322 on each of the negative collection plates 308. As best shown in figure 4B, when the assemblies 300A, 300C are positioned adjacent to each other in the longitudinal end-to-end orientation shown in figure 4A, the series connection portion 320A of sub-assembly 300A is in contact with the series connection portion 322C of the sub-assembly 300C. As best shown in figure 4B, the first series connection portion 320A substantially
5 overlies the second series connection portion 322C.

Figure 4B shows a schematic cross sectional view taken through an arrangement similar to that shown in figure 4A, taken along the XZ plane shown in figure 4A. In figure 4B, only the respective collection plates 308, 314 and insulating layers 310 are visible, for ease of illustration. As can be seen in figure 4B, each of the positive collection plates 314A, C includes a first series connection portion 320A, C, which extends beyond the ends of the respective
10 insulating layer 310A, C and negative collection plate 308A, C. The first series connection portions 320A, C also extend in a downward direction, such that a lower surface of the series connection portion is substantially coplanar with an upper surface of the negative collection plates 308A, C.

Each of the assemblies 300A, C also includes a second series connection portion 322A, C at an opposite end to the respective first series connection portion 320A, C. The second series connection portions 322A, C comprise a
15 portion of the negative collection plates 308A, C that extends beyond the ends of the respective insulating layer 310A, C and positive collection plate 314A, C. In this way, when the two assemblies 300A, C are placed adjacent to each other in the orientation shown in figures 4A and 4B, the first series connection portion 320A of the sub-assembly 300A is in contact with the second series connection portion 322C of the sub-assembly 300B, thereby providing an electrical connection between the positive collection plate 314A and the negative collection plate 308C. The first
20 series connection portion 320A and the second series connection portion 322C are then mechanically joined by welding. This improves the electrical connection between the collection plates, and also helps to mechanically fix the assemblies 300A, C together in the required orientation.

It will be understood that various configurations of the first and second series connection portions are possible and would allow series connections to be made between assemblies placed adjacent to one another in a longitudinal
25 end-to-end arrangement as shown in figures 4A and B (i.e. adjacent to one another and arranged in a linear fashion along the X axis shown in figure 4A). For example, instead of the first connection portions 320 extending in a downward direction (as shown in figure 4B), the second connection portions 322 could extend in an upward direction, or both connection portions could extend towards one another. As will be well understood, what is important is that, when two assemblies 300 are placed adjacent to one another in a longitudinal end-to-end arrangement, the
30 respective first and second series connection portions 320, 322 must be sufficiently close together that they can be easily electrically connected together. A reliable and robust electrical and mechanical connection between the series connection portions is preferably formed by welding and/or soldering, but it will be understood that other connection means such as screws, bolts or rivets could be used instead or in addition. In some embodiments, the first series connection portions 320 may have a reduced thickness compared to the rest of the positive collection plate 314, so
35 as to facilitate welding of the first and second connection portions 320, 322 together through the top surface of the first connection portion 320.

Referring back to figure 4A, it will be recognised that parallel connections are also present between assemblies that are adjacent to one another and arranged in a linear fashion along the Y axis shown in figure 4A (i.e. assemblies

positioned in a transverse end-to-end arrangement). Specifically, a parallel connection is present between assemblies 300A and 300B, and another parallel connection is present between assemblies 300C and 300D. Each of the negative collection plates 308 comprises a first parallel connection portion 324 and a second parallel connection portion 326 located at opposite transverse ends of the negative collection plate 308. When the assemblies are placed in a transverse end-to-end arrangement (as is the case in figure 4A for assemblies 300A and B, and for assemblies 300C and D) the first parallel connection portion 324 of one of the negative collection plated 308 is positioned proximate to, but not in contact with, the second parallel connection portion 326 of another one of the negative collection plates 308. In the arrangement shown in figure 4A, the first connection portions 324B, D are positioned proximate to the second connection portions 326A, C, respectively. Parallel connections between assemblies 300A and 300B, and between assemblies 300C and 300D, are then formed by connectors 328, which electrically connect the proximate first and second parallel connection portions.

The array of assemblies 300 shown in figure 4A may be utilised as a battery by connecting a negative terminal connector (not shown in figure 4) to the series connection portions 322A and 322B, and connecting a positive terminal connector (not shown in figure 4) to the series connection portions 320C, 320D. Such a battery would have a voltage level that is double the voltage of an individual cell, because there are effectively two groups of cells in series with each other, the first group comprising all the cells in assemblies 300A and 300B, and the second group comprising all of the cells in assemblies 300C and 300D. In some embodiments, such a battery may be placed within a housing, to form a battery module. However, it will be understood that typical battery modules may comprise substantially more assemblies 300 than are shown in figure 4, with the total number of assemblies depending on the required voltage level and charge capacity. For example, figure 5 shows an exploded view of a battery module 500 including a total of 22 modules 300, arranged in two rows, each row comprising eleven modules 300 arranged in a transverse end-to-end arrangement, and with the two rows being adjacent to each other in a transverse end-to-end arrangement.

In the module 500, the assemblies 300 are with the first ends 104 of the cells facing downwards, such that the busbar components are underneath the cells. Because no connections are present at the second ends 102 of the cells, it is possible for the second ends to be cooled by cooling plate 502, without intermediate components affecting the cooling efficiency. A layer of thermal interface material 504 is positioned between the second ends 102 of the cells 100 and the cooling plate 502, to improve the thermal connection between the cells and the cooling plate.

It is a particular advantage of embodiments of the present invention that a battery module having a very large overall number of cells can be constructed from a large number of substantially identical assemblies, each of which can be individually tested before it is incorporated into the battery module. A method of assembling such a battery module will be discussed in more detail below with respect to figure 6.

A particular advantage of providing first and second parallel connection portions 324, 326 that are proximate to one another but not in electrical contact when two assemblies 300 are positioned adjacent to one another in a transverse end-to-end arrangement is that this allows parallel connections to be made if required, but also retains the possibility that parallel connections between adjacent assemblies are not made. This introduces flexibility in the voltage output that can be provided by a given array of assemblies 300. For example, in some embodiments, four assemblies 300 may be arranged as shown in figure 4A, but the connectors 328 that provide the parallel connections between

adjacent assemblies may be omitted. Instead, a harness or other component may be provided to connect the series connection portion 320C to the series connection portion 322B, thereby producing a battery having four groups of cells arranged in series with one another, albeit with half of the number of cells in each group as compared to the arrangement actually shown in figure 4A. Conveniently, the harness may run along the space between the adjacent busbar assemblies.

Figure 6 is a flow chart showing a method 600 of manufacturing a battery module comprising a plurality of cylindrical cells, in an embodiment of the present invention.

The method starts at step 602 and proceeds to step 604, in which a plurality of cylindrical cells are positioned in a common orientation such that the first ends of the cells are substantially coplanar. Adjacent cells within the plurality of cells may abut one another, or they may be spaced apart by a small distance, which distance may be up to 2mm, but is preferably 0.5mm or less, most preferably 0.3mm or less. To ensure accurate positioning of the cells at the desired locations, this step may take place within a jig.

The cells are then joined together using an adhesive on the cylindrical surfaces in step 606. The adhesive may have a thickness of 0.5mm or less, preferably 0.3mm or less. It will be understood that in some embodiments, the adhesive could be applied before the cells are positioned relative to one another.

A busbar assembly is then connected adjacent to the first ends of the cells at step 608. The busbar assembly may comprise a positive connection plate which may be electrically connected to the positive terminals of all of the cells 100 that were joined together in step 606, and a negative connection plate which may be electrically connected to the negative terminals of all of the cells 100 that were joined together in step 606. In this way, all of the cells that were joined together in step 606 are electrically connected in parallel, thereby creating a sub-assembly 300. In some embodiments, the busbar assembly may be a busbar assembly 304 as shown in figure 3, and the electrical connections may be made by welding, preferably by laser welding.

The method then proceeds to step 610, in which to apply an electrically-insulating wrap around the sub-assembly 300, on the exposed cylindrical surfaces of the outermost cells in the sub-assembly 300.

In step 612 it is determined whether or not enough sub-assemblies have been made to produce the battery module with the desired voltage and/or capacity. If more sub-assemblies are still required, then the method returns to step 604. Once enough sub-assemblies have been manufactured, the method proceeds to step 614, in which the sub-assemblies are positioned within a housing, with at least some of the sub-assemblies arranged in a longitudinal end-to-end arrangement with each other. The sub-assemblies are then electrically connected together in step 616. In the case of the sub-assemblies that are arranged in a longitudinal end-to-end arrangement with one another, the electrical connections are established by electrically connecting a first series connection portion on a negative collection plate of one sub-assembly with a second series connection portion on a positive collection plate of another, adjacent sub-assembly, thereby electrically connecting the sub-assemblies in series. The electrical connections between the series connection portions may be established by welding the series connection portions together. If any of the sub-assemblies are to be positioned in a transverse end-to-end arrangement, then parallel connections may be made between such sub-assemblies by connecting corresponding parallel connection portions on the respective busbar assemblies. Such parallel connection portions may connect the negative collection plates of

adjacent sub-assemblies together, or they may connect the positive collection plates of adjacent sub-assemblies together. It will be understood that in some embodiments the order of steps 614 and 616 may be reversed, so that the sub-assemblies are electrically connected together and then subsequently positioned within the housing.

Once the requisite electrical connections are made between the sub-assemblies, the housing is sealed in step 617.

- 5 It will be understood that in some embodiments the housing or part of it will be substantially sealed against ingress of moisture. However, the sealing of the housing need not necessarily prevent ingress or egress of gases and/or moisture. Instead, the housing may be considered to be sealed once a closure is in place that prevents removal of the sub-assemblies from the housing.

The method then ends at step 618.

- 10 As will be well understood by the skilled person, various quality control checks may be carried out during different stages of the method 600. However, it is a particularly advantageous feature of the present invention that quality control checks can be carried out on the sub-assemblies before they are assembled together to produce the battery module. The only electrical connections that are made after the sub-assemblies are positioned in the module housing are between the busbar assemblies of adjacent sub-assemblies, and such connections are generally more reliable
- 15 than the connections between cells and the busbar assemblies. Accordingly, embodiments of the present invention help to avoid a situation in which a defective cell or connection can render an entire module unusable, requiring either an expensive repair process or scrapping of the entire battery module.

It will be understood that the order of the operations shown in figure 6 is not essential, and that in some embodiments the steps may be reordered, and/or some steps may be omitted entirely.

- 20 As will be well understood by the skilled person, it can be the case that a vehicle platform will provide a predefined amount of space for a battery module, and/or that battery modules having substantially similar geometry may be used between various different vehicle lines. Accordingly, it is particularly advantageous that embodiments of the present invention allow for battery modules having different voltage outputs and/or capacities to be produced with minimal alteration to the design of the module, and without affecting the module's packaging requirements.

- 25 Figure 7 shows part of a battery module 700 in another embodiment of the present invention constructed from a plurality sub-assemblies 702 and a busbar assembly 704. The battery module 700 comprises a plurality of groups 200 of cells 100 similar to those shown in figure 2. The cells 100 are mechanically bonded together with adhesive on the cylindrical surfaces of adjacent cells. As will be appreciated, in order to ensure consistency, the placement and subsequent joining of the cells may be performed using an assembly jig. Accordingly, adjacent cells within each
- 30 sub-assembly 702 are preferably spaced apart by less than 0.3mm.

- The groups 200 of cells 100 are then surrounded by an insulating wrap on the exposed cylindrical surfaces of the outermost cells, such that two sub-assemblies may be placed adjacent to one another without establishing electrical connections between the negative terminals of the adjacent groups. Accordingly, the sub-assemblies 702 differ from the sub-assemblies 300 only in that they are not provided with an individual busbar assembly before they are
- 35 assembled together. Instead, the six sub-assemblies 702 are positioned side-by-side, adjacent to one another within a battery module housing (not shown), and a busbar assembly 704 is subsequently welded to the first ends 104 of

the cells 100. Although the boundaries between the sub-assemblies 702A-F are not clearly visible in figure 7, it will be understood that each sub-assembly comprises six offset adjacent rows of five cells, the rows of five cells being parallel to the X axis shown in figure 7.

5 The busbar assembly 704 comprises a negative end busbar component 706, having an end bar 706E and seven fingers 706F extending from the negative end bar. The fingers 706F may be referred to as a first group of fingers 706F1. The middle five fingers 706F all follow a serpentine path, which helps to reduce the resistance to flow of vent gases out of any of the cells that may undergo a venting event, as the serpentine path avoids blocking the vent means 100V in the first ends 104 of the cells 100.

10 Each of the fingers comprises a plurality of negative connection tabs 712, which electrically connect the fingers to the negative terminals of all of the cells in sub-assemblies 702A and 702B. Specifically, the negative connection tabs are connected to the shoulder regions 100S of the cells. As can be clearly seen in figure 7, several of the negative connection tabs are connected to the shoulder regions 100S of two adjacent cells. This may simplify the process of welding the negative connection tabs to the shoulder regions 100S.

15 The busbar assembly 704 further comprises first and second intermediate components 708, 710. The first intermediate component 708 comprises a second group of fingers 708F2 and a third group of fingers 708F3. As can be seen from figure 7, the second group of fingers interleave with the first group of fingers 706F1, and are connected to the positive terminals of all of the cells within sub-assemblies 702A and 702B via positive connection tabs 714. The third group of fingers 708F3 are connected to the negative terminals of all of the cells within the sub-assemblies 702C and 702D, via negative connection tabs similar to the tabs 712 on the negative end component. Accordingly, 20 the first intermediate component and the negative end component connect all of the cells within sub-assemblies 702A and 702B in parallel, and the first intermediate component establishes a series connection with the cells in groups 702C and 702D.

25 The second intermediate component 710 is similar to the first intermediate component 708, and comprises a fourth group of fingers 710F4, which are similar to the second group of fingers 708F2, and which interleave with the third group of fingers 708F3. The second intermediate component also comprises a fifth group of fingers 710F5, which are similar to the third group of fingers 708F3. Although not shown in figure 7, a positive end component having a positive end bar and a sixth group of fingers that interleave with the fifth group of fingers and connect to the positive terminals of the cells within groups 702E and 702F may also be provided. However, in some embodiments, additional sub-assemblies and intermediate components may be present before the positive end component. As will 30 be well understood by the skilled person, the positive and negative end bars provide the positive and negative terminals of the battery module 700.

Figure 8 shows a busbar assembly 800 similar to the busbar assembly shown in figure 7. As will be understood by the skilled person, the busbar assembly 800 is arranged to make electrical connections between cells (not shown) in four groups 801A-D located at the positions indicated in figure 8. The cells within each group are all electrically 35 connected together in parallel, and adjacent groups are connected together in series.

Busbar assembly 800 comprises a negative end component 806, first, second and third intermediate components 808, 810, 812, and a positive end component 820. The end components 806, 820 each comprise a respective end

bar 806E, 820E. These end bars 806E, 820E can form or be connected to the respective terminals of the assembled battery module. The busbar assembly shown in figure 8 comprises interleaved fingers similar to those shown in figure 7. However, in the embodiment shown in figure 8, each finger is arranged to connect to 18 cells, so a higher current may be present in the fingers of the busbar shown in figure 8 as compared to the fingers of the busbar shown in figure 7, especially towards the proximal ends of the fingers. The fingers of the busbar shown in figure 8 are therefore tapered, such that they have a higher cross sectional area at their proximal ends as compared to their distal ends. This ensures that the overall current density is relatively uniform throughout the fingers of the busbar components shown in figure 8, and helps to reduce the overall cost and weight of the busbar assembly 800 and mitigates against localized hotspots occurring in the busbar in use which may otherwise adversely affect cells adjacent to those locally hotter regions.

Figure 9 shows a vehicle 900, into which a battery module 500, 700 according to an embodiment of the present invention can be incorporated.

It will be appreciated that embodiments of the present invention can be realised in the form of hardware, software or a combination of hardware and software. Any such software may be stored in the form of volatile or non-volatile storage such as, for example, a storage device like a ROM, whether erasable or rewritable or not, or in the form of memory such as, for example, RAM, memory chips, device or integrated circuits or on an optically or magnetically readable medium such as, for example, a CD, DVD, magnetic disk or magnetic tape. It will be appreciated that the storage devices and storage media are embodiments of machine-readable storage that are suitable for storing a program or programs that, when executed, implement embodiments of the present invention. Accordingly, embodiments provide a program comprising code for implementing a system or method as claimed in any preceding claim and a machine readable storage storing such a program. Still further, embodiments of the present invention may be conveyed electronically via any medium such as a communication signal carried over a wired or wireless connection and embodiments suitably encompass the same.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed. The claims should not be construed to cover merely the foregoing embodiments, but also any embodiments which fall within the scope of the claims.

CLAIMS

1. A battery module comprising a busbar assembly and a plurality of cylindrical cells, each of the cylindrical cells comprising a first end surface, wherein:
 - a first terminal of each of the cylindrical cells is located in a substantially central region of the first end surface;
 - 5 at least a part of a second terminal of each of the cylindrical cells is located in a peripheral region of the first end surface;
 - each of the cylindrical cells is arranged to circumferentially abut at least two other cylindrical cells and the cylindrical cells are arranged within the battery module in a common orientation, such that the first end surfaces of all of the cylindrical cells are substantially coplanar;
 - 10 the busbar assembly is located proximate to the first end surfaces of the plurality of cylindrical cells and comprises a first component electrically connected to the first terminals via a plurality of first terminal connection tabs and a second component electrically connected to the second terminals via a plurality of second terminal connection tabs; and
 - at least some of the second terminal connection tabs are electrically connected to the second terminal of at least two of the cylindrical cells.
 - 15
2. A battery module as claimed in claim 1, wherein the first component comprises a first group of fingers and the second component comprises a second group of fingers, and wherein at least some of the first terminal connection tabs extend from the first group of fingers and at least some of the second terminal connection tabs extend from the second group of fingers.
- 20 3. A battery module as claimed in claim 1 or claim 2, wherein the first terminal comprises a positive terminal and the second terminal comprises a negative terminal.
4. A battery module as claimed in any preceding claim, wherein the negative terminal of each cell comprises a casing of the cell.
5. A battery module as claimed in any preceding claim, wherein the second terminal connection tabs are connected to the peripheral regions of two adjacent cells.
- 25 6. A battery module as claimed in any preceding claim wherein each of the first and second busbar components are formed from aluminium.
7. A battery module assembly as claimed in claim 6, wherein the first and second terminal connection tabs are formed from copper.
- 30 8. A battery module as claimed in any preceding claim, wherein the first and second terminal connection tabs are coated with a material to prevent oxidation.
9. A battery module as claimed in claim 8, wherein the first and second connection tabs are coated with nickel.
10. A vehicle comprising a battery module as claimed in any preceding claim.

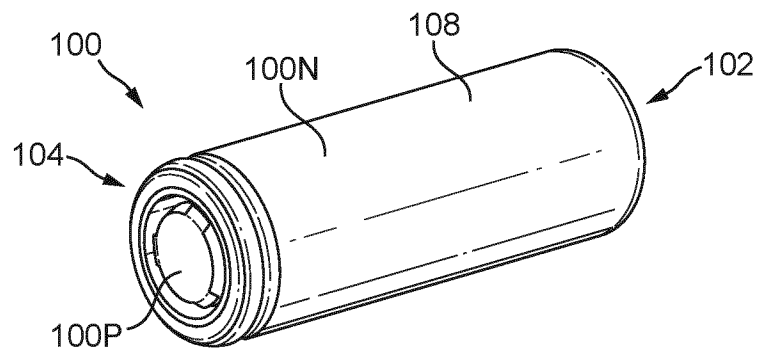


FIG. 1A
PRIOR ART

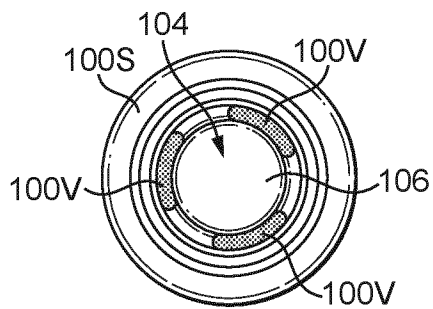


FIG. 1B
PRIOR ART

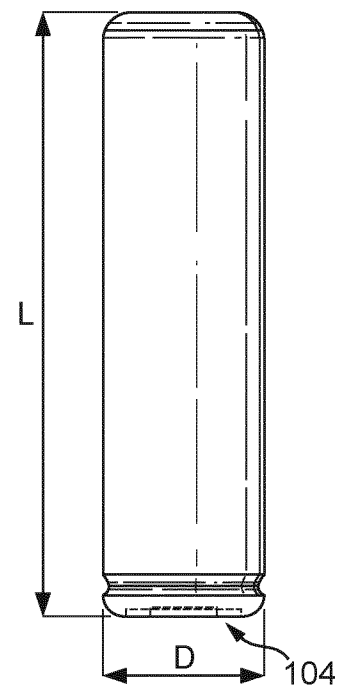


FIG. 1C
PRIOR ART

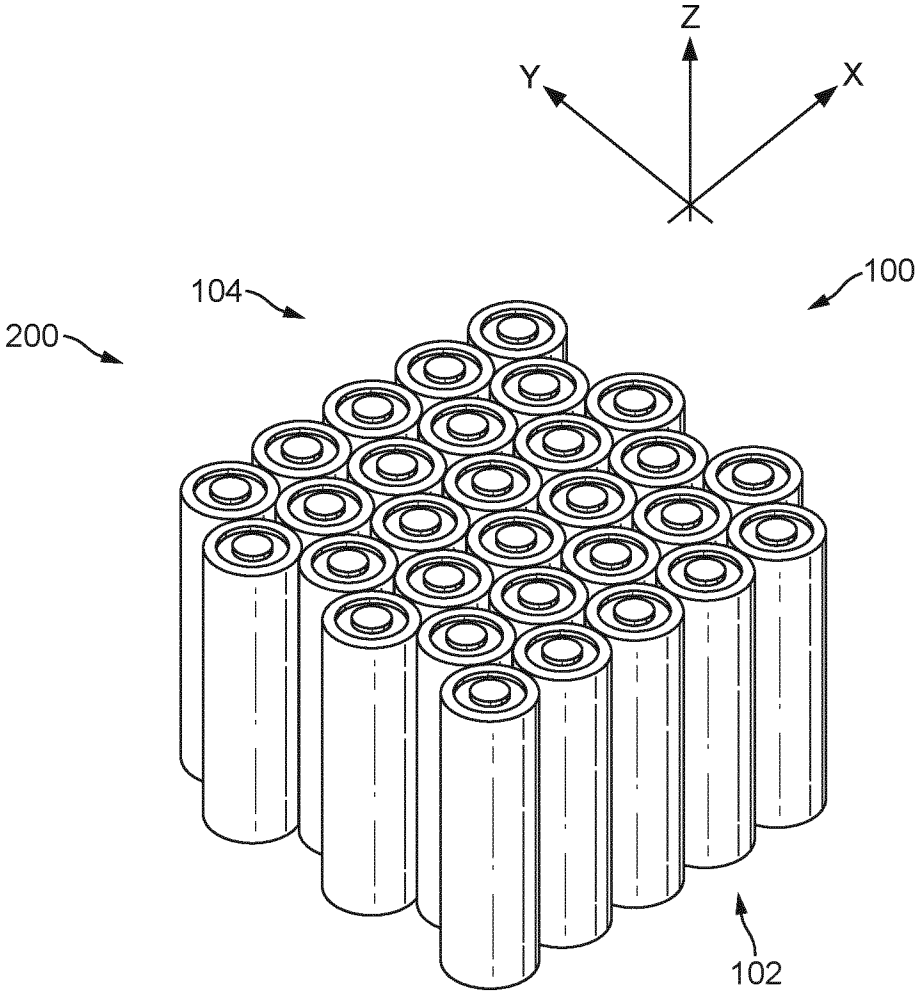


FIG. 2

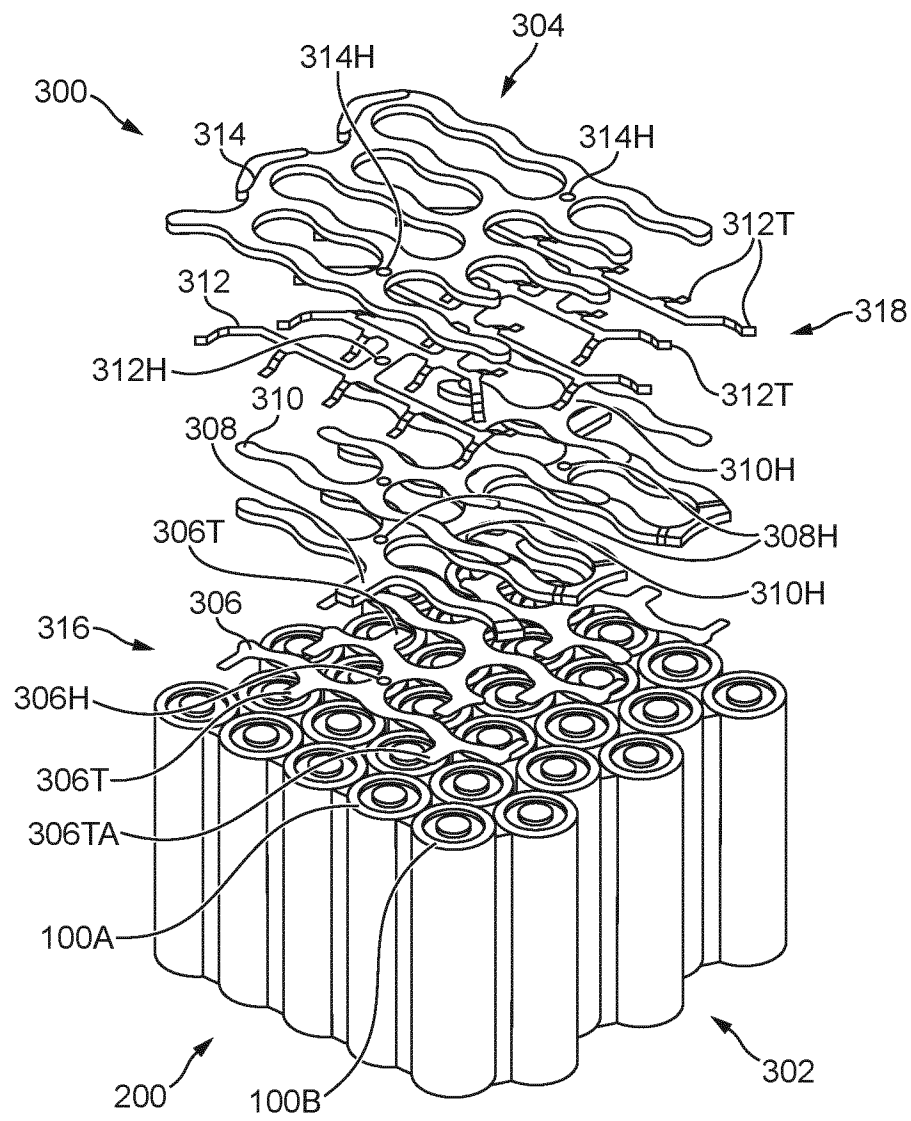


FIG. 3

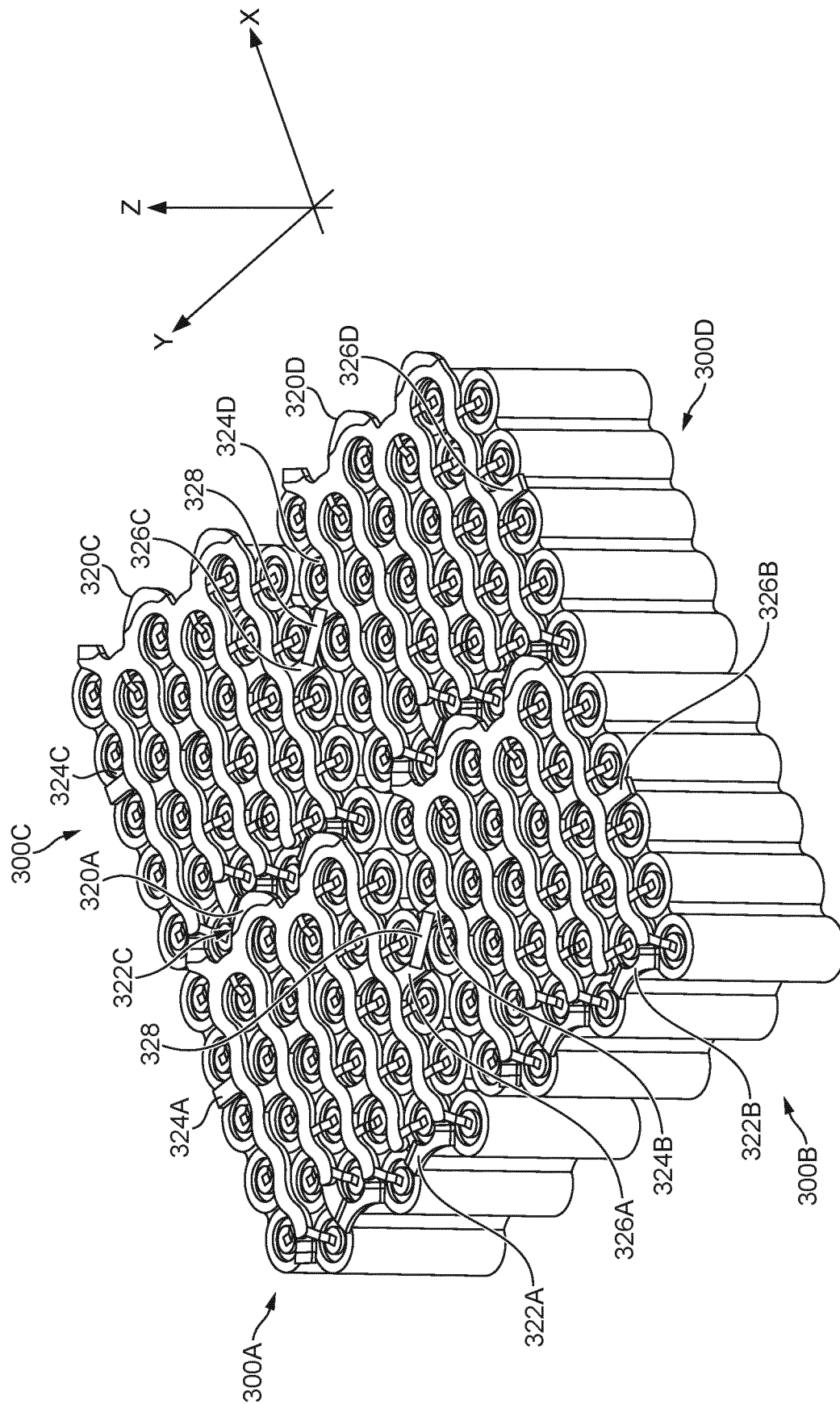


FIG. 4A

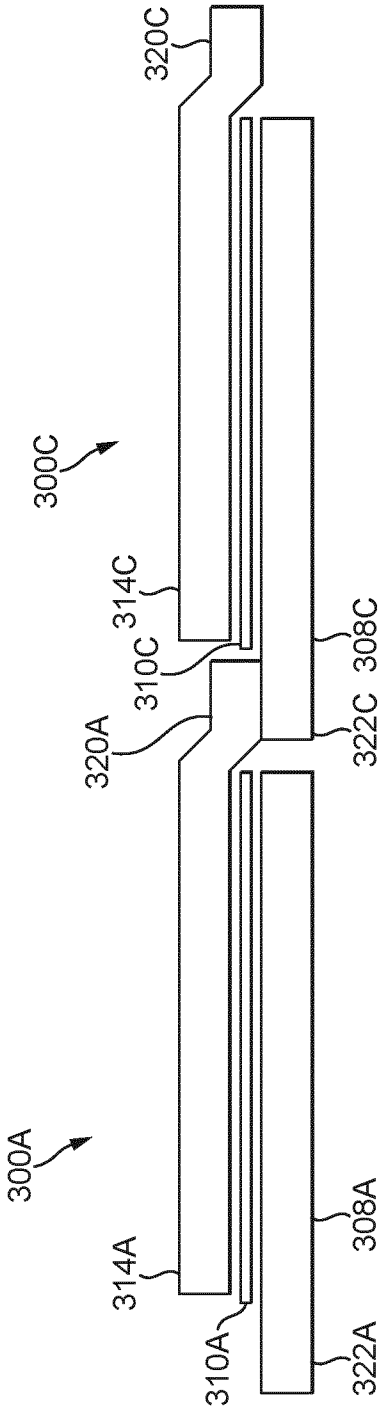


FIG. 4B

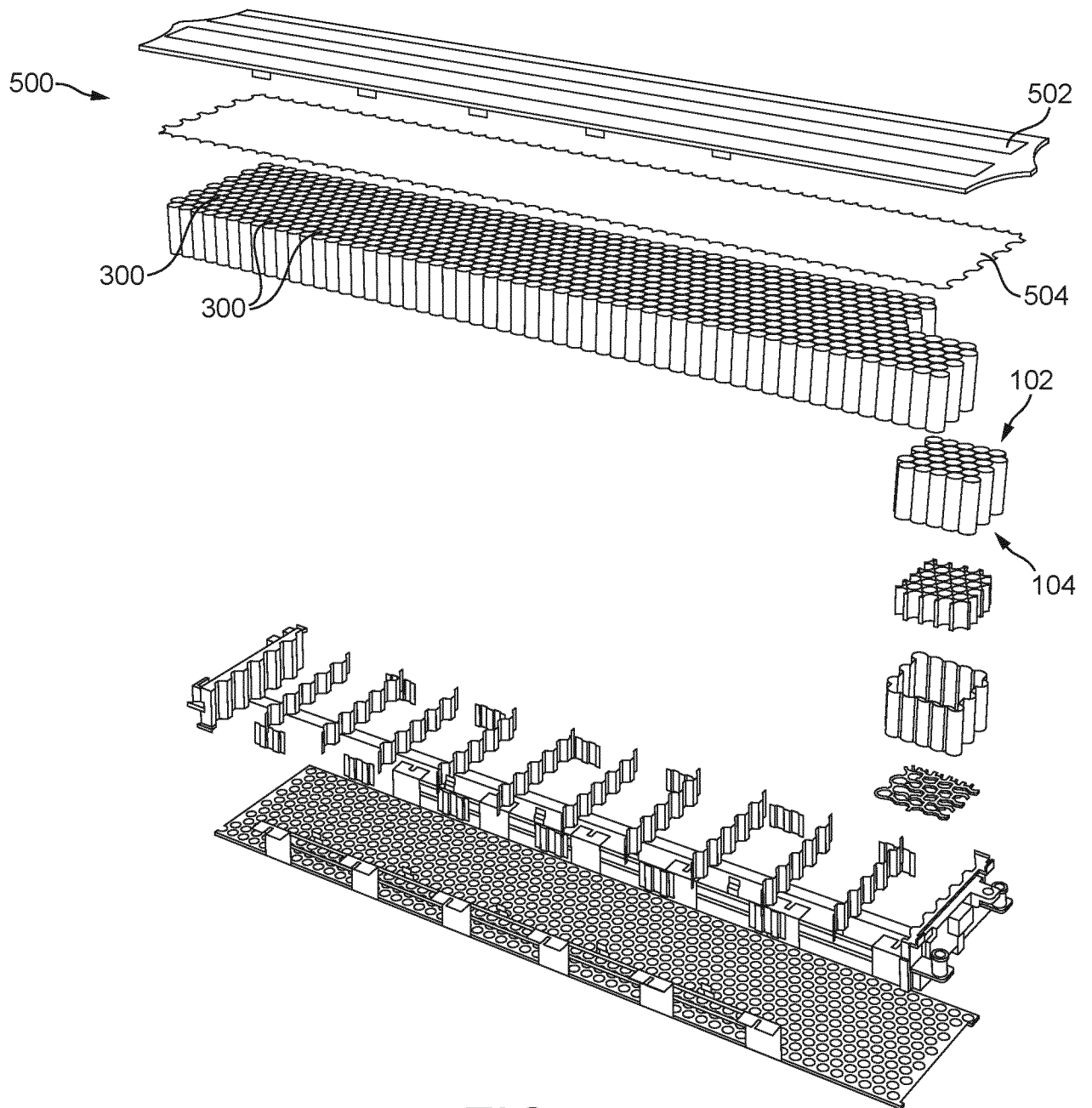


FIG. 5

7 / 10

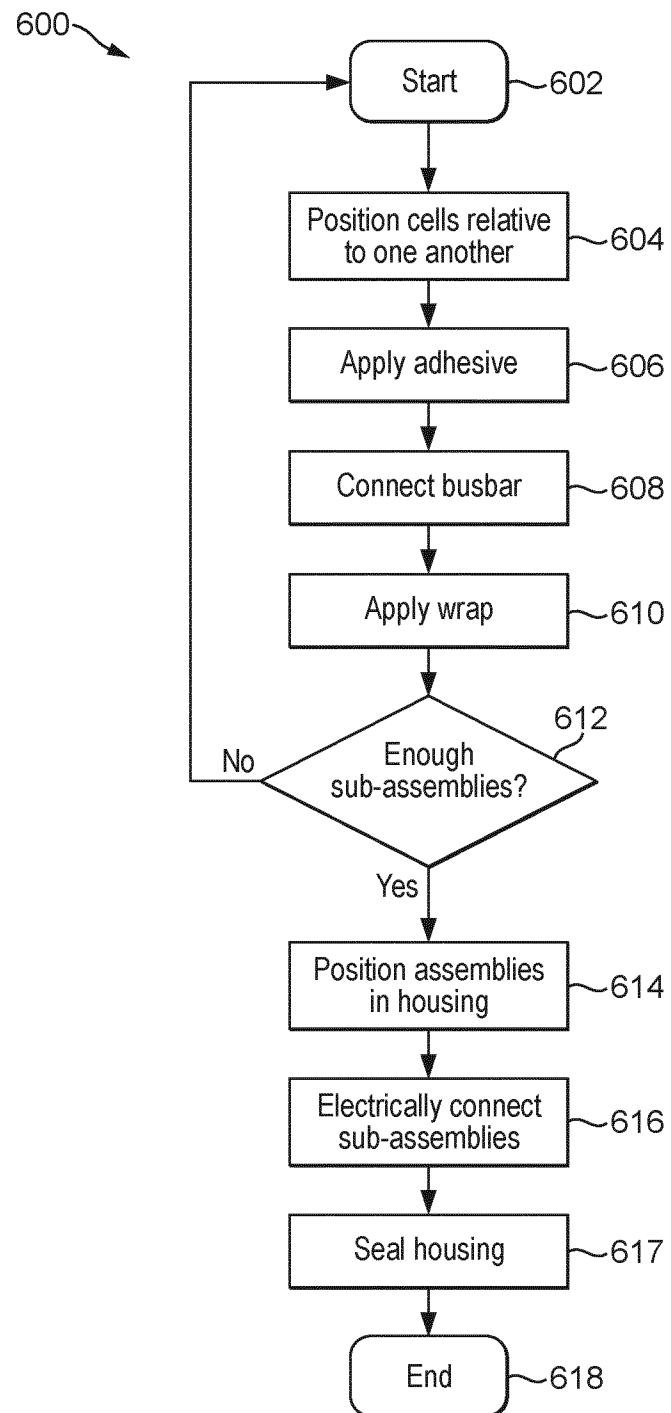


FIG. 6

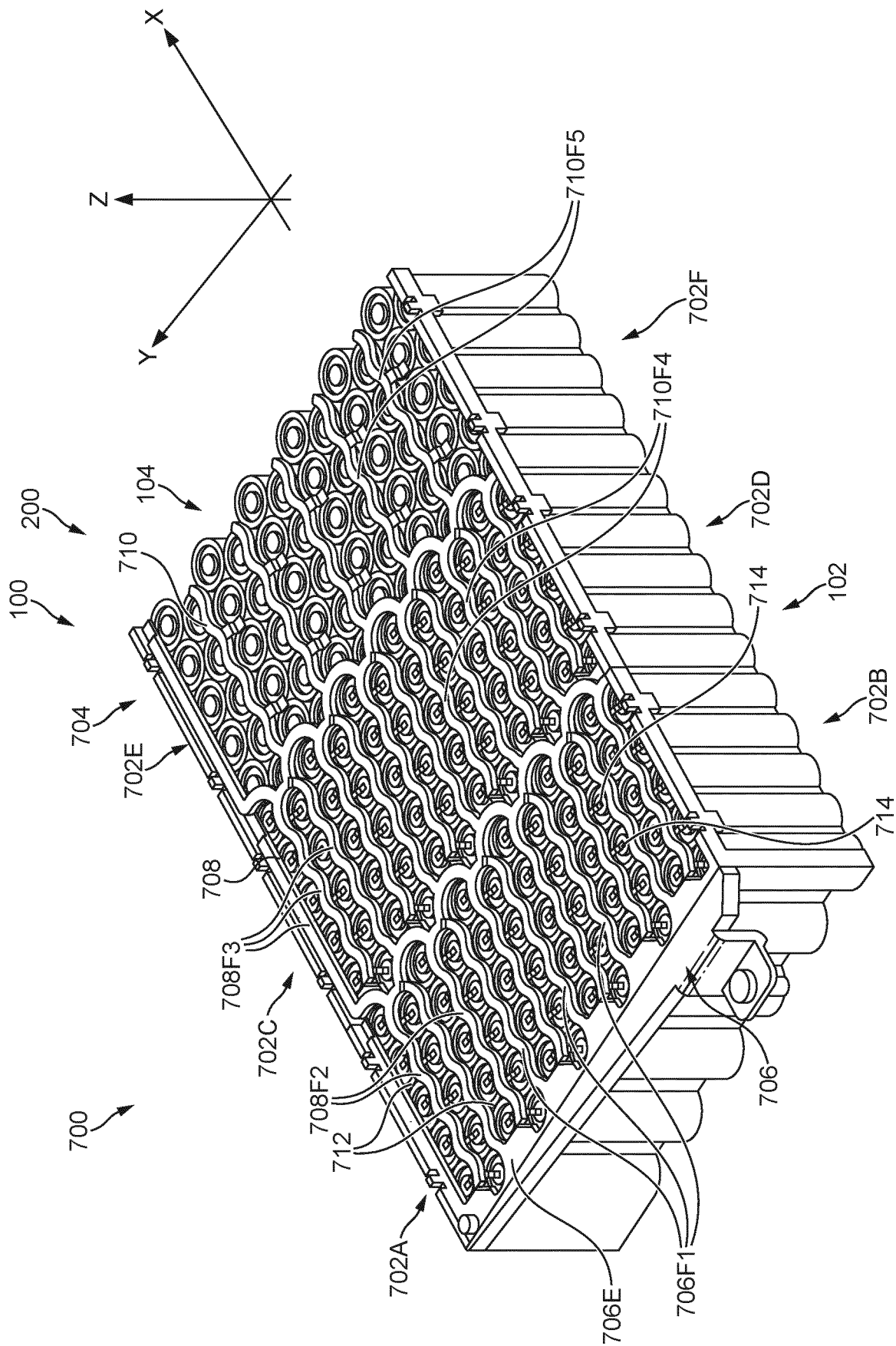


FIG. 7

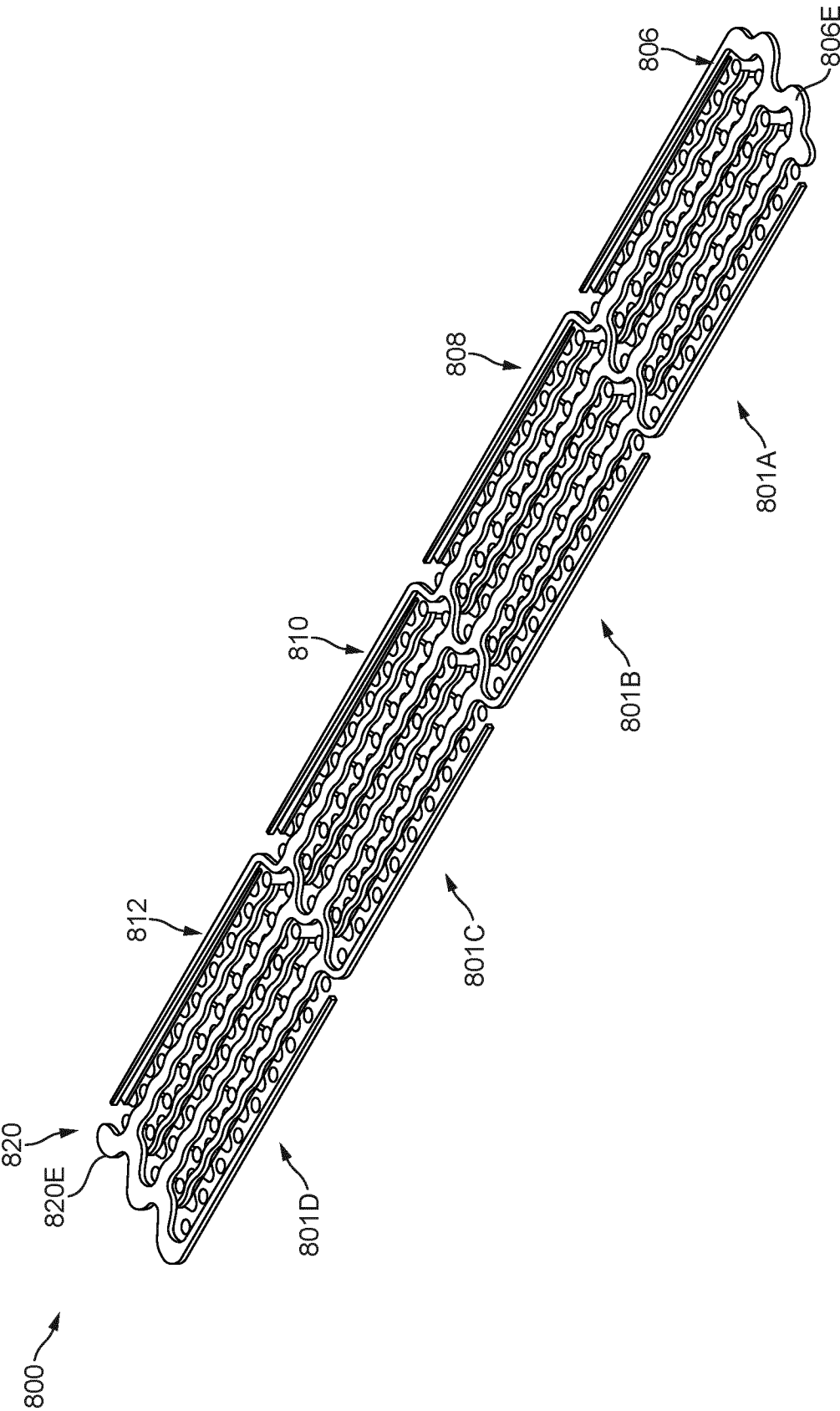


FIG. 8

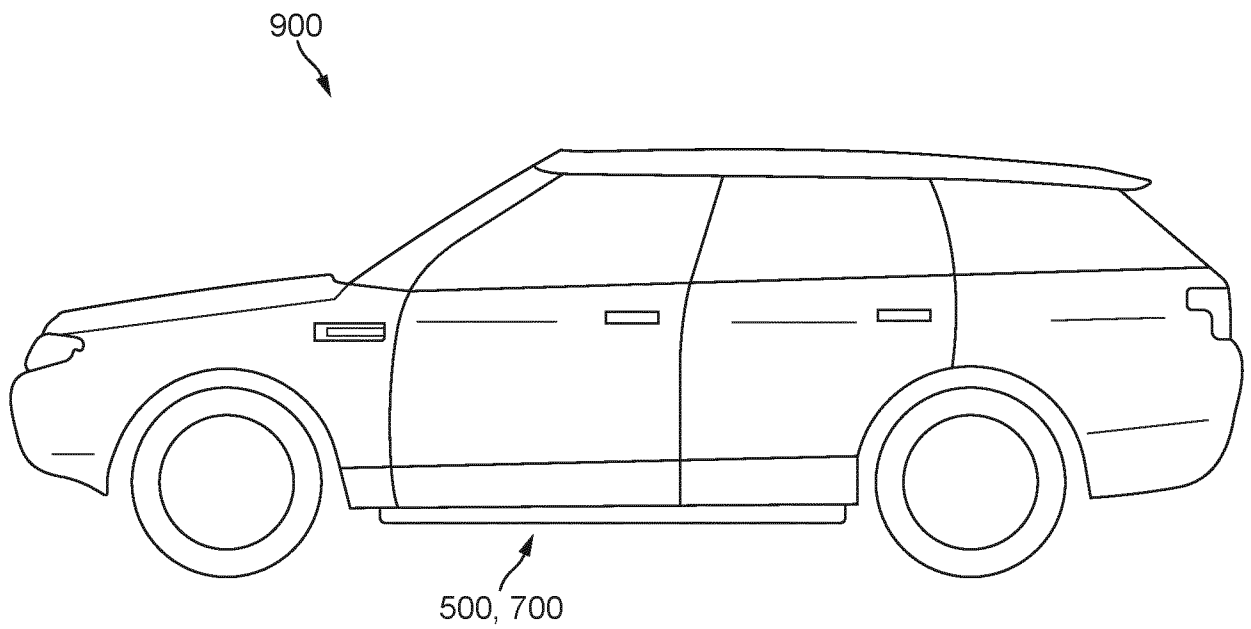


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/073206

A. CLASSIFICATION OF SUBJECT MATTER INV. H01M10/617 H01M10/643 H01M50/213 H01M50/249 H01M50/503 H01M50/509 H01M50/55 H01M50/559 H01M50/526 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	US 2020/067060 A1 (COLLINS TYLER DAVID [US] ET AL) 27 February 2020 (2020-02-27)	1-7
Y	paragraphs [0060] - [0065], [0069] - [0075], [0078], [0094] - [0101], [0105]; figures 3-10, 12-15 -----	8, 9
X	WO 2018/071765 A1 (INEVIT LLC [US]) 19 April 2018 (2018-04-19) paragraphs [0002], [0074], [0076], [0111] - [0115], [0156], [0204]; figures 6, 11, 16C, 21 -----	1-6, 10
Y	JP H01 200571 A (HITACHI LTD) 11 August 1989 (1989-08-11) see underlined passage in the attached machine translation -----	8, 9
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "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 22 December 2021		Date of mailing of the international search report 07/01/2022
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Dunn, Halina

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2021/073206

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2020067060	A1	27-02-2020	NONE
WO 2018071765	A1	19-04-2018	CN 110024158 A 16-07-2019
			CN 110024164 A 16-07-2019
			CN 110024165 A 16-07-2019
			CN 110024166 A 16-07-2019
			CN 110024167 A 16-07-2019
			CN 110036502 A 19-07-2019
			CN 110061168 A 26-07-2019
			CN 110061169 A 26-07-2019
			CN 110062966 A 26-07-2019
			CN 110073514 A 30-07-2019
			CN 110112355 A 09-08-2019
			EP 3526828 A2 21-08-2019
			EP 3526832 A1 21-08-2019
			EP 3526833 A1 21-08-2019
			EP 3526834 A1 21-08-2019
			EP 3526836 A1 21-08-2019
			EP 3526837 A1 21-08-2019
			EP 3526838 A1 21-08-2019
			EP 3526839 A1 21-08-2019
			EP 3526841 A2 21-08-2019
			EP 3565025 A1 06-11-2019
			US 2018108878 A1 19-04-2018
			US 2018108886 A1 19-04-2018
			US 2018108895 A1 19-04-2018
			US 2018108896 A1 19-04-2018
			US 2018108897 A1 19-04-2018
			US 2018108899 A1 19-04-2018
			US 2018108900 A1 19-04-2018
			US 2018108901 A1 19-04-2018
			US 2018108955 A1 19-04-2018
			US 2019329825 A1 31-10-2019
			US 2020099035 A1 26-03-2020
			US 2020168882 A1 28-05-2020
			US 2020343514 A1 29-10-2020
			US 2020343515 A1 29-10-2020
			US 2021104718 A1 08-04-2021
			US 2021288384 A1 16-09-2021
			WO 2018071765 A1 19-04-2018
			WO 2018071769 A1 19-04-2018
			WO 2018071772 A1 19-04-2018
			WO 2018071776 A1 19-04-2018
			WO 2018071785 A1 19-04-2018
			WO 2018071811 A1 19-04-2018
			WO 2018071820 A1 19-04-2018
			WO 2018071823 A2 19-04-2018
			WO 2018071825 A2 19-04-2018
JP H01200571	A	11-08-1989	NONE