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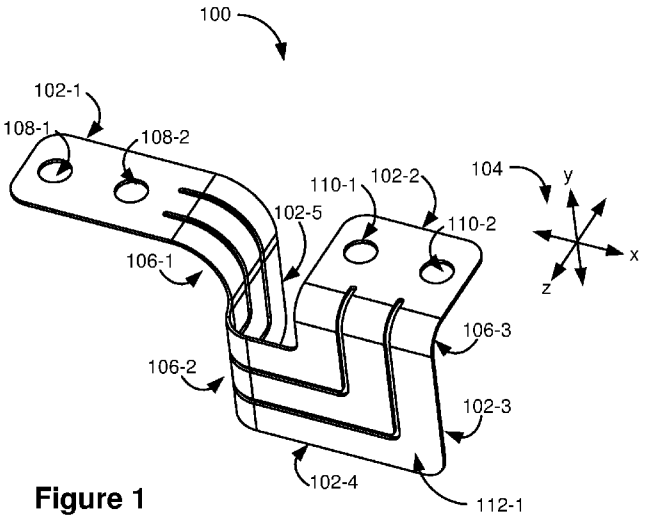


Figure 1

(57) **Abstract**: A battery cell connector includes a plurality of segments. Each segment defines a respective plane and has a respective longitudinal axis. The battery cell connector further includes a plurality of bends coupling the plurality of segments together into a 3-D object, each bend located between a unique pair of adjacent segments of the plurality of segments, where the unique pair of adjacent segments define two distinct respective planes. A first segment of the plurality of segments includes one or more first connecting elements for a battery pole of a first battery cell and a second segment of the plurality of segments includes one or more second connecting elements for a battery pole of a second battery cell. The one or more first connecting elements are electrically coupled with the one or more second connecting elements.

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# BATTERY CELL CONNECTOR

## CROSS REFERENCE TO RELATED APPLICATION

This application claims priority to Chinese Patent No. 201510233602.6, entitled "POWER BATTERY CELL CONNECTOR, POWER BATTERY MODULES, POWER BATTERY PACKAGES, AND CAR," filed on May 8, 2015 at State Intellectual Property Office, and Chinese Patent No. 201510234575.4, entitled "POWER BATTERY CELL CONNECTOR, POWER BATTERY MODULES, POWER BATTERY PACKAGES, AND CAR," filed on May 8, 2015 at State Intellectual Property Office, both of which are incorporated by reference in their entirety.

## FIELD

The disclosed embodiments relate generally to apparatuses for connecting battery cells, and more particularly to apparatuses that electrically couple battery cells while providing mechanical rigidity and/or vibration dampening.

## BACKGROUND

Batteries have become a commonplace form of energy storage (e.g., for use in hybrid and electric vehicles). Often, one or more battery cells (e.g., modules) are connected (e.g., in series or parallel) to increase the storage capacity and/or power output of the battery system. To connect two battery cells in series, an anode of a first battery is typically connected with a cable to the cathode of a second battery.

A problem with battery cell connections arises when batteries are used, for example, in vehicles, because battery cables offer little if any mechanical support. For example, tolerances between the shape and size of the battery cells, along with vibrations experienced by the battery system from operating in a vehicle (e.g., vibrations between battery cells), can lead to mechanical and/or electrical failure of the battery system.

## SUMMARY

Thus, there is need for battery cell connectors that provide mechanical rigidity, support and/or vibration damping. To that end, disclosed are battery module connectors that provide mechanical support and/or vibration damping when connecting battery cells.

In accordance with some embodiments, a battery cell connector includes a plurality of segments. Each segment defines a respective plane and has a respective longitudinal axis. The battery cell connector further includes a plurality of bends coupling the plurality of segments

together into a 3-D object, each bend located between a unique pair of adjacent segments of the plurality of segments, where the unique pair of adjacent segments define two distinct respective planes. A first segment of the plurality of segments includes one or more first connecting elements for a battery pole of a first battery cell and a second segment of the plurality of segments includes one or more second connecting elements for a battery pole of a second battery cell. The one or more first connecting elements are electrically coupled with the one or more second connecting elements.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a perspective view of a first battery cell connector, in accordance with some embodiments.

Figure 2 illustrates a partially-exploded-view of a first battery system utilizing the first battery cell connector, in accordance with some embodiments.

Figure 3 illustrates an assembly view of the first battery system utilizing the first battery cell connector, in accordance with some embodiments.

Figure 4 illustrates a close-up of a portion of the assembly view of the first battery system utilizing the first battery cell connector, in accordance with some embodiments.

Figure 5 illustrates a perspective view of a second battery cell connector, in accordance with some embodiments.

Figure 6 illustrates a top view of the second battery cell connector, in accordance with some embodiments.

Figure 7 illustrates a partially-exploded-view of a second battery system utilizing the second battery cell connector, in accordance with some embodiments.

Figure 8 illustrates a close-up of a portion of an assembly view of the second battery system utilizing the second battery cell connector, in accordance with some embodiments.

Figure 9 illustrates a partially-exploded-view of a third battery system utilizing a third battery cell connector, in accordance with some embodiments.

Figure 10 illustrates another partially-exploded-view of the third battery system utilizing the third battery cell connector, in accordance with some embodiments.

Figure 11 illustrates an assembly view of the third battery system utilizing the third battery cell connector, in accordance with some embodiments.

Figure 12 illustrates a close-up of a portion of the assembly view of the third battery system utilizing the third battery cell connector, in accordance with some embodiments.

Figure 13 illustrates a perspective view of a fourth battery cell connector, in accordance with some embodiments.

Figure 14 illustrates a partially-exploded-view of a fourth battery system utilizing the fourth battery cell connector, in accordance with some embodiments.

Figure 15 illustrates another partially-exploded-view of the fourth battery system utilizing the fourth battery cell connector, in accordance with some embodiments.

Figure 16 illustrates an assembly view of the fourth battery system utilizing the fourth battery cell connector, in accordance with some embodiments.

Figure 17 illustrates a close-up of a portion of the assembly view of the fourth battery system utilizing the fourth battery cell connector, in accordance with some embodiments.

Figure 18 illustrates a perspective view of a fifth battery cell connector, in accordance with some embodiments.

Figure 19 illustrates a partially-exploded-view of a fifth battery system utilizing the fifth battery cell connector, in accordance with some embodiments.

Figure 20 illustrates an assembly view of the fifth battery system utilizing the fifth battery cell connector, in accordance with some embodiments.

Figure 21 illustrates a close-up of a portion of the assembly view of the fifth battery system utilizing the fifth battery cell connector, in accordance with some embodiments.

Figures 22-25 illustrates perspective views of additional battery cell connectors, in accordance with various embodiments.

Figures 26A-26C illustrate a sheet metal process in accordance with some embodiments.

Like reference numerals refer to corresponding parts throughout the drawings.

## DETAILED DESCRIPTION

The battery cell connectors described herein include a sheet of material (e.g., metal) with bends and turns configured in such a way as to provide mechanical rigidity and vibration dampening in one or more directions, thus providing mechanical support to the interconnects between battery cell terminals. For example, in some embodiments, the battery cell connectors described herein include segments of substantially flat sheets of metal that efficiently carry bending and shear loads along a longitudinal direction of each segment. The segments are coupled by bends (e.g., connections between two segments having non-planar longitudinal axes) and/or turns (e.g., connections between two segments having non-parallel, but planar, longitudinal axis). By coupling segments by bends and turns, the battery cell connectors described herein are configured into a three-dimensional (3-D) object that provides mechanical compressional/shearing rigidity (e.g., efficient carrying of bending and/or shear stress) in more than one direction (e.g., two or three perpendicular directions) as well as rotational rigidity along more than one rotational axis (e.g., two or three rotational axes). In addition,

in some embodiments, the bends coupling segments act a stiff springs that provide vibration damping along one or more rotational axes. As described below, Figures 1-21 illustrate exemplary embodiments which are configured to provide rigid support and vibration dampening while fitting conveniently to existing battery module geometries (e.g., the embodiments described below describe example geometries for battery cell connectors).

Reference will now be made in detail to various implementations, examples of which are illustrated in the accompanying drawings. In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the present disclosure and the described implementations herein. However, implementations described herein may be practiced without these specific details. In other instances, well-known methods, procedures, components, and mechanical apparatus have not been described in detail so as not to unnecessarily obscure aspects of the implementations.

Figure 1 illustrates a perspective view of a first battery cell connector 100 (e.g., also called a bus bar or a battery module connector), in accordance with some embodiments. First battery cell connector 100 includes a plurality of segments 102 (e.g., segments 102-1 through 102-5). In some embodiments, a battery cell connector includes two segments, three segments, or more segments. For example, first battery cell connector 100 includes five segments.

Each segment 102 defines a respective plane (e.g., lies in the respective plane). For example, as shown by axes 104, segments 102-1 and 102-2 are parallel to an *xz*-plane; segments 102-3 and 102-4 are parallel to a *xy*-plane; segment 102-5 is parallel to a *yz*-plane. In some embodiments, a battery cell connector includes a plurality of segments that define a plurality of respective planes (e.g., two or three planes). For example, first battery cell connector 100 includes five segments that define three planes (e.g., *xy*-plane, *xz*-plane, and *yz*-plane). In some embodiments, for example, as shown in first battery cell connector 100, the three planes are mutually substantially perpendicular.

Each segment has a respective longitudinal axis. For example, segments 102-1 and 102-4 have respective longitudinal axes along the x-direction (i.e., left and right direction); segment 102-2 has a longitudinal axis along the z-direction (i.e., front and rear direction); segments 102-3 and 102-5 have respective longitudinal axes along the y-direction (up and down direction). In some embodiments, a segment's longitudinal axis is along a direction from a center of the segment to an adjacent bend or turn. In some embodiments, a segment's longitudinal axis is along a direction connecting a bend or a turn on a first end of the segment and a bend or a turn on a second end of the segment, opposite the first.

First battery cell connector 100 includes a plurality of bends 106 (e.g., bend 106-1; bend 106-2; and bend 106-3) coupling the plurality of segments together into a 3-D object (e.g., an object having

substantial spatial extent and/or substantial rigidity in three orthogonal directions). The plurality of bends coupling the plurality of segments into a 3-D object comprises bends pointing in at least three different directions (e.g., having bending axes along three distinct directions). In some embodiments, the three different directions are orthogonal (perpendicular) directions. In some embodiments, at least two of the plurality of bends are not parallel to each other. In some embodiments, at least three of the plurality of bends are not parallel to each other. In some embodiments, two bends are not parallel to each other when they have respective bending axes that are not parallel to each other. Each bend 106 is located between (e.g., couples) a unique pair of adjacent segments of the plurality of segments. For example, bend 106-1 is located between segment 102-1 and segment 102-5; bend 106-2 is located between segment 102-5 and segment 102-4; and bend 106-3 is located between segment 102-3 and segment 102-2. In this example, bend 106-1 has an axis that is approximately in the *z*-direction; bend 106-2 has an axis that is approximately in the y-direction; and bend 106-3 has an axis that is approximately in the x-direction. As will be described below in connection with Figures 26A-26C, the first battery cell connector 100 is formed from a two-dimensional U-shape metal sheet 2606 by bending different portions of the U-shape metal sheet 2606 into different directions at predefined locations. For example, both terminal segments are formed by bending the corresponding side portions of the U-shape metal sheet 2606 into two opposite directions perpendicular to the plane defined by the U-shape metal sheet 2606 (see, e.g., 2626-2 and 2626-3 in Figure 26C) and another bend 2626-1 is formed by bending the bottom portion of the U-shape metal sheet 2606. The unique pair of adjacent segments on either side of a bend defines two distinct respective planes. In some embodiments, the two distinctive planes are perpendicular to one another (e.g., the bend is a 90 degree bend). In some embodiments, a bend has a radius of curvature. In some embodiment, a bend is bent along a respective bending axis that is parallel with both of the two distinct respective planes (e.g., the bend is characterized by a bending axis). For example, the bending axis for bend 106-1 is parallel to the z-axis. In some embodiments, the plurality of bends 106 includes at least three bends having three distinct bending axes. In some embodiments, the three distinct bending axes are perpendicular to one another. In some embodiments, the plurality of bends serves as vibration dampening elements (e.g., damp vibrations along directions perpendicular to the bend's respective bending axis).

Specifically, a right edge of segment 102-1 is connected with an upper edge of segment 102-5 via bend 106-1, a front edge of segment 102-5 is connected with a left edge of segment 102-4 via bend 106-2, and an upper edge of segment 102-4 is connected with a front edge of segment 102-2 via bend 106-3.

In some embodiments, the battery cell connector is for use in a vehicle (e.g., an electrical car) and the bends are elastically deformable under predefined operating conditions of the vehicle (e.g., vibration or shock). For example, in some embodiments, the bends act as springs having a stiffness designed to dampen one or more resonance modes of the vehicle and/or the battery system.

In the example shown in Figure 1, segment 102-1 is a first segment of the plurality of segments 102 that includes one or more first connecting elements 108 for a battery pole (e.g., an anode, a cathode, or a connecting terminal or contact for an anode or a cathode) of a first battery cell. Segment 102-2 is a second segment of the plurality of segments 102 that includes one or more second connecting elements 110 for a battery pole of a second battery cell. In some embodiments, the first connecting elements 108 include at least two connecting elements (e.g., first connecting elements 108-1 and 108-2) to provide rotational stiffness for the connection to the first battery cell. In some embodiments, the second connecting elements include at least two connecting elements (e.g., second connecting elements 110-1 and 110-2) to provide rotational stiffness for the connection to the second battery cell. In some embodiments, a respective connecting element of the first connecting elements and the second connecting elements comprises an opening adapted to receive a battery terminal, wherein the battery terminal is mechanically connected at least partially along a circumference of the opening (e.g., as shown in first battery cell connector 100, each of the connecting elements 108/110 comprises an opening adapted to receive a battery terminal, which may comprise a bolt screwed into the battery). The one or more first connecting elements are electrically coupled with the one or more second connecting elements. In some embodiments, the plurality of segments comprise an electrical conductor forming the electrical coupling between the one or more first connecting elements 108 and the one or more second connecting elements 110. In some embodiments, for example as shown in first battery cell connector 100, the plurality of segments and the plurality of bends are formed by a single continuous metal sheet that comprises an electrical conductor forming the electrical coupling between the one or more first connecting elements 108 and the one or more second connecting elements 110. In some embodiments, the connector 100 is made of copper or aluminum.

In some embodiments, the segments 102 that include connecting elements 108/110 do not have a clearly discernible longitudinal axis. In some embodiments, the segments 102 that include connecting elements 108/110 are respective segments in a plurality of segments that includes one or more additional segments, each additional segment having a longitudinal axis.

In some embodiments, first battery cell connector 100 includes one or more (or a plurality of) turns 112 (for visual clarity, only a single turn 112-1 is given a reference number in Figure 1). Each turn 112 couples a second unique pair of adjacent segments 102 in the plurality of segments 102. For

example, turn 112-1 couples segment 102-3 and 102-4. The second unique pair of adjacent segments 102 have distinct respective longitudinal axes within the same respective plane. For example, segment 102-3 has a longitudinal axis in the y-direction, segment 102-4 has a longitudinal axis in the x-direction, and both segment 102-3 and 102-4 are parallel with the xy-plane. In some embodiments, the respective axes of segments coupled by a turn are perpendicular (e.g., the segments form an L-shape). In some embodiments, the plurality of segments has an L-shaped opening (e.g., at least a portion of the opening is L-shaped).

Figures 2-4 illustrate alternate views of first battery cell connector 100, in accordance with some embodiments. Figure 2 illustrates a partially-exploded-view of a first battery system 200 utilizing first battery cell connector 100. Battery system 200 includes a plurality of (e.g., two or more) battery cells (also called modules) 202 (e.g., battery cell/module 202-1 and 202-2). First battery cell connector 100 is coupled with battery cell/module 202-1 and 202-2 by bolts 204 running through connecting elements 108/110 (Figure 1), where the bolts serve as terminals of the battery cells. For example, in some embodiments, a cathode of battery cell/module 202-1 is coupled with an anode of battery cell/module 202-2 so that battery cell/module 202-1 and battery cell/module 202-2 are electrically connected in series. Figure 3 illustrates an assembly view of the first battery system 200 utilizing the first battery cell connector 100, in accordance with some embodiments. Figure 4 illustrates a close-up of a portion 300 of the assembly view of the first battery system 200 utilizing the first battery cell connector 100, in accordance with some embodiments. In particular, Figure 3 illustrates that first battery cell connector 100 fits snuggly (e.g., securely) between battery cell/module 202-1 and battery cell/module 202-2.

Figures 5-8 illustrate various views of a second battery cell connector 500, in accordance with some embodiments. In particular, Figure 5 illustrates a perspective view of second battery cell connector 500; Figure 6 illustrates a top view of second battery cell connector 500; Figure 7 illustrates a partially-exploded-view of second battery system 700 utilizing second battery cell connector 500; and Figure 8 illustrates a close-up of a portion 800 of an assembly view of the second battery system 700 utilizing second battery cell connector 500. Second battery cell connector 500 is largely analogous to first battery cell connector 100, but second battery cell connector 500 is arranged geometrically differently from first battery cell connector 100. Nevertheless, second battery cell connector 500 includes a plurality of segments 102 (e.g., segments 102-6 through 102-10 and optionally others, not labeled for visual clarity), a plurality of bends 106 (e.g., bends 106-4 and optionally others, not labeled for visual clarity), connecting elements 108/110, and a plurality of turns 112 (e.g., turn 112-2 and optionally others, not labeled for visual clarity). Segments 102, bends 106, connecting elements 108/110 and turns 112 have analogous features to those

described above with reference to Figures 1-4. As shown in Figures 7-8, second battery cell connector 500 is used to connect battery cell/module 702-1 and battery cell/module 702-2.

Specifically, a front edge of segment 102-6 is connected with an upper edge of segment 102-7 via a bend, a right edge of segment 102-7 is connected with a front edge of segment 102-8 via bend 106-4, and an upper edge of segment 102-8 is connected with a left edge of segment 102-10 via a bend.

Figures 9-12 illustrate various views of a third battery cell connector 900, in accordance with some embodiments. In particular, Figure 9 illustrates a partially-exploded-view of a third battery system 950 utilizing third battery cell connector 900; Figure 10 illustrates another partially-exploded-view of third battery system 950 utilizing third battery cell connector 900; Figure 11 illustrates an assembly view of third battery system 950 utilizing third battery cell connector 900; and Figure 12 illustrates a close-up of a portion 1200 of the assembly view of third battery system 950 utilizing the third battery cell connector 900. Third battery cell connector 900 includes a plurality of segments 102 (segment 102-11, segment 102-12 and other segments); a plurality of bends 106 (e.g., bends 106-5 and 106-6), and connecting elements 108/110, which each have analogous features to those described above with reference to Figures 1-4. However, two respective segments 102 (to wit, segment 102-11 and 102-12) of third battery cell connector 900 are welded together (e.g., coupled together by a weld) to form a spring (e.g., a shock absorber or vibration dampener). In some embodiments, the spring forms a tweezer structure. In some embodiments, the tweezer structure includes two planar segments having planes separated by a single rotation (e.g., not a compound or multi-dimensional rotation) of a few degrees (e.g., between 5-30 degrees). In some embodiments, each longitudinal axis of the respective segments 102 of third battery cell connector 900 lie in a common plane. In some embodiments, third battery cell connector 900 does not include any turns. In some embodiments, the longitudinal axes of each segment of third battery cell connector 900 are co-planar. As shown in Figures 11-12, the welded segments of third battery cell connector 900 are configured to be positioned between respective battery/cells modules with the common plane of their longitudinal axes perpendicular to the plane of attachment to the battery terminals.

Specifically, a first fixing segment is connected with an upper edge of segment 102-11 via bend 106-5 and extended away from segment 102-11, and a second fixing segment is connected with an upper edge of segment 102-12 via bend 106-6 and extended away from segment 102-12. In other words, the first fixing segment is disposed on segment 102-11 and extended away from an included angle between segment 102-11 and segment 102-12, and the second fixing segment is disposed on segment 102-12 and extended away from the included angle between segment 102-11

and segment 102-12. Moreover, a plane in which the first fixing segment is may be parallel with a plane in which the second fixing segment is.

In some embodiments, the first fixing segment is disposed on an upper end of segment 102-11, connected with the upper edge of segment 102-11 and bent leftwards to a horizontal position; the second fixing segment is disposed on an upper end of segment 102-12, connected with the upper edge of segment 102-12 and bent rightwards to a horizontal position.

In some embodiments, the first fixing segment is in flush with the second fixing segment.

Figures 13-17 illustrate various views of a fourth battery cell connector 1300, in accordance with some embodiments. In particular, Figure 13 illustrates a perspective view of a fourth battery cell connector 1300; Figure 14 illustrates a partially-exploded-view of fourth battery system 1400 utilizing fourth battery cell connector 1300; Figure 15 illustrates another partially-exploded-view of fourth battery system 1400 utilizing fourth battery cell connector 1300; Figure 16 illustrates an assembly view of fourth battery system 1400 utilizing the fourth battery cell connector 1300; and Figure 17 illustrates a close-up of a portion 1406 of the assembly view of fourth battery system 1400 utilizing fourth battery cell connector 1300, in accordance with some embodiments. Fourth battery cell connector 1300 includes a plurality of segments 102 (e.g., segments 102-13 through 102-18); a plurality of bends 106 (e.g., bends 106-7 through 106-9), and connecting elements 108/110, as described above. Fourth battery cell connector 1300 electrically couples battery cell module 1402-1 and battery cell module 1402-2 of fourth battery system 1400. Fourth battery cell connector 1300 is largely analogous to third battery cell connector 900 (e.g., includes two welded segments that together form a spring/tweezer structure). However, the longitudinal axes of each non-terminal segment of fourth battery cell connector 1300 are parallel with the respective planes of the terminal segments of battery cell connector 1300. As shown in Figures 16-17, the welded segments of fourth battery cell connector 1300 are configured to be positioned between respective battery/cells modules with their longitudinal axes lying in a plane parallel to the plane of attachment to the battery terminals. The plurality of segments 102 of fourth battery cell connector 1300 has an L-shaped opening 1302.

Specifically, rear ends of segment 102-16 and segment 102-17 are connected with each other and front ends of segment 102-16 and segment 102-17 are separated from each other by a single rotation of a few degrees, i.e., an included angle. Segment 102-13 is connected with an edge of segment 102-15 via bend 106-7 and extended away from segment 102-15, and segment 102-18 is connected with an edge of segment 102- 17 via bend 106-9 and extended away from segment 102-17. Segment 102-15 is connected with an edge of segment 102-16 via bend 106-8.

In some embodiments, a right edge of segment 102-13 is connected with a lower edge of segment 102-15 via bend 106-7, a left edge of segment 102-18 is connected with a lower edge of segment 102- 17 via bend 106-9, a rear edge of segment 102-15 is connected with a front edge of segment 102-16 via bend 106-8 and segment 102-13 is in flush with segment 102-18.

Figures 18-21 illustrate various views of a fifth battery cell connector 1800, in accordance with some embodiments. In particular, Figure 18 illustrates a perspective view of fifth battery cell connector 1800; Figure 19 illustrates a partially-exploded-view of a fifth battery system 1900 utilizing fifth battery cell connector 1800; Figure 20 illustrates an assembly view of fifth battery system 1900 utilizing fifth battery cell connector 1800; and Figure 21 illustrates a close-up of a portion 2000 of the assembly view of fifth battery system 1900 utilizing fifth battery cell connector 1800, in accordance with some embodiments. Fifth battery cell connector 1800 includes a plurality of segments 102 (e.g., segments 102-19 through 102-26); a plurality of bends 106 (e.g., bends 106-10 through 106-12), and connecting elements 108/110, as described above. Fifth battery cell connector 1800 electrically couples battery cell/module 1902-1 and battery cell/module 1902-2 of fifth battery system 1900. Fifth battery cell connector 1800 is largely analogous to third battery cell connector 900 (e.g., includes two welded segments that together form a spring/tweezer structure). As shown in Figures 20-21, the welded segments of fifth battery cell connector 1800 are configured to be positioned adjacent to and outside of the respective battery/cells modules connect by fifth battery cell connector 1800. Moreover, the welded segments of fifth battery cell connector 1800 have their longitudinal axes in a plane parallel to the plane of attachment to the battery terminals.

Specifically, segment 102-20 is attached to a left portion of segment 102-19, and a right edge of segment 102-20 is connected with a left edge of segment 102-21. A right edge of segment 102-21 is separated from segment 102-19 by an included angle so as to form a substantial V-shaped structure, a left edge of segment 102-22 is connected with the right edge of segment 102-21, and an upper edge of segment 102-22 is connected with a front edge of segment 102- 26 via bend 106-10. Furthermore, a right edge of segment 102-19 is connected with a front edge of segment 102-23 via bend 106-11, and an upper edge of segment 102-24 is connected with a left edge of segment 102-25.

In some embodiments, segment 102-26 and segment 102- 25 may be located at a same side of the substantial V-shaped structure, or may be located at different sides of the substantial V-shaped structure respectively. Moreover, segment 102-26 is in flush with segment 102-25.

Figures 22-23 illustrates perspective views of additional battery cell connectors, in accordance with various embodiments. The battery cell connectors shown in Figures 22-23 are largely analogous to the other battery cell connectors formed of a single metal sheet discussed above.

However, the battery cell connectors shown in Figures 22-23 illustrate the wide variety of arrangements of bends, segments, and turns that are contemplated. For example, in Figure 22A, the battery cell connector has an elongated intermediate segment 2204 between the first terminal segment 2202 and the second terminal segment 2206. There are multiple bends and other intermediate segments connecting each end of the elongated segment 2204 to one of the first terminal segment 2202 and the second terminal segment 2206. Figure 22B depicts a battery cell connector that is a slight variation of the battery cell connector shown in Figure 22A. In particular, the elongated intermediate segment (2214-1, 2214-2) between the first terminal segment 2212 and the second terminal segment 2216 has a bump 2218. This bump is formed by bending the elongated intermediate segment 2214 and separates the elongated intermediate segment into two sub-segments 2214-1 and 2214-2. This bump 2218 serves as a spring that is elastically deformable along the axis 2220 of the elongated intermediate segment 2214 to absorb the vibration movement between the battery cells connected to the two terminal segments 2220 and 2216. In some embodiments, the elongated intermediate segment 2214 includes more than one bump; in some other embodiments, the bump may be present in more than one segment including both intermediate segments and terminal segments.

Specifically, as shown in Fig. 22A, a rear edge of the first terminal segment 2202 is connected with a front edge of segment 2203 via bend 2207, and a rear edge of segment 2203 is connected with a lower edge of the elongated intermediate segment 2204 via bend 2208. The elongated intermediate segment 2204 has a leftwards bent portion at an upper end thereof and a left edge of the leftwards bent portion is connected with a front edge of segment 2205 via bend 2010, and an upper edge of segment 2205 is connected with a left edge of segment 2206 via bend 2209.

In some embodiments, a plane in which segment 2202 is may be parallel with a plane in which segment 2206 is.

Similarly, as shown in Fig. 22B, a right edge of segment 2212 is connected with a front edge of segment 2220 via a bend. Sub-segment 2214-2 has a rightwards bent portion at a front end thereof, and a right edge of the rightwards bent portion is connected with an upper edge of segment 2220 via a bend. A rear edge of sub-segment 2214-2 is connected with a front edge of sub-segment 2214-1 via the bump 2218, sub-segment 2214-1 has a rightwards bent portion at a rear end thereof, and a right edge of the rightwards bent portion is connected with an upper edge of segment 2216 via a bend.

In some embodiments, a plane in which segment 2212 is may be perpendicular to a plane in which segment 2216 is.

As shown in Figures 24-25, in some embodiments, a battery cell connector is provided that is formed of single continuous metal sheet. The battery cell connector includes a plurality of segments including a first terminal segment that includes one or more first connecting elements for a battery pole of a first battery cell; a second terminal segment that includes one or more second connecting elements for a battery pole of a second battery cell; and a plurality of additional segments connecting the first terminal segment to the second terminal segment. Each additional segment defines a respective plane and having a respective longitudinal axis. The battery cell connector also includes a plurality of bends coupling the plurality of segments together into a 3-D object, each bend located between a unique pair of adjacent segments of the plurality of segments. The unique pair of adjacent segments define two distinct respective planes. The first terminal segment is not parallel to the second terminal segment and the one or more first connecting elements are electrically coupled with the one or more second connecting elements. For example, as shown in Figure 24, the plurality of bends includes a first bend 2408 having a first bending axis 2410 and a second bend 2412 having a second bending axis 2414 that is substantially perpendicular to the first bending axis. First terminal segment 2402 is not parallel to second terminal segment 2404. In some embodiments, first terminal segment 2402 is substantially perpendicular to second terminal segment 2404. In some embodiments, the battery cell connector includes a third bend with a bending axis parallel to either the first bending axis or the second bending axis.

Specifically, as shown in Fig. 24, a rear edge of segment 2402 is connected with an upper of segment 2403 via the first bend 2408, and a right edge of segment 2403 is connected with a front edge of segment 2405 via bend 2416. A rear edge of segment 2405 is connected with a left edge of segment 2404 via the second bend 2412.

As shown in Figure 25, in some embodiments, the battery cell connector includes only two bends. In some embodiments, the battery cell connector further comprises a single turn that, together with the two bends, forms the plurality of segments into the 3-D object. In Figure 25, first terminal segment 2502 is not parallel to second terminal segment 2504.

Specifically, a front edge of first terminal segment 2502 is connected with an upper edge of intermediate segment 2506 via a bend, and a right edge of intermediate segment 2506 is connected with a front edge of second terminal segment 2504. In some embodiments, first terminal segment 2502 may be substantially perpendicular to second terminal segment 2504

In some embodiments, at least two continuous sheets of metal, the at least two continuous sheets of metal coupled together by the welding of the two respective segments forming the spring. In some embodiments, the plurality of bends point to at least three different directions. In some

embodiments, the first and second segments of the plurality of segments are not parallel to each other.

Alternatively, in some embodiments, a battery cell connector is provided that is formed of two or more continuous metal sheets. Battery cell connector 900 (discussed above with reference to Figures 9-12), battery cell connector 1300 (discussed above with reference to Figures 13-17) and battery cell connector 1800 (discussed above with reference to Figures 18-21) are examples of such a battery cell connector. In some embodiments, the battery cell connector includes a plurality of segments of a metal conducting sheet, each segment defining a respective plane and having a respective longitudinal axis. The battery cell connector also includes a plurality of bends coupling the plurality of segments together into a 3-D object, each bend located between a unique pair of adjacent segments of the plurality of segments. The unique pair of adjacent segments define two distinct respective planes. The battery cell connector includes at least one spring comprising two respective segments welded together (e.g., in a "tweezer" arrangement"). A first segment of the plurality of segments includes one or more first connecting elements for a battery pole of a first battery cell. A second segment of the plurality of segments includes one or more second connecting elements for a battery pole of a second battery cell. The one or more first connecting elements are electrically coupled with the one or more second connecting elements.

Figures 26A-26C illustrate a sheet metal process 2600 in accordance with some embodiments. In some embodiments, any of the battery cell connectors described herein (e.g., with reference to Figures 1-25) are manufactured (e.g., formed), or partially manufactured (e.g., in the case of a battery cell connector with "tweezers"), using sheet metal process 2600. For ease of explanation, sheet metal process is described herein as producing a battery cell connector analogous to battery cell connector 100, shown in Figure 1.

The sheet metal process involves cutting (2602) a sheet of metal 2604 into a two-dimensional (e.g., planar) U-shape 2606 comprising a first plurality of planar segments 2608 (e.g., planar segments 2608-1 through 2608-3) separated by a plurality of turns 2610 (e.g., turn 2610-1 and 2610-2). For example, in some embodiments, the sheet of metal is a 1 millimeter (mm) or 2 mm copper sheet. In some embodiments, cutting the sheet of metal into the two-dimensional shape comprises blanking the sheet of metal. In some embodiments, the two-dimensional shape is substantially L-shaped or U-shaped. For example, two-dimensional shape 2606 is substantially U-shaped.

In some embodiments, sheet metal process 2600 includes cutting (2612) (e.g., punching, sawing, milling, nibbling, or drilling) additional features into the two-dimensional shape 2606. For example, in some embodiments, sheet metal process 2600 includes cutting, in a first segment 2608-1

of the plurality of segments 2608, one or more first connecting elements 2614 for a battery pole of a first battery cell. Sheet metal process 2600 also includes cutting, in a second segment 2608-3 of the plurality of segments, one or more second connecting elements 2616 for a battery pole of a second battery cell. In some embodiments, cutting the one or more first connecting elements and cutting the one or more second connecting elements comprises drilling or hole punching the one or more first connecting elements and the one or more second connecting elements. In some embodiments, the additional features include L-shaped or U-shaped cutouts 2618.

Sheet metal process 2600 includes bending 2620 the two-dimensional shape 2606 into a three-dimensional shape 2622 comprising a second plurality of planar segments 2624 (for visual clarity, only some of planar segments 2624 have been labeled in Figure 26C). In some embodiments, the second plurality of planar segments 2624 having a greater number of segments than the first plurality of planar segments 2608 (e.g., the operation of bending creates additional planar segments—that is, when a planar segment is bent, in some circumstances, it creates two planar segments coupled by a bend). The three-dimensional shape includes a plurality of bends 2626 separating respective segments of the second plurality of planar segments and pointing to at least three different directions. In some embodiments, the three different directions are mutually orthogonal directions (e.g., the plurality of bends includes three bends with three different bending axes that are all mutually orthogonal to the other bending axes). In some embodiments, after bending, the first segment and the second segment are not parallel to each other.

The foregoing description, for purposes of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated.

It will be understood that, although the terms “first,” “second,” etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first segment could be termed a second segment, and, similarly, a second segment could be termed a first segment, without changing the meaning of the description, so long as all occurrences of the “first segment” are renamed consistently and all occurrences of the “second segment” are renamed consistently. The first segment and the second segment are both segments, but they are not the same segment.

The terminology used herein is for the purpose of describing particular implementations only and is not intended to be limiting of the claims. As used in the description of the implementations and the appended claims, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will also be understood that the term "and/or" as used herein refers to and encompasses any and all possible combinations of one or more of the associated listed items. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

As used herein, the term "if" may be construed to mean "when" or "upon" or "in response to determining" or "in accordance with a determination" or "in response to detecting," that a stated condition precedent is true, depending on the context. Similarly, the phrase "if it is determined [that a stated condition precedent is true]" or "if [a stated condition precedent is true]" or "when [a stated condition precedent is true]" may be construed to mean "upon determining" or "upon a determination that" or "in response to determining" or "in accordance with a determination" or "upon detecting" or "in response to detecting" that the stated condition precedent is true, depending on the context.

What is claimed is:

1. A battery cell connector, comprising:

a plurality of segments, each segment defining a respective plane and having a respective longitudinal axis; and

a plurality of bends coupling the plurality of segments together into a 3-D object and whose associated axes point to at least three different directions, each bend located between a unique pair of adjacent segments of the plurality of segments, wherein the unique pair of adjacent segments define two distinct respective planes, wherein:

a first segment of the plurality of segments includes one or more first connecting elements for a battery pole of a first battery cell;

a second segment of the plurality of segments includes one or more second connecting elements for a battery pole of a second battery cell; and

the one or more first connecting elements are electrically coupled with the one or more second connecting elements.

2. The battery cell connector of claim 1, further comprising a plurality of turns, each turn coupling a second unique pair of adjacent segments in the plurality of segments, wherein the second unique pair of adjacent segments have distinct respective longitudinal axis within the same respective plane.

3. The battery cell connector of claim 1, wherein the plurality of segments comprise an electrical conductor forming the electrical coupling between the one or more first connecting elements and the one or more second connecting elements.

4. The battery cell connector of claim 1, wherein the plurality of segments has an L-shaped opening.

5. The battery cell connector of claim 1, wherein the plurality of bends comprise vibration dampening elements.

6. The battery cell connector of claim 1, wherein the battery cell connector is for use in a vehicle and the plurality of bends are elastically deformable under predefined operating conditions of the vehicle.

7. The battery cell connector of claim 1, wherein the plurality of bends includes three bends.

8. The battery cell connector of claim 7, wherein the three bends have three distinct axes of bending.

9. The battery cell connector of claim 8, wherein the three distinct axes of bending are substantially perpendicular to one another.

10. The battery cell connector of claim 1, wherein the plurality of segments includes at least four segments.

11. The battery cell connector of claim 1, wherein the connector is formed by a continuous metal sheet.

12. The battery cell connector of claim 1, wherein the connector is made of copper or aluminum.

13. The battery cell connector of claim 1, wherein the connector is covered with a metal coating layer.

14. The battery cell connector of claim 1, wherein the connector is covered with an insulating layer.

15. The battery cell connector of claim 10, wherein the four segments define three distinct respective planes.

16. The battery cell connector of claim 15, wherein the three distinct respective planes are substantially perpendicular.

17. The battery cell connector of claim 1, wherein a respective connecting element of the first connecting elements and the second connecting elements comprises an opening adapted to receive a battery terminal, wherein the battery terminal is mechanically connected at least partially along a circumference of the opening.

18. The battery cell connector of claim 1, further including at least one vibration-absorbent bump formed in a respective segment of the plurality of segments.

19. The battery cell connector of claim 1, wherein:

the plurality of bends includes a first bend having a first bending axis and a second bend having a second bending axis that is substantially perpendicular to the first; and

the first segment of the plurality of segments and the second segment of the plurality of segments are substantially perpendicular to each other.

20. The battery cell connector of claim 19, wherein:

the plurality of bends includes only two bends; and

the battery cell connector further comprises a single turn that, together with the two bends, forms the plurality of segments into the 3-D object, wherein the turn couples a second unique pair of adjacent segments in the plurality of segments, wherein the second unique pair of adjacent segments have distinct respective longitudinal axis within the same respective plane

21. The battery cell connector of claim 19, wherein the plurality of bends includes a third bend having a third bending axis that is substantially parallel to the first bending axis.

22. A battery cell connector formed by a process comprising the steps of:

cutting a sheet of metal into a two-dimensional shape; and

bending the two-dimensional shape into a three-dimensional shape comprising a plurality of planar segments separated by a plurality of bends whose associated axes point to at least three different directions.

23. The battery cell connector of claim 22, wherein cutting the sheet of metal into the two-dimensional shape comprises blanking the sheet of metal.

24. The battery cell connector of claim 22, wherein each turn couples a unique pair of adjacent segments in the plurality of segments.

25. The battery cell connector of claim 22, wherein the two-dimensional shape is L-shaped or U-shaped.

26. The battery cell connector of claim 22, the process further comprising:

cutting, in a first segment of the plurality of segments, one or more first connecting elements for a battery pole of a first battery cell; and

cutting, in a second segment of the plurality of segments, one or more second connecting elements for a battery pole of a second battery cell.

27. The battery cell connector of claim 26, wherein cutting the one or more first connecting elements and cutting the one or more second connecting elements comprises drilling or hole punching the one or more first connecting elements and the one or more second connecting elements.

28. The battery cell connector of claim 26, wherein sheet of metal comprises an electrical conductor forming an electrical coupling between the one or more first connecting elements and the one or more second connecting elements.

29. The battery cell connector of claim 26, wherein a respective connecting element of the first connecting elements and the second connecting elements comprises an opening adapted to receive a battery terminal, wherein the battery terminal is mechanically connected at least partially along a circumference of the opening.

30. The battery cell connector of claim 22, the process further comprising cutting an L-shaped or U-shaped opening into the sheet of metal.

31. The battery cell connector of claim 22, wherein the plurality of bends comprise vibration dampening elements.

32. The battery cell connector of claim 22, wherein the battery cell connector is for use in a vehicle and the plurality of bends are elastically deformable within a set of operating conditions of the vehicle.

33. The battery cell connector of claim 22, wherein the plurality of bends includes three bends.

34. The battery cell connector of claim 33, wherein the three bends have three distinct axes of bending.

35. The battery cell connector of claim 34, wherein the three distinct axes of bending are substantially perpendicular to one another.

36. The battery cell connector of claim 22, wherein the plurality of segments includes three segments.

37. The battery cell connector of claim 36, wherein the three segments define three distinct respective planes.

38. The battery cell connector of claim 37, wherein the three distinct respective planes are substantially perpendicular.

39. The battery cell connector of claim 22, the process further comprising bending at least one vibration-absorbent bump formed in a respective segment of the plurality of segments.

40. The battery cell connector of claim 22, wherein:

the plurality of bends includes a first bend having a first bending axis and a second bend having a second bending axis that is substantially perpendicular to the first; and

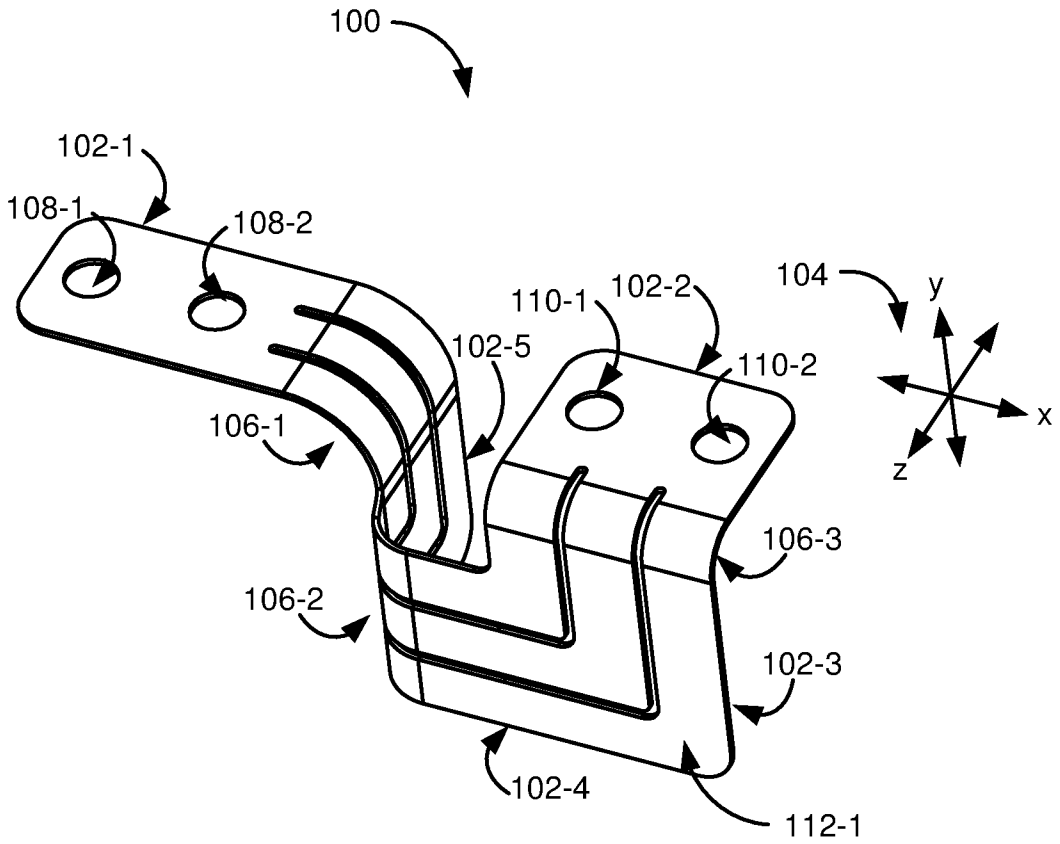
after bending the two-dimensional shape into the three-dimensional shape, the battery cell connector includes a first terminal segment and a second terminal segment that are substantially perpendicular to each other.

41. The battery cell connector of claim 22, wherein:

the plurality of bends includes only two bends; and

the battery cell connector further comprises a single turn that, together with the two bends, forms the plurality of segments into the three-dimensional shape, wherein the turn couples a unique pair of adjacent segments in the plurality of segments, wherein after bending the two-dimensional shape into the three-dimensional shape, the unique pair of adjacent segments have distinct respective longitudinal axis within the same respective plane.

42. The battery cell connector of claim 22, wherein the plurality of bends includes a third bend having a third bending axis that is substantially parallel to the first bending axis.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102-2
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x
106-1
z
106-3
106-2
102-3
102-4
112-1

**Figure 1**

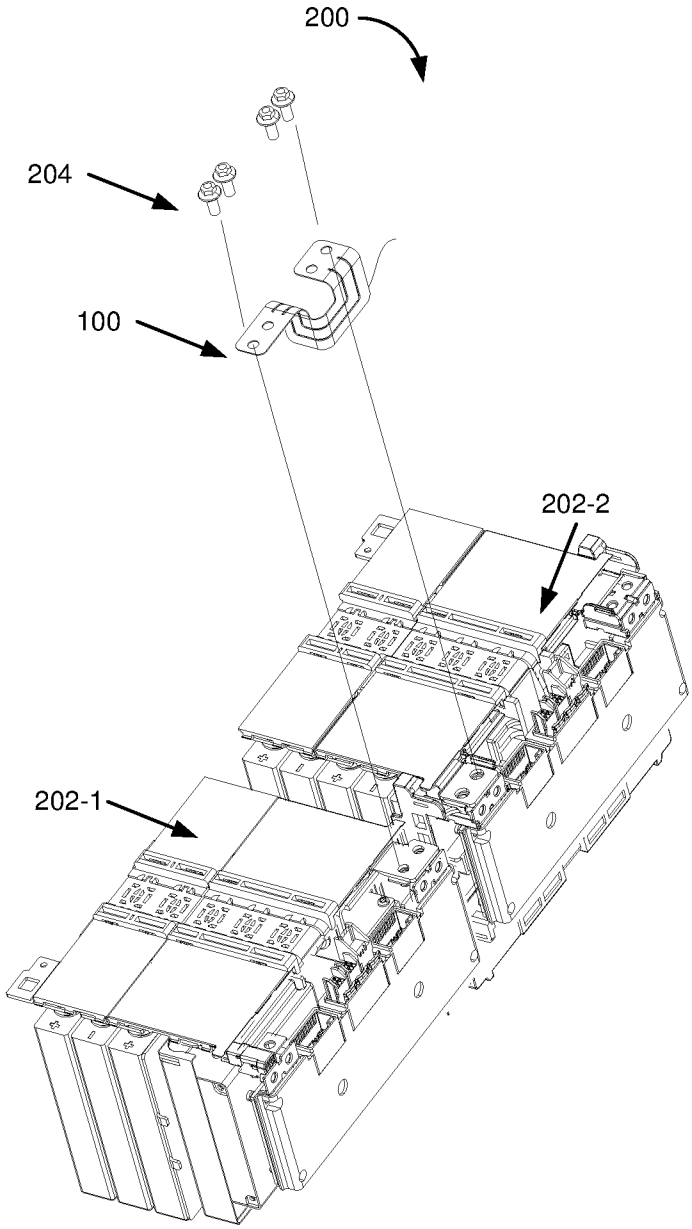



Figure 2

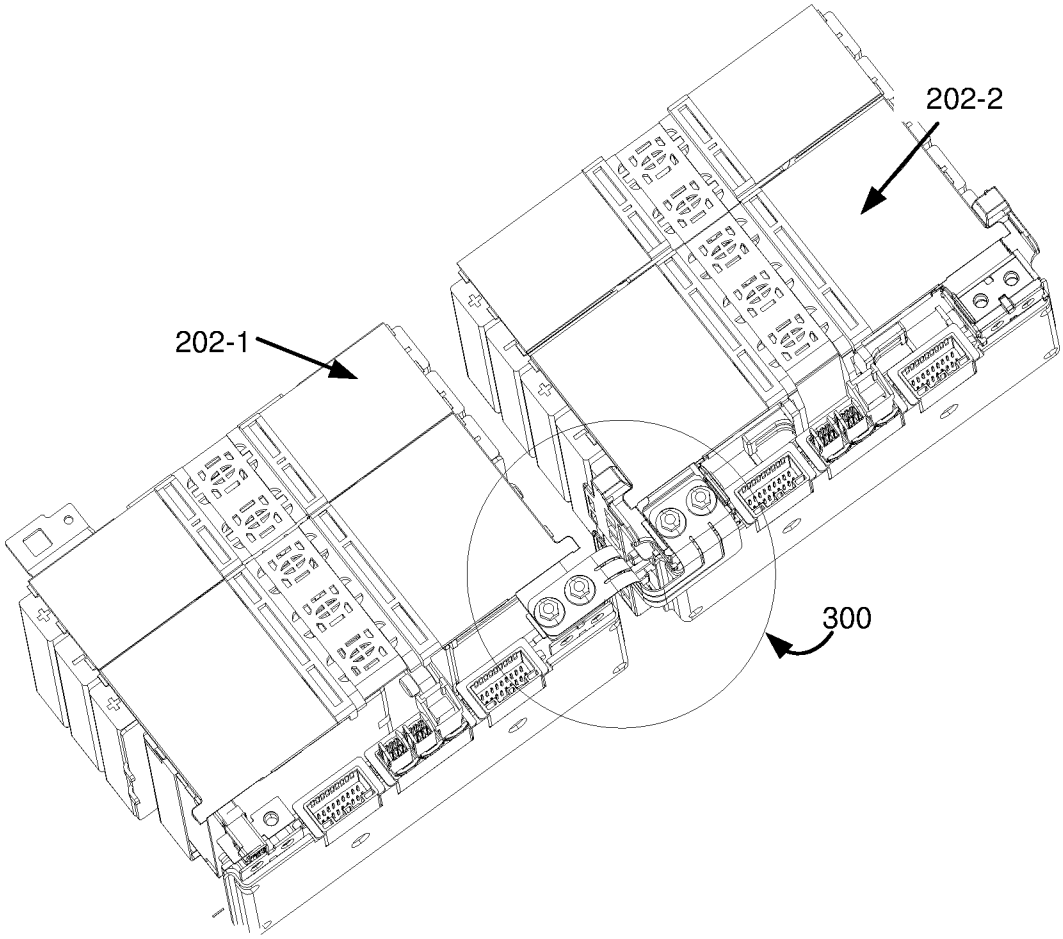



**Figure 3**

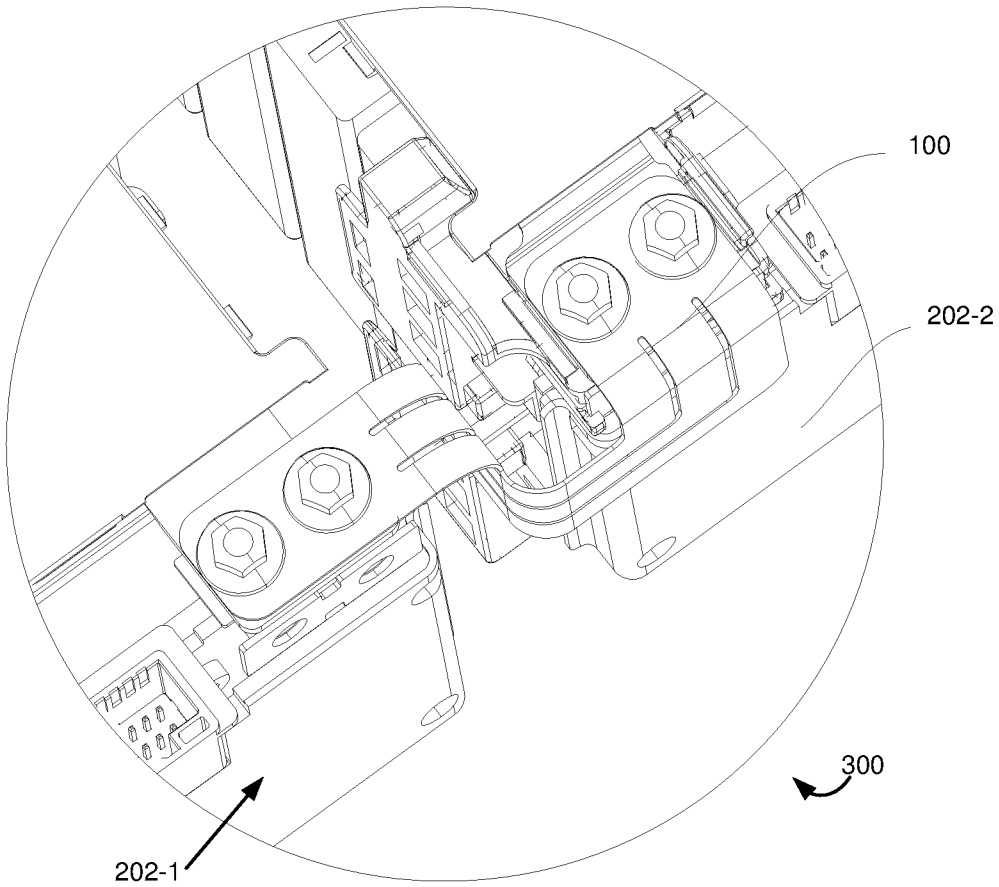



**Figure 4**

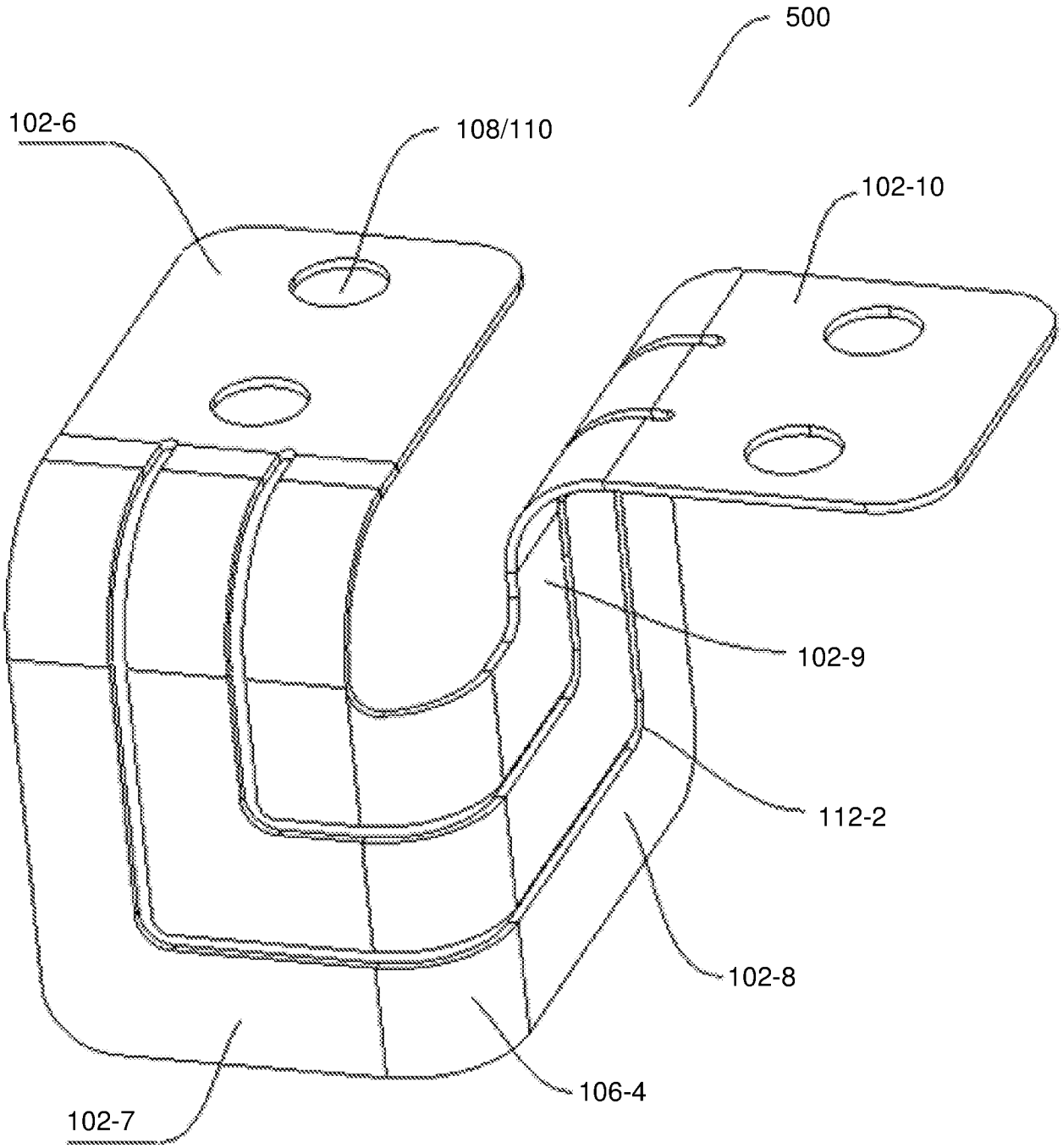



**Figure 5**

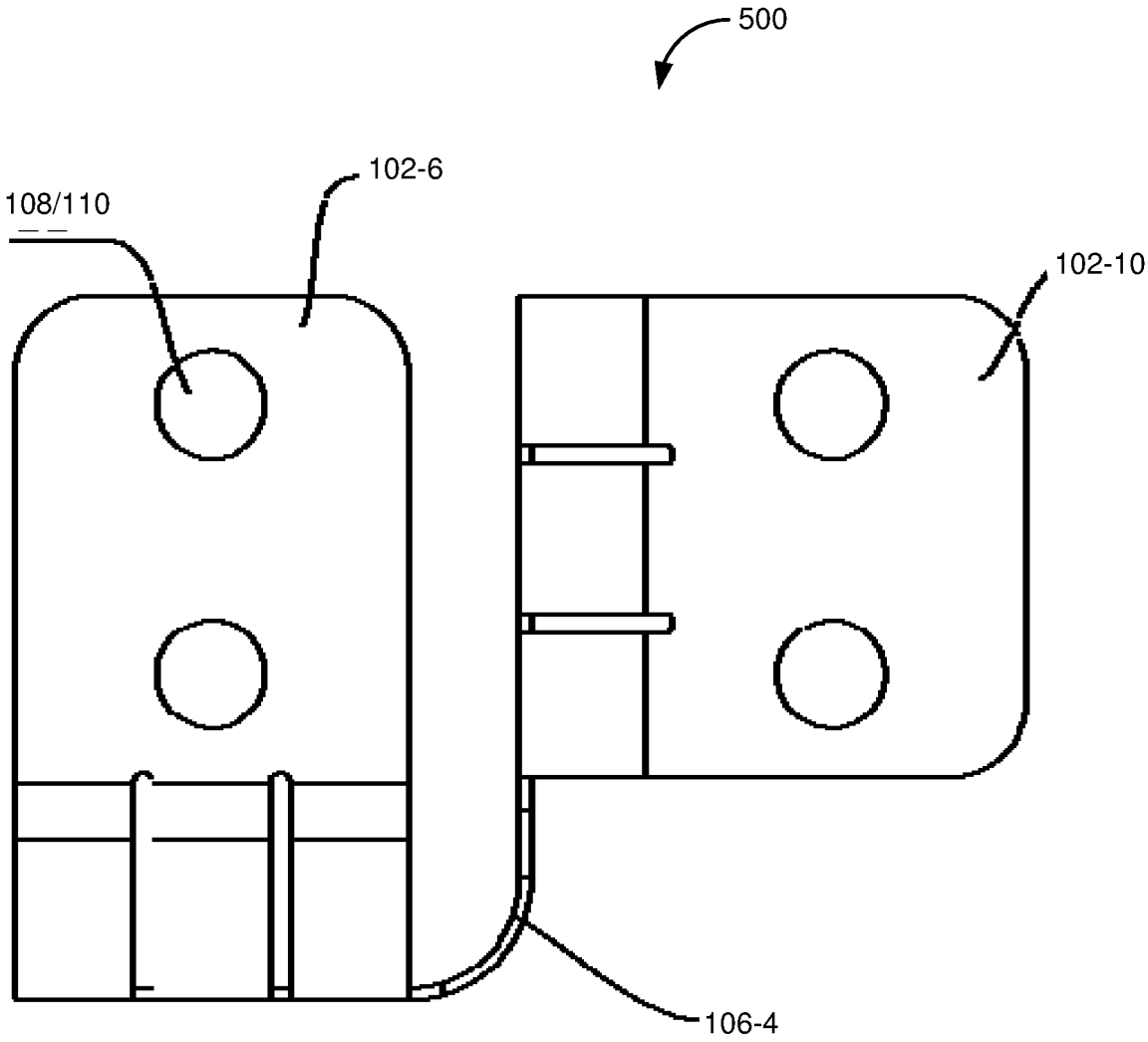



**Figure 6**

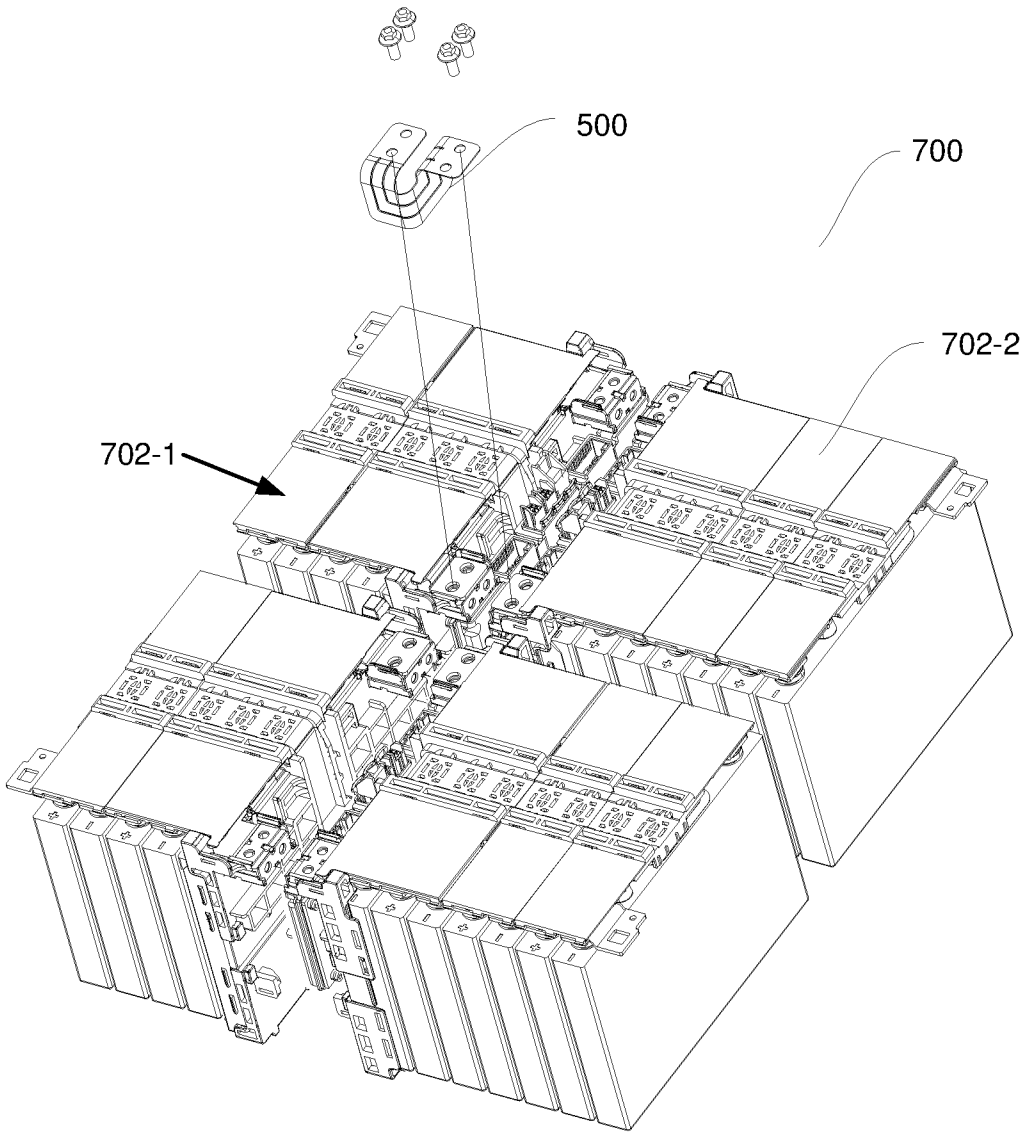



Figure 7

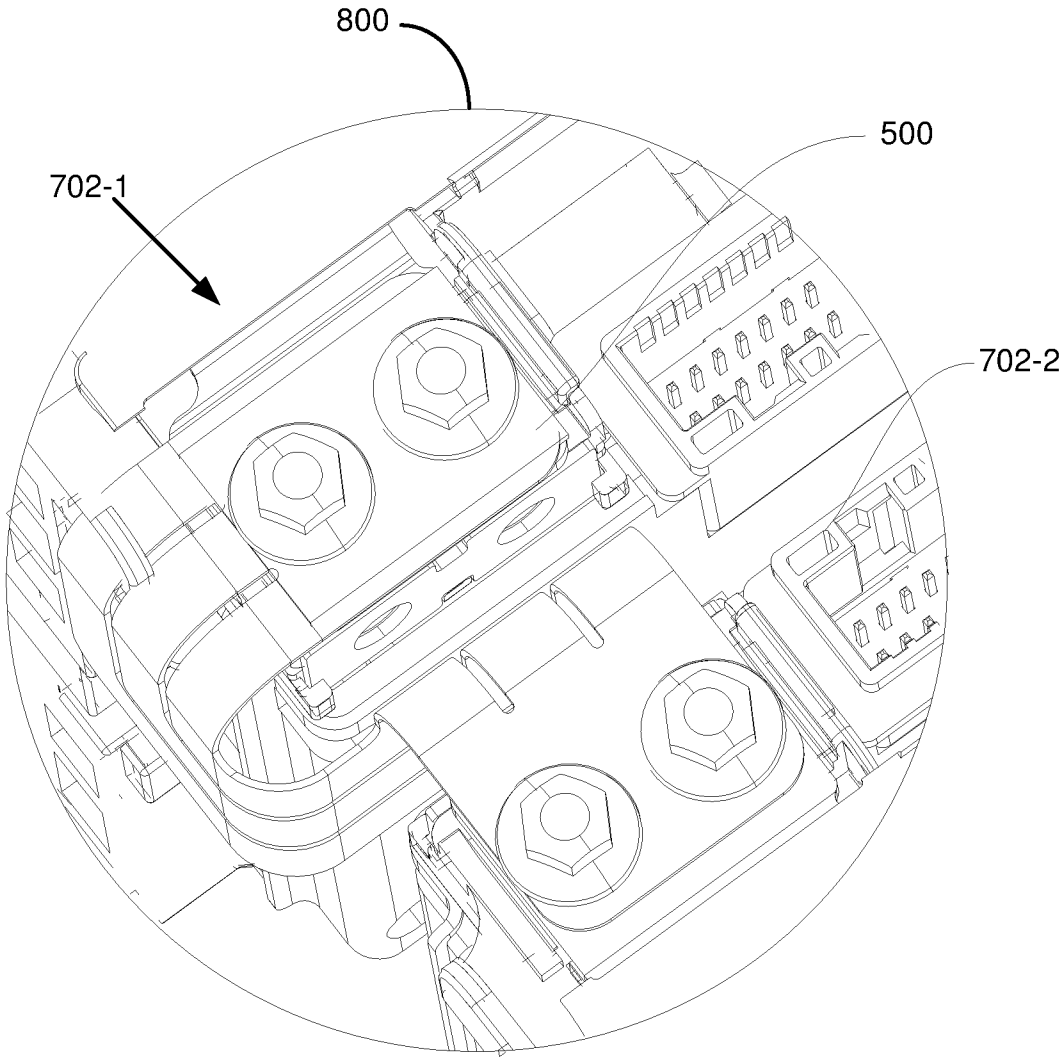



**Figure 8**

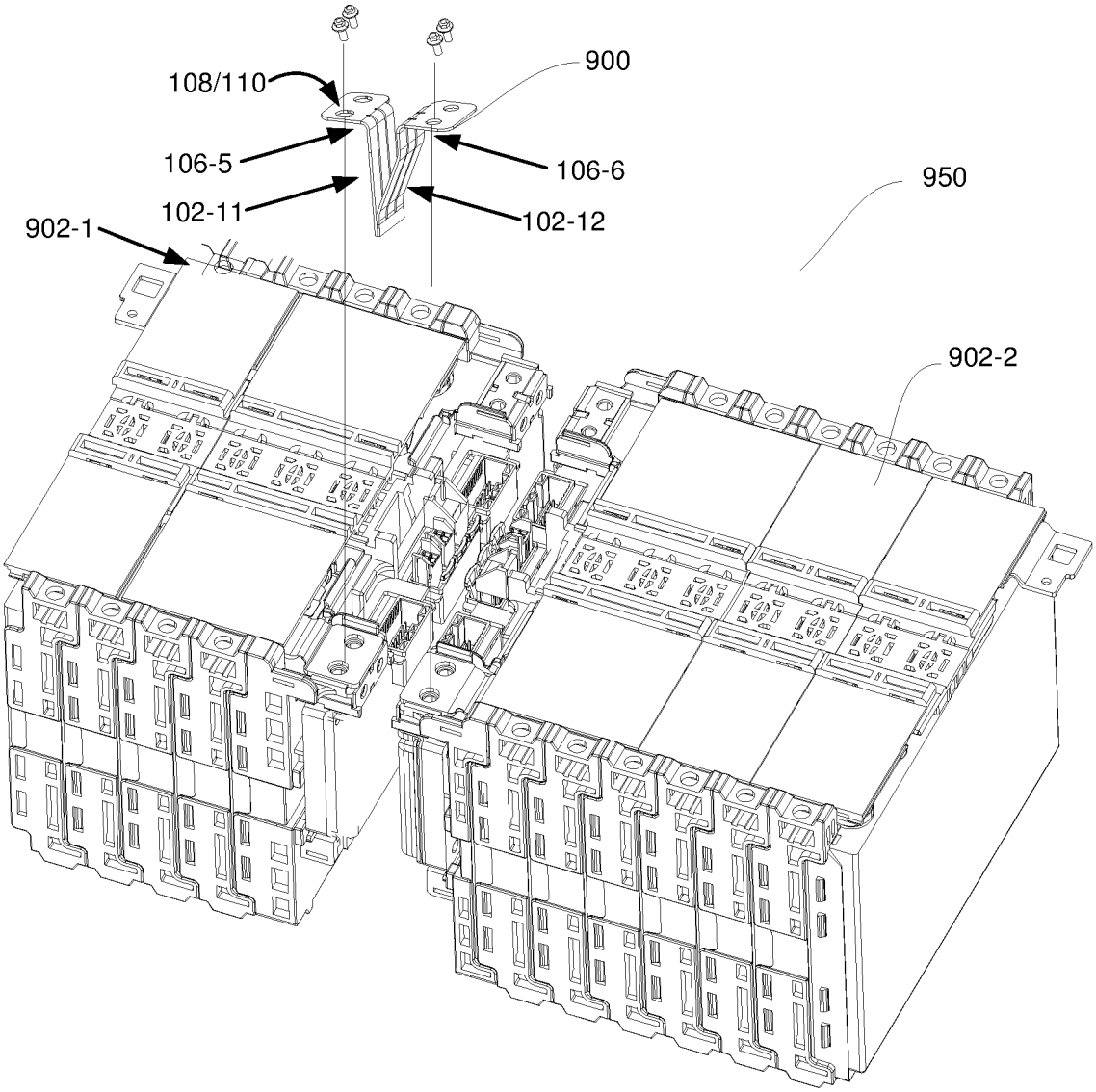



**Figure 9**

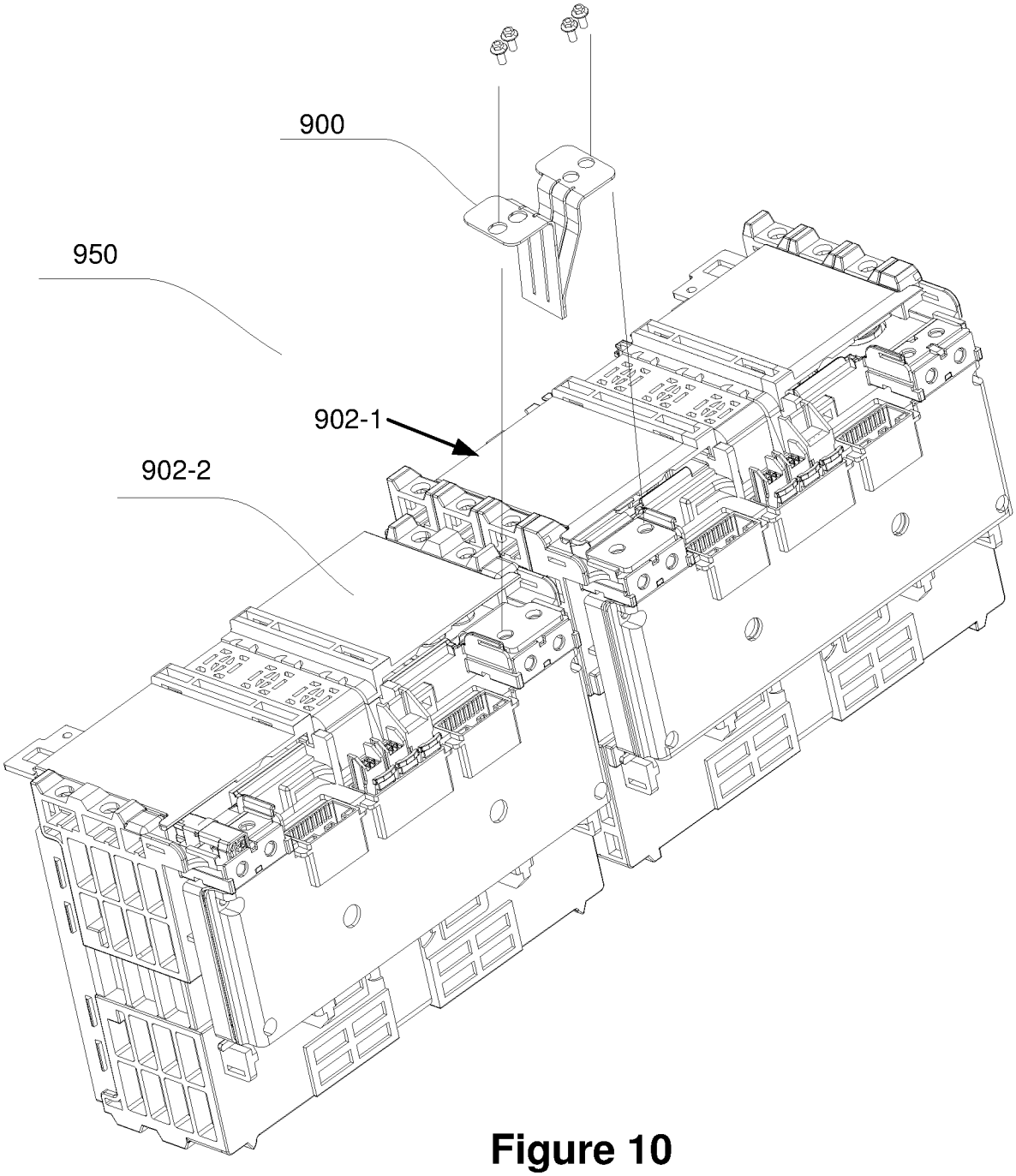



Figure 10

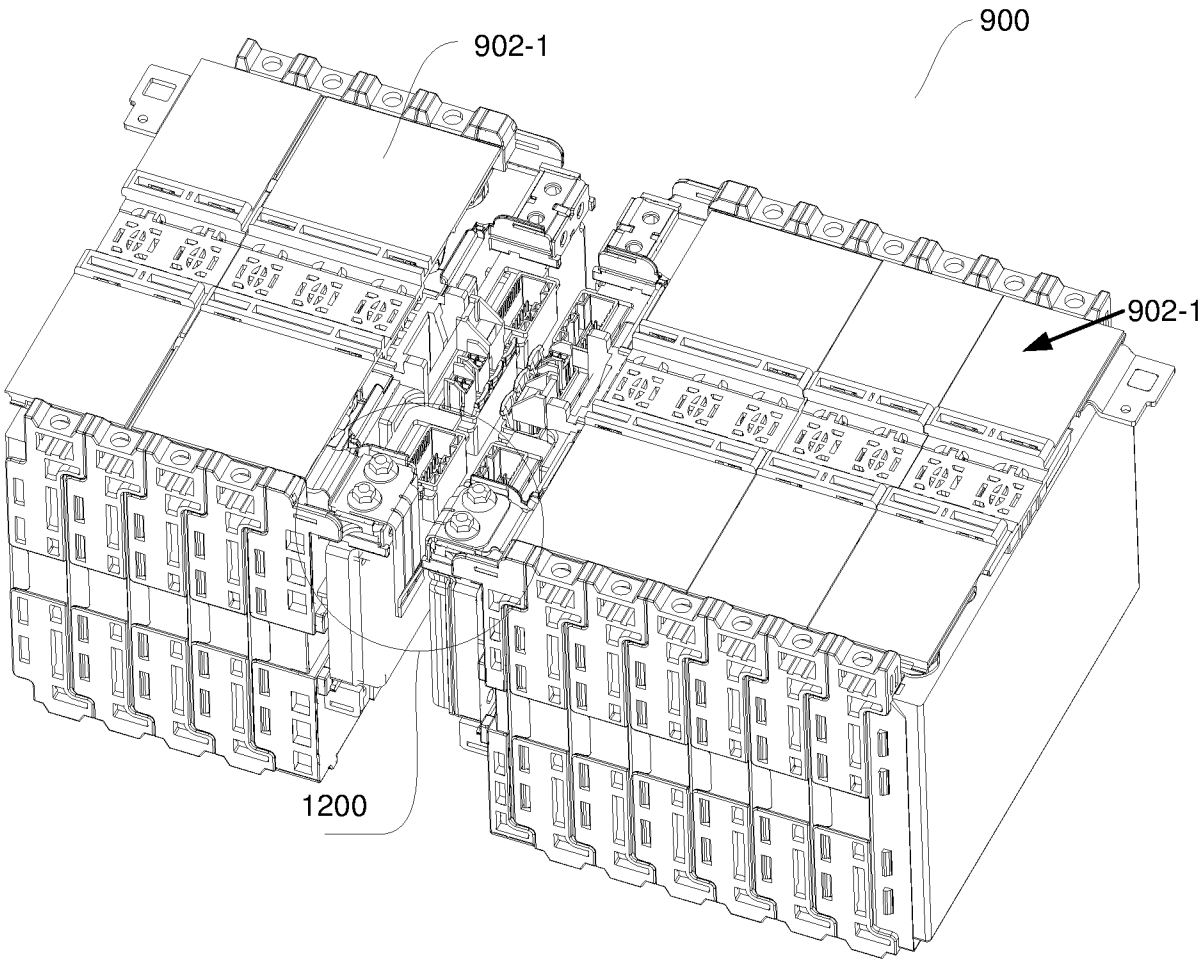



**Figure 11**

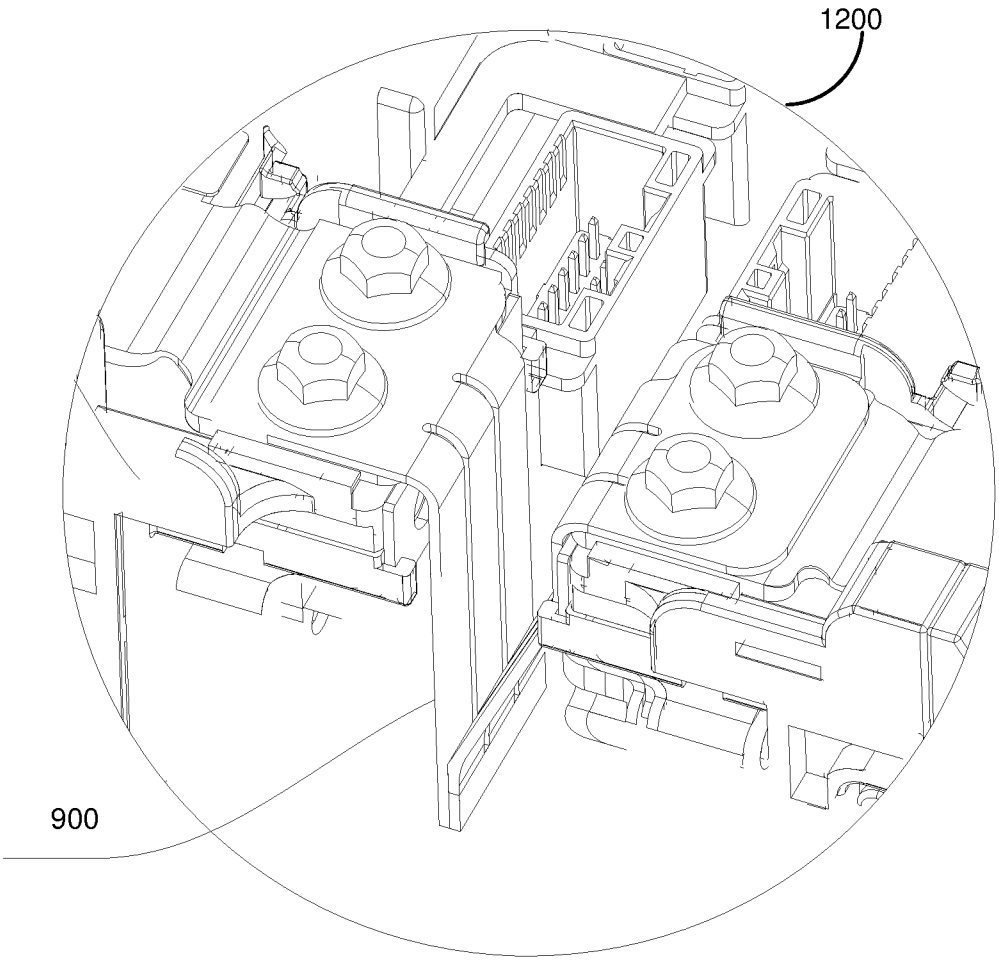
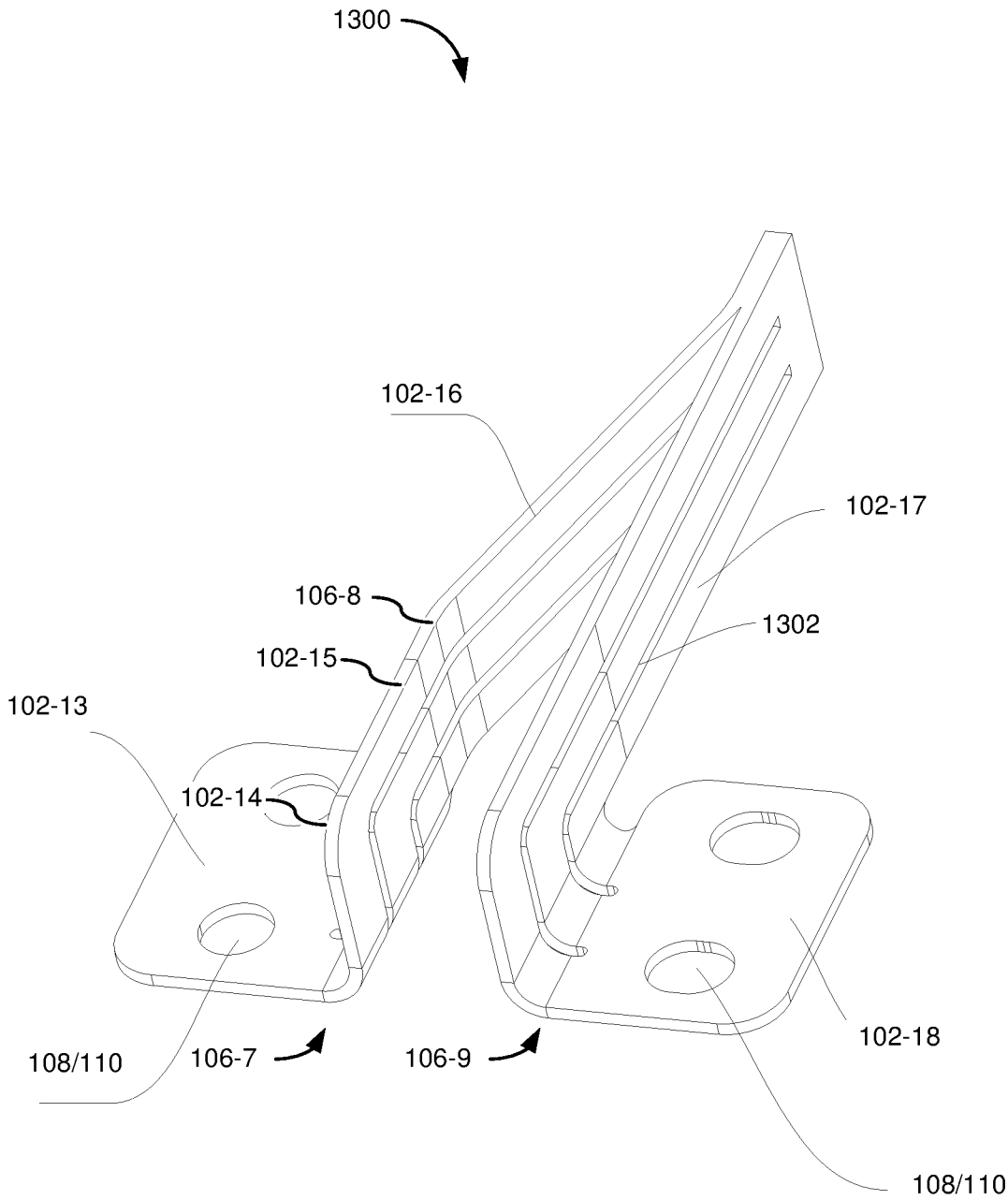



**Figure 12**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106-7
106-9
102-18
108/110

**Figure 13**

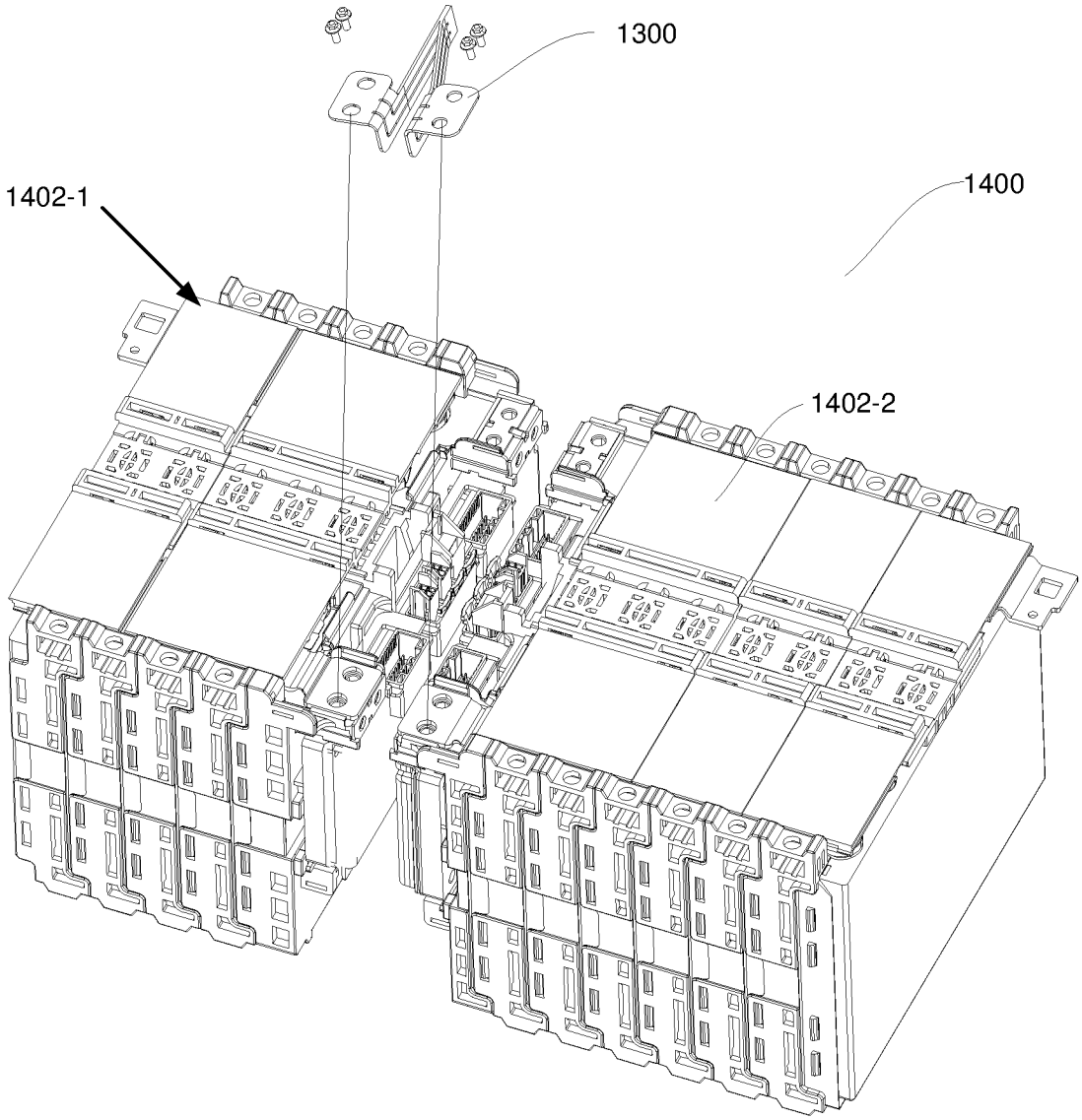



**Figure 14**

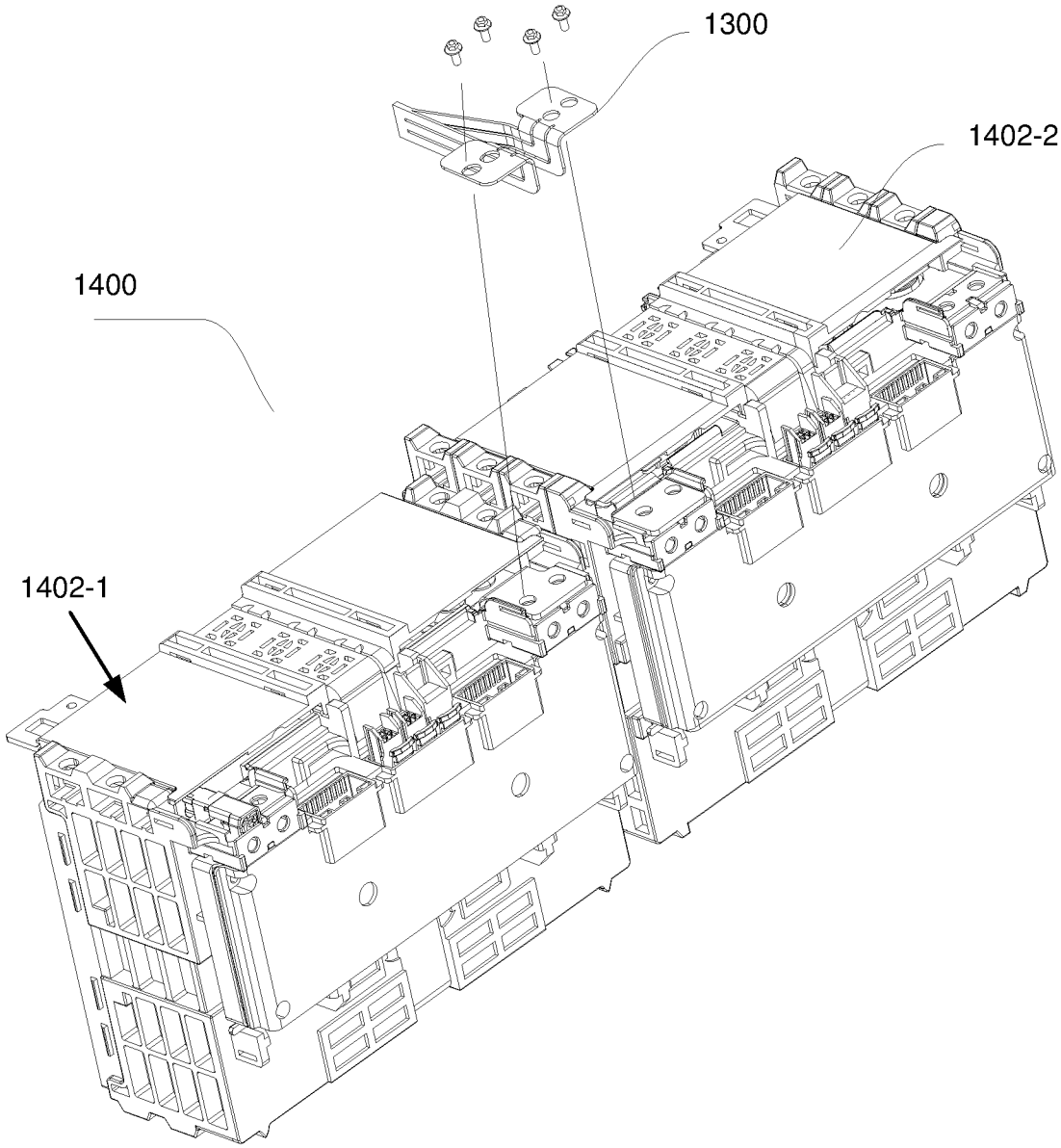



**Figure 15**

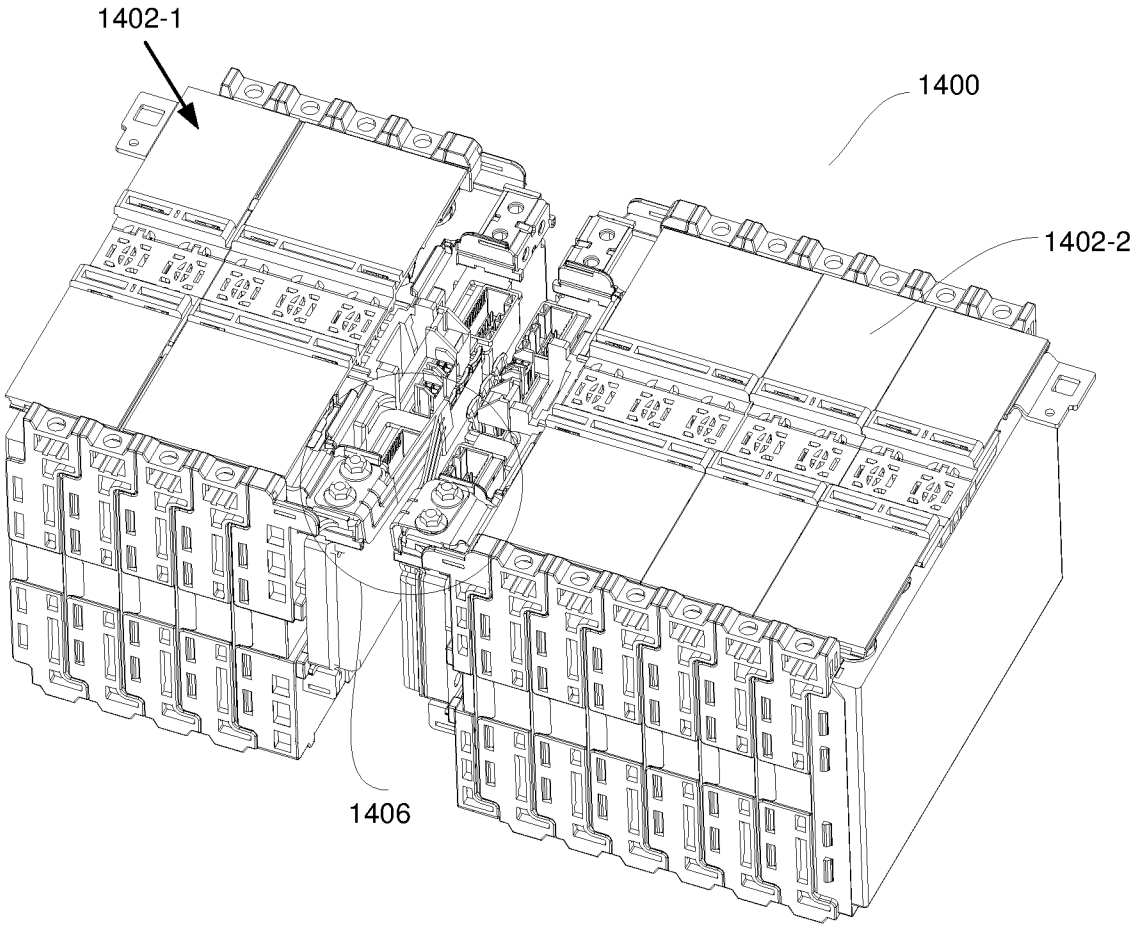



**Figure 16**

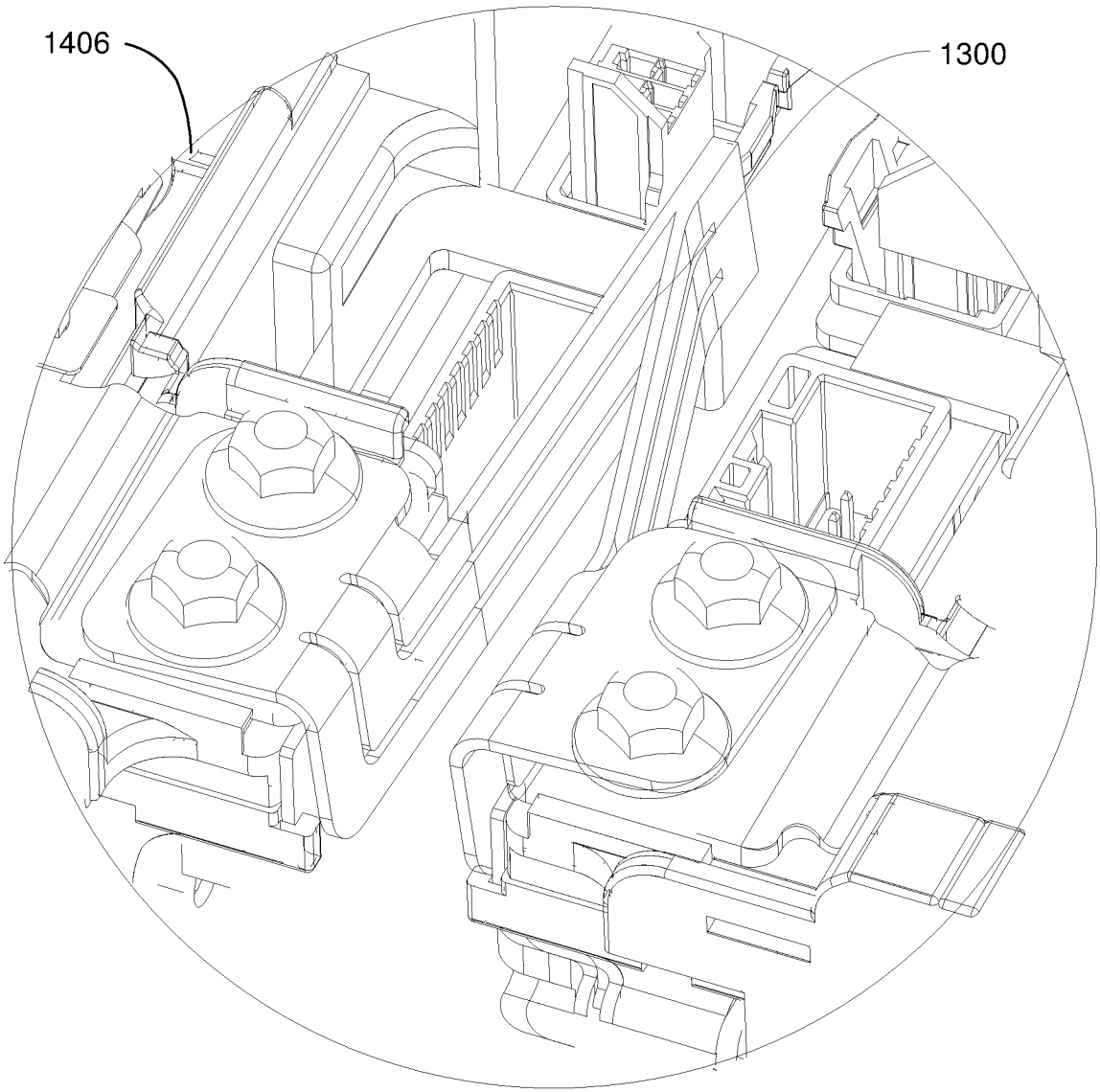
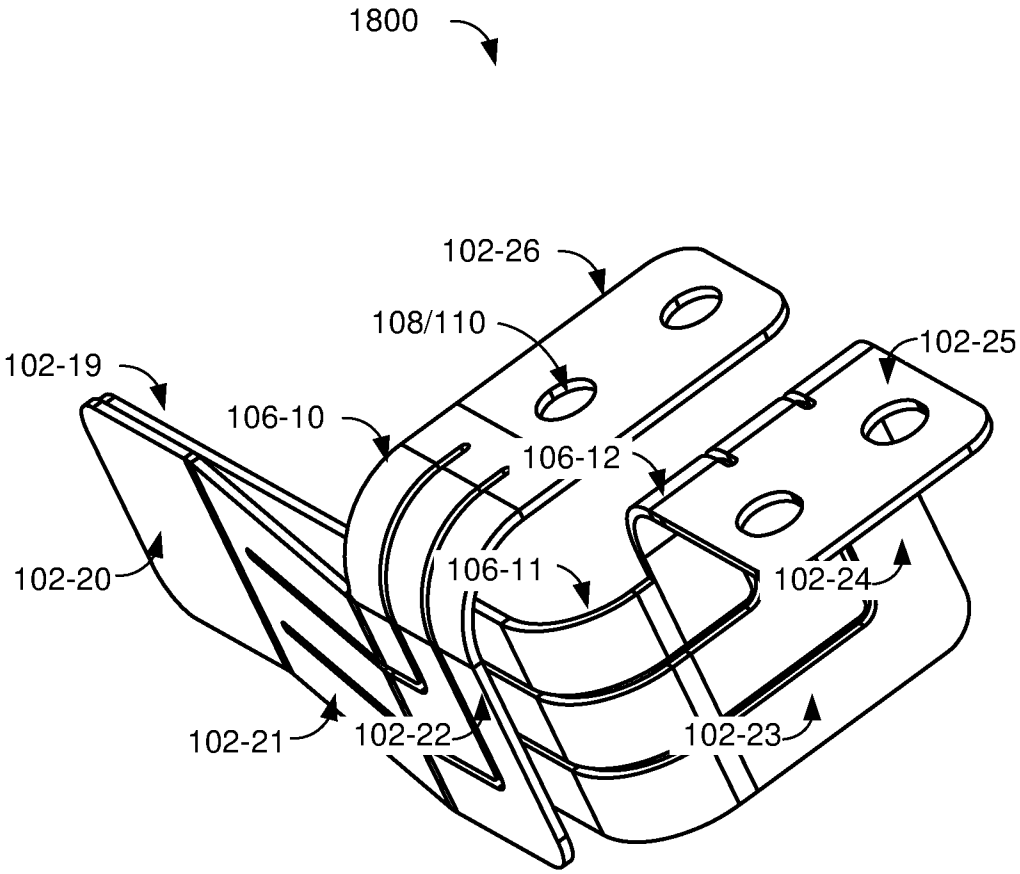



**Figure 17**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102-26
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106-11
102-24
102-21
102-22
102-23

**Figure 18**

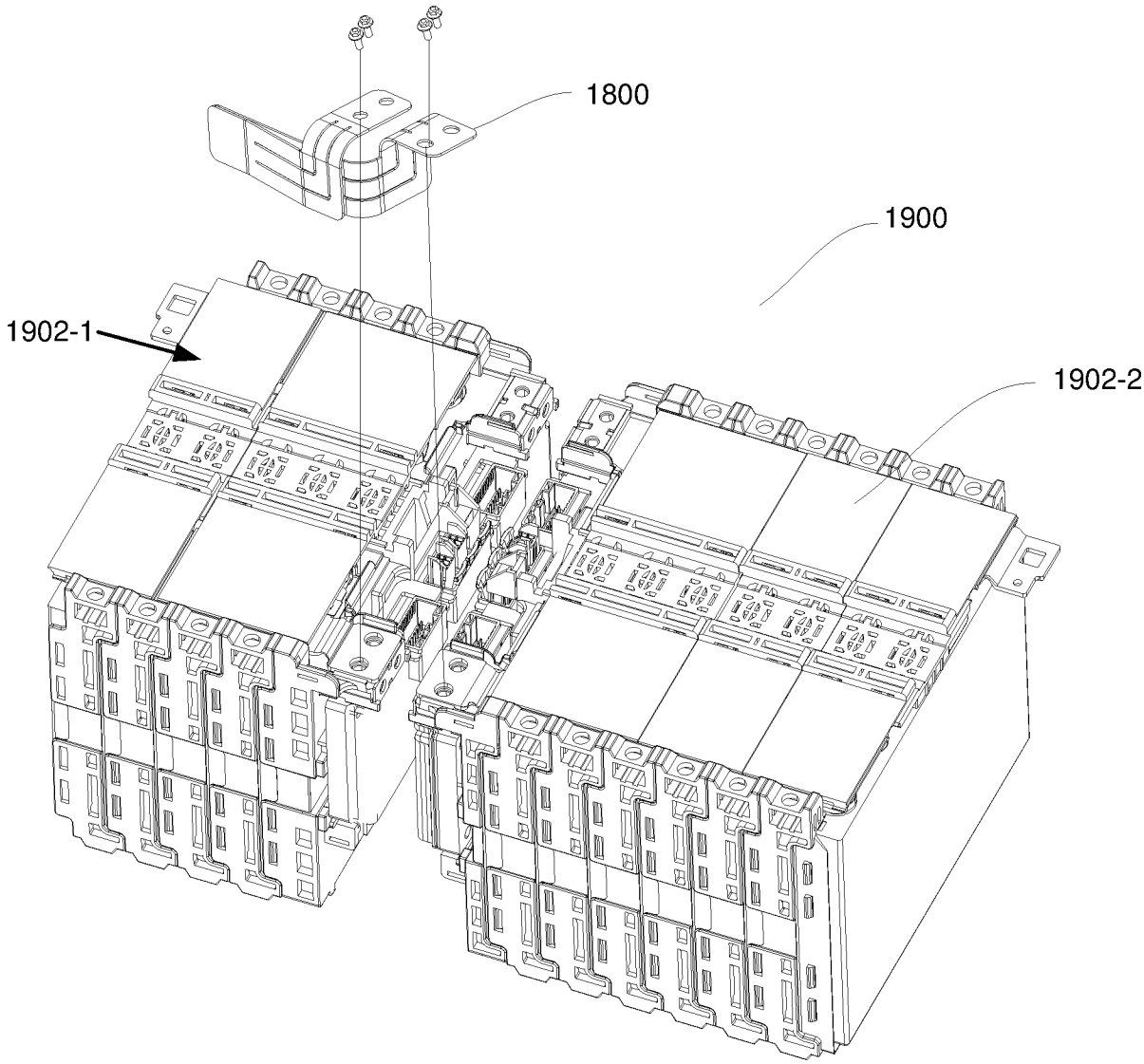



**Figure 19**

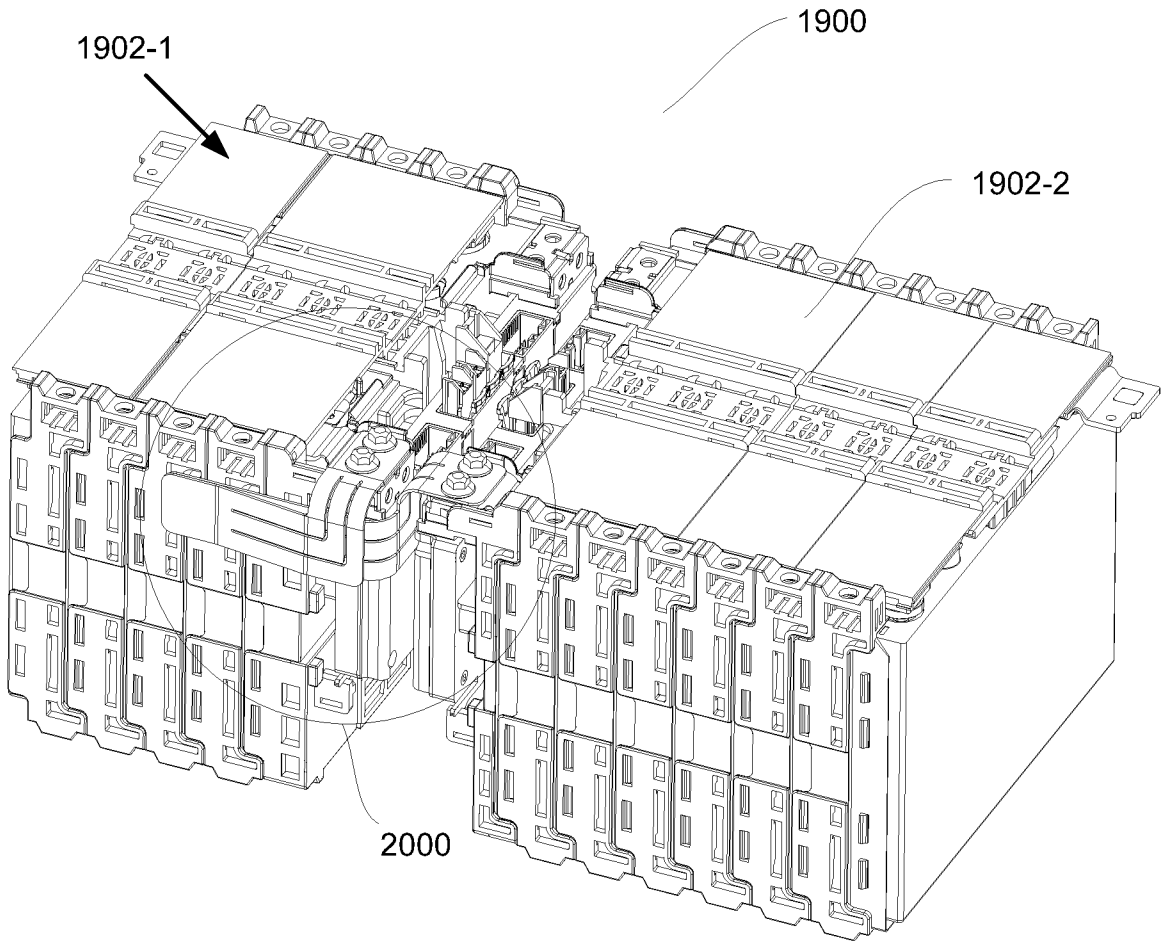



Figure 20

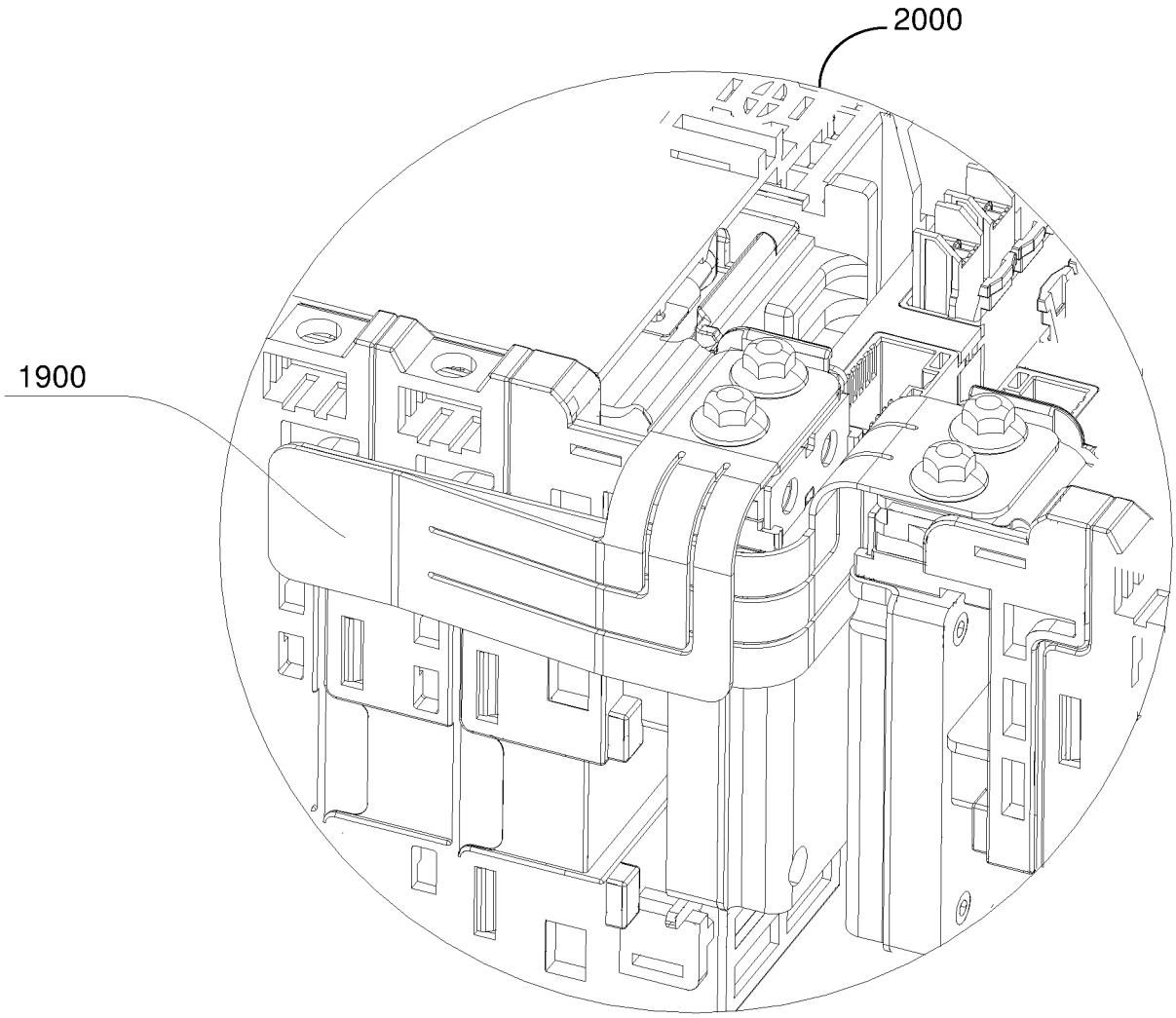



**Figure 21**

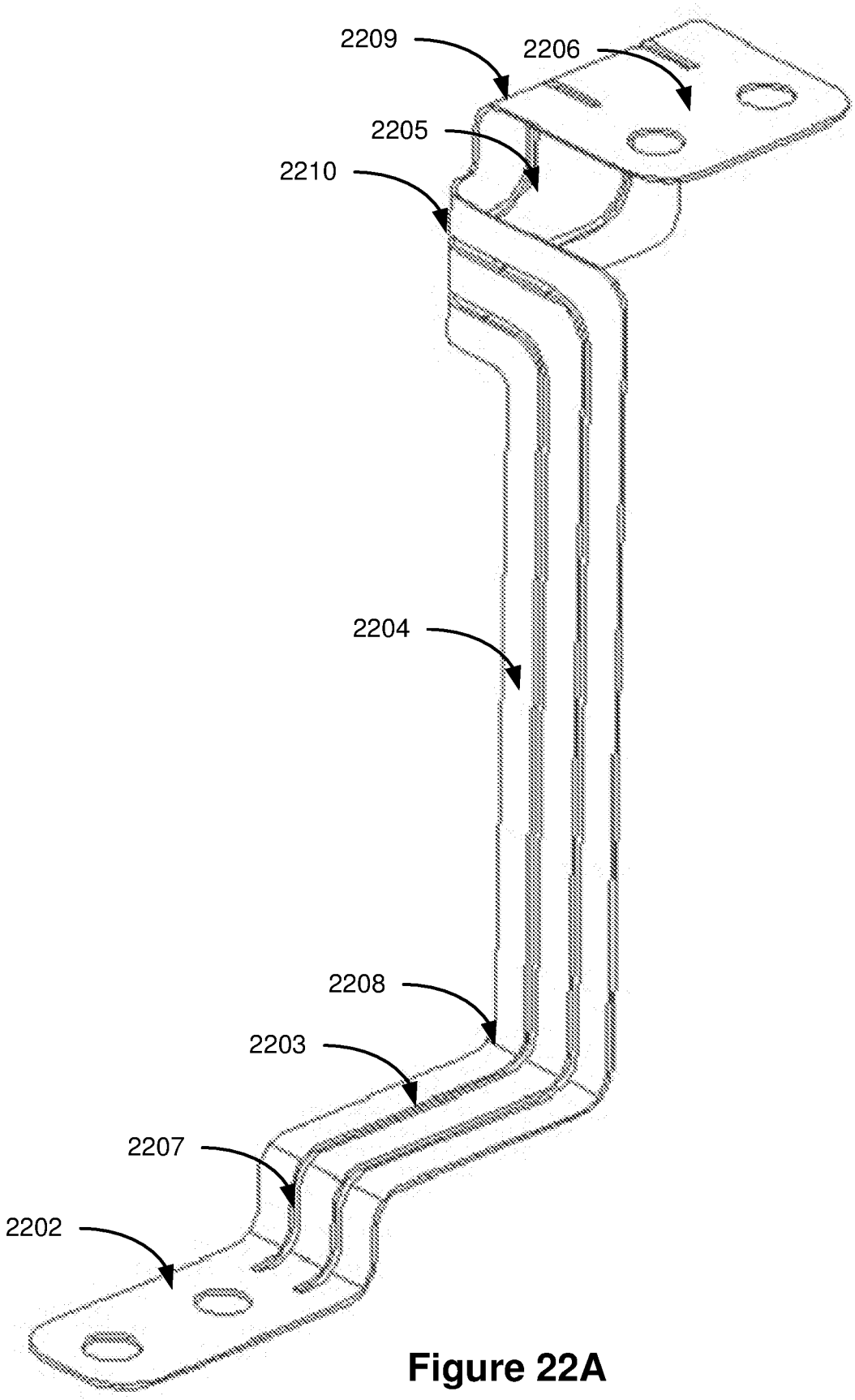



Figure 22A

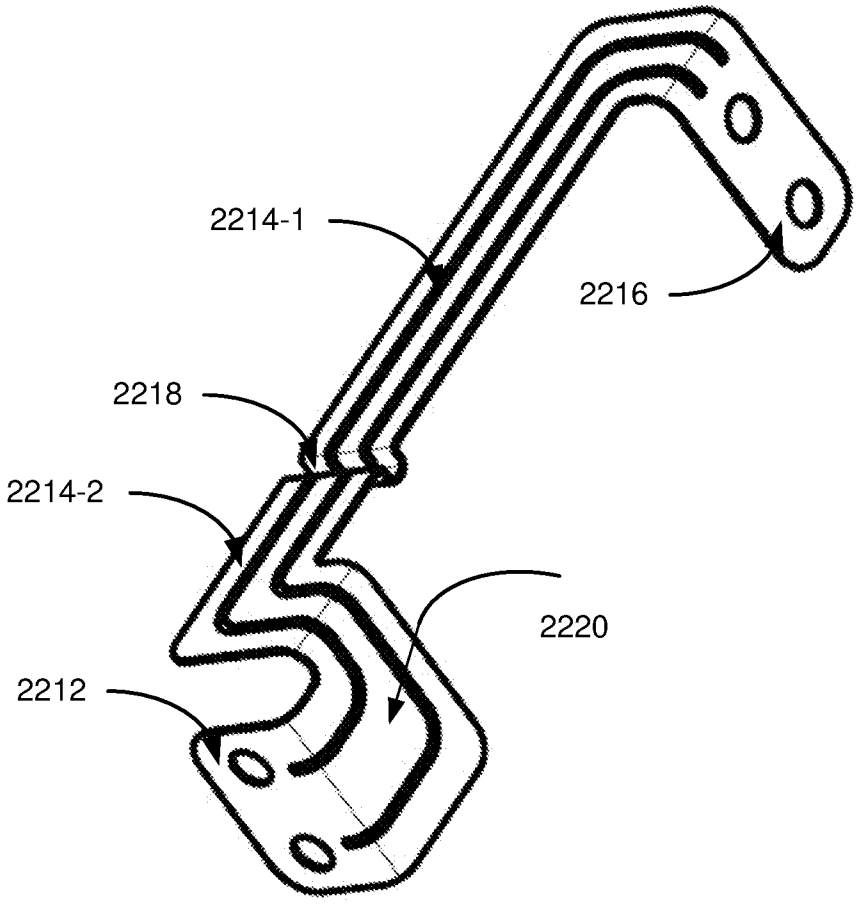



Figure 22B

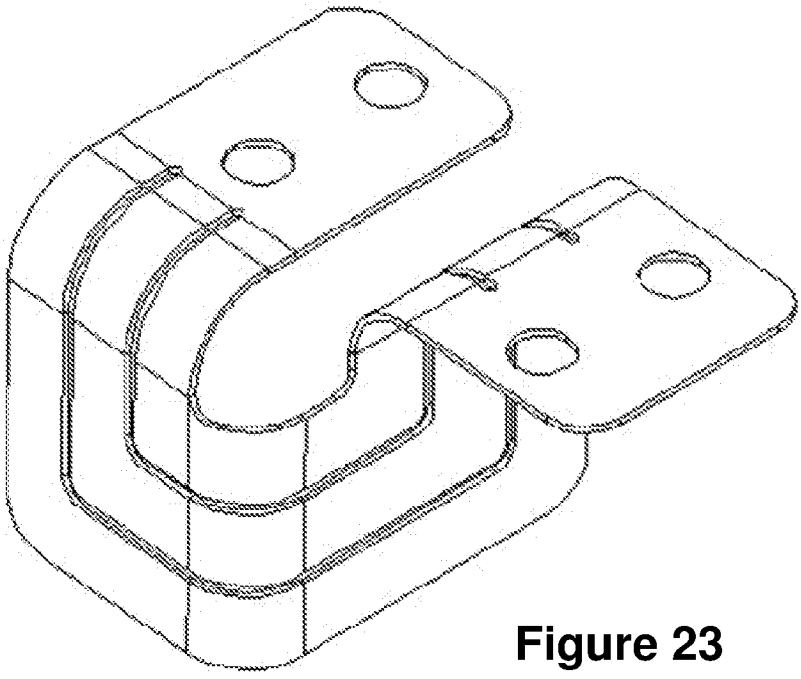


Figure 23

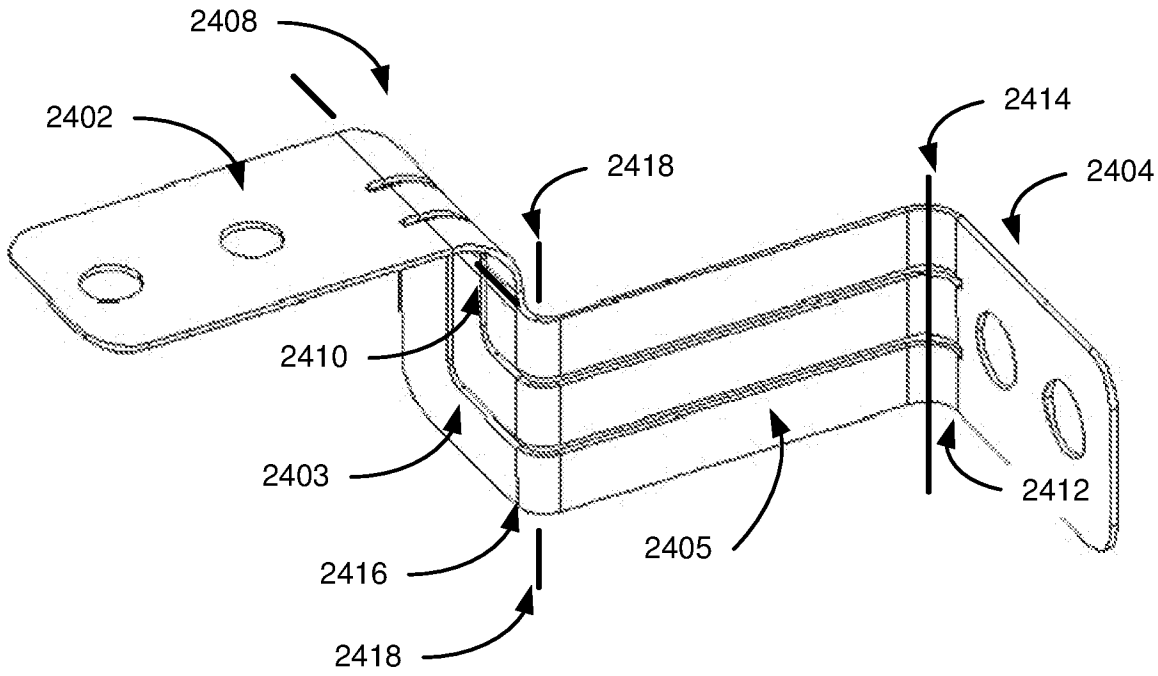



Figure 24

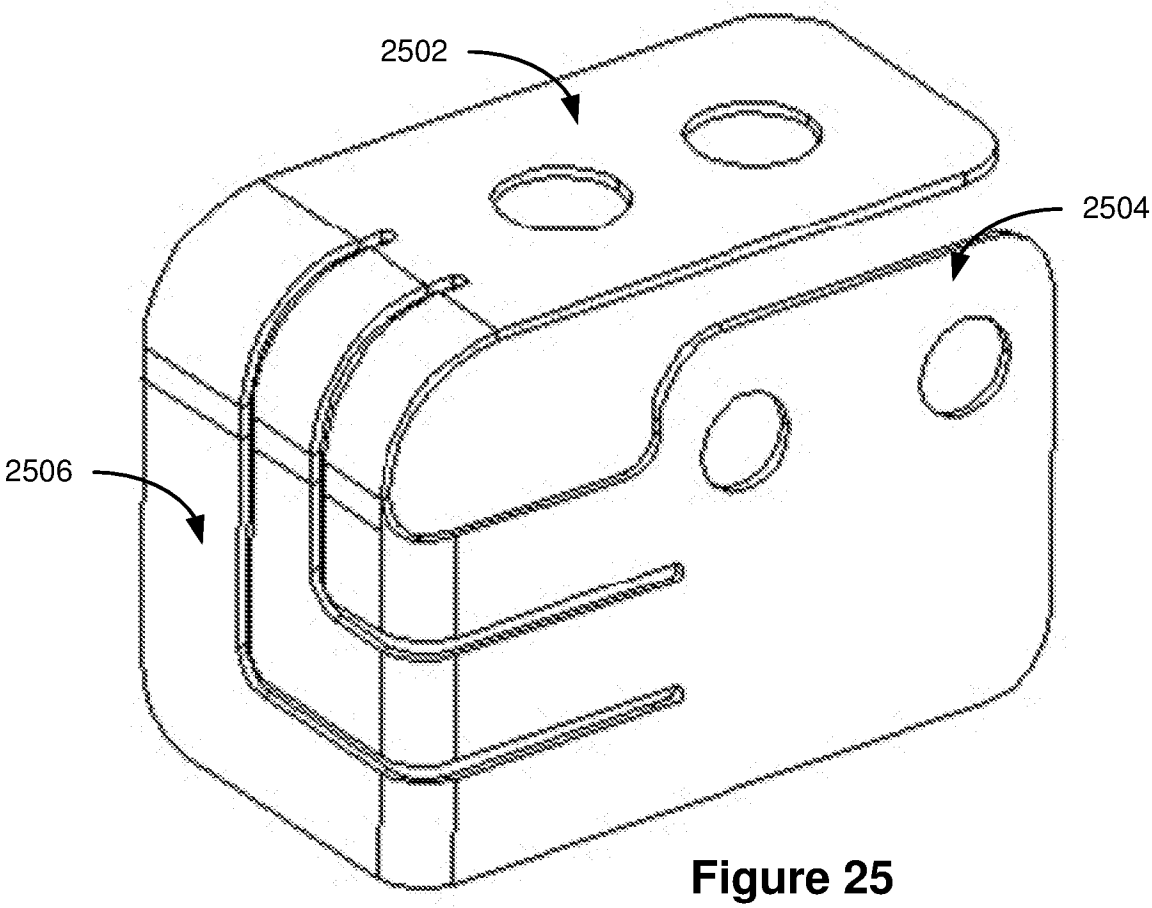



Figure 25

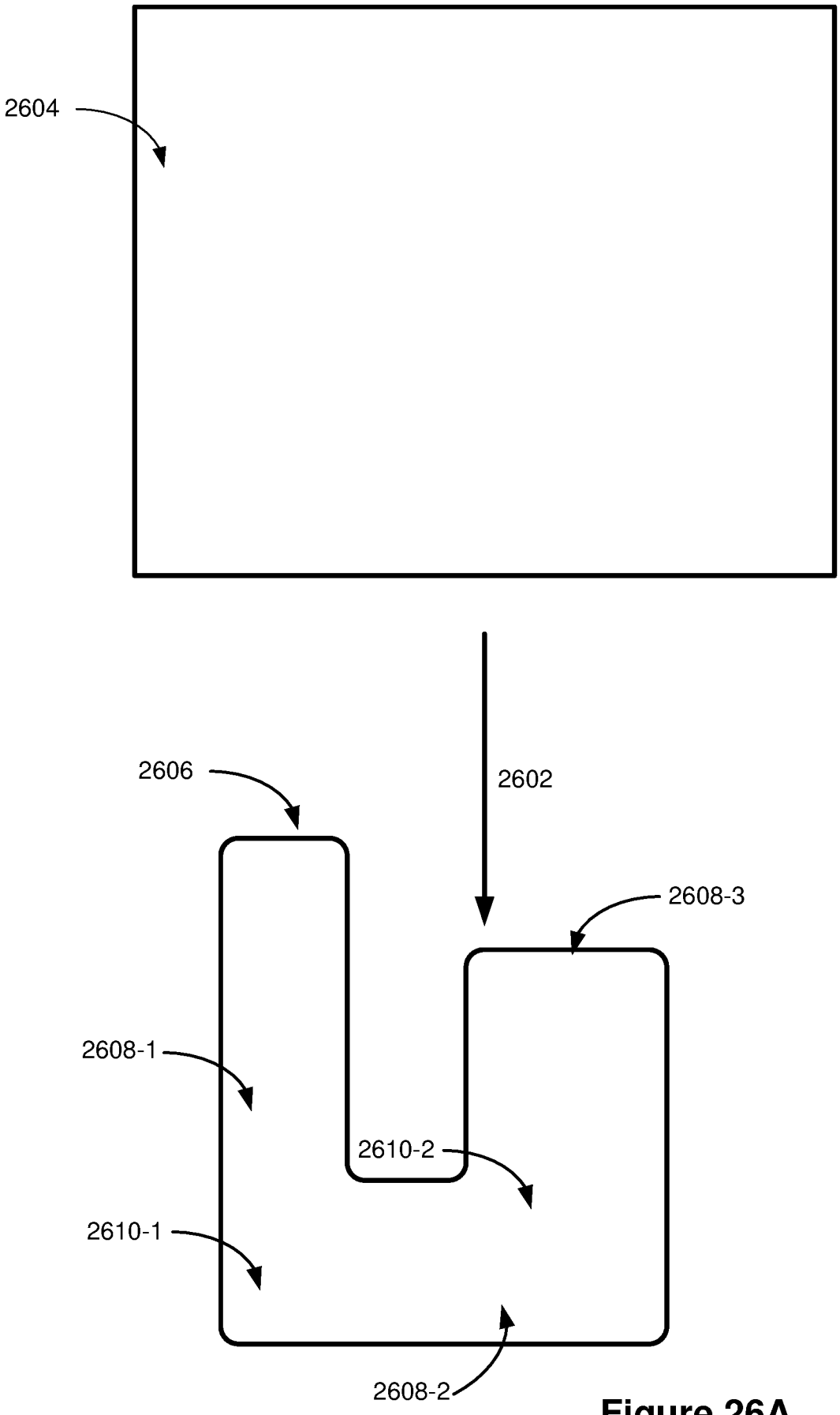
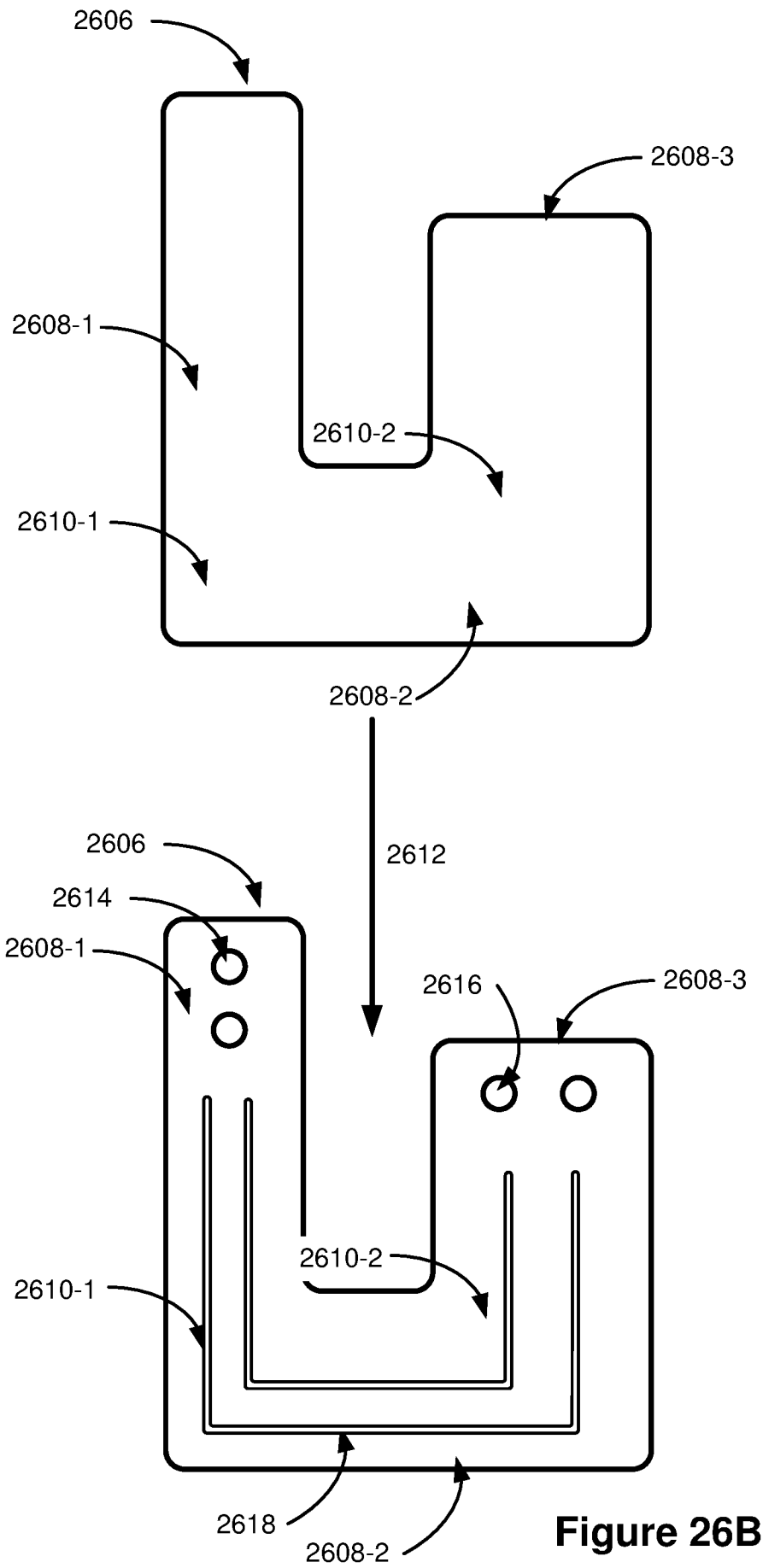



Figure 26A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2608-2
2612
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2610-1
2618
2608-2

Figure 26B

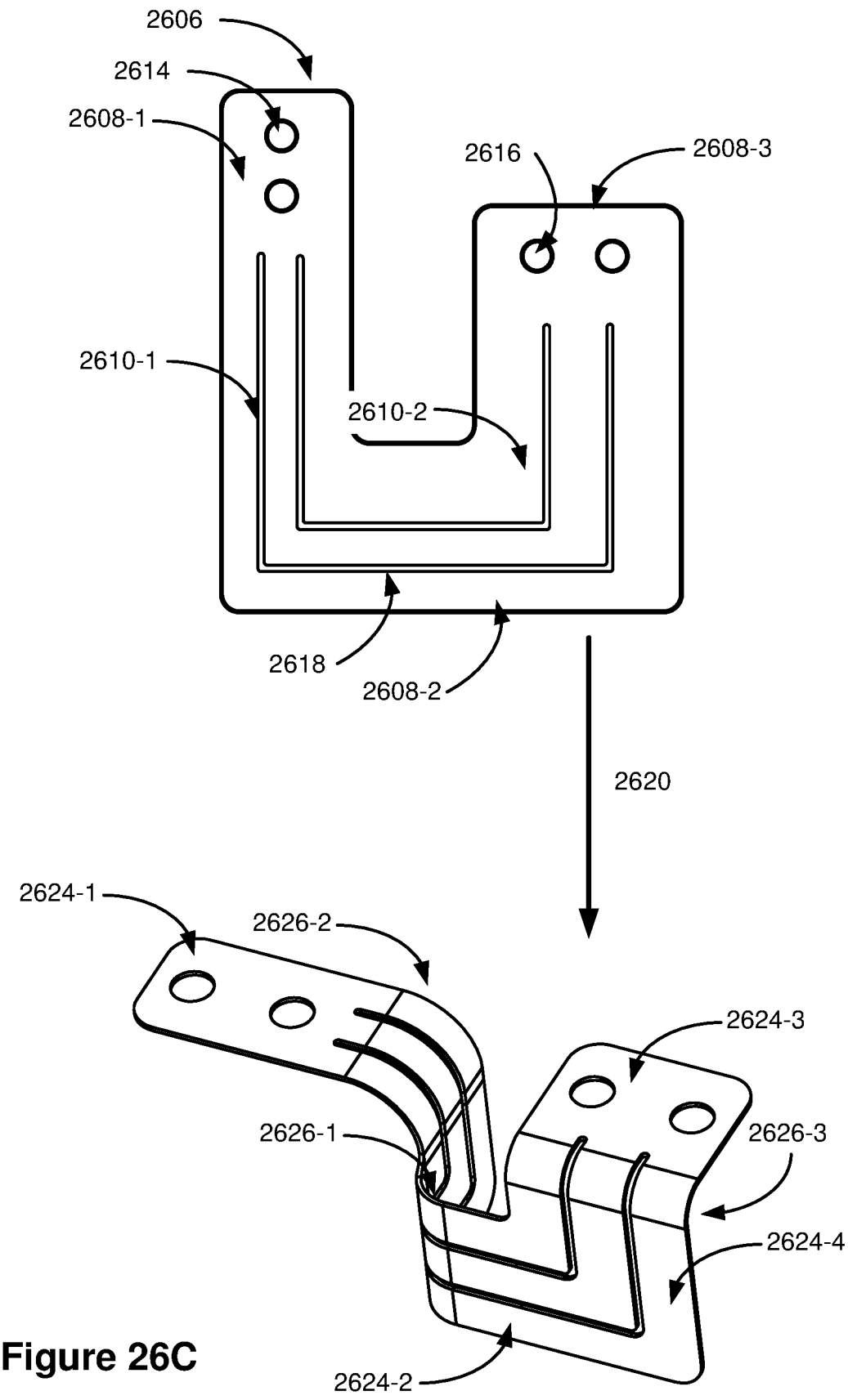
2606
2614
2608-1
2616
2608-3
2610-1
2610-2
2618
2608-2
2620
2624-1
2626-2
2624-3
2626-1
2626-3
2624-4
2624-2

Figure 26C

# INTERNATIONAL SEARCH REPORT

International application No.
**PCT/CN2015/091268**

## A. CLASSIFICATION OF SUBJECT MATTER

H01M 2/20(2006.01)i

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)

CNPAT;CNKI;WPI;EPODOC;GOOGLE:battery,cell,connector,direction?,axis, bend?,electrode

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | CN 101820056 A (BYD CO., LTD.) 01 September 2010 (2010-09-01)<br>description, paragraphs [0009]-[0036], figures 2、4 | 1-42 |
| A | CN 103563128 A (ELRINGKLINGER AG. ET AL.) 05 February 2014 (2014-02-05)<br>the whole document | 1-42 |
| A | WO 2013111522 A1 (YAZAKI CORPORATION) 01 August 2013 (2013-08-01)<br>the whole document | 1-42 |
| A | CN 2763986 Y (LIANZHAN TECH. SHENZHEN CO., LTD.) 08 March 2006 (2006-03-08)<br>the whole document | 1-42 |

☐ 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 | Date of mailing of the international search report |
|---|---|
| **20 January 2016** | **05 February 2016** |

| Name and mailing address of the ISA/CN | Authorized officer |
|---|---|
| **STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA**<br>**6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China** | **JIAO,Yonghan** |
| Facsimile No. **(86-10)62019451** | Telephone No. **(86-10)62413983** |

**INTERNATIONAL SEARCH REPORT**
**Information on patent family members**

International application No.
**PCT/CN2015/091268**

| Patent document cited in search report | | | Publication date (day/month/year) | Patent family member(s) | | | Publication date (day/month/year) |
|---|---|---|---|---|---|---|---|
| CN | 101820056 | A | 01 September 2010 | None | | | |
| CN | 103563128 | A | 05 February 2014 | WO | 2012163642 | A3 | 11 April 2013 |
| | | | | US | 9136039 | B2 | 15 September 2015 |
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| | | | | EP | 2807693 | A1 | 03 December 2014 |
| | | | | JP | 2013157129 | A | 15 August 2013 |
| CN | 2763986 | Y | 08 March 2006 | None | | | |