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(71) Applicant (for all designated States except US): **A123 SYSTEMS, INC.** [US/US]; 200 West Street, Waltham, Massachusetts 02451 (US).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **AHMAD, Arfan** [CA/CA]; 4243 Whiskey Avenue, Windsor, Ontario N9G 3B6 (CA).

(74) Agent: **LEWIS, Donald J.**; Alleman Hall McCoy Russell & Tuttle LLP, 806 SW Broadway, Suite 600, Portland, Oregon 97205 (US).

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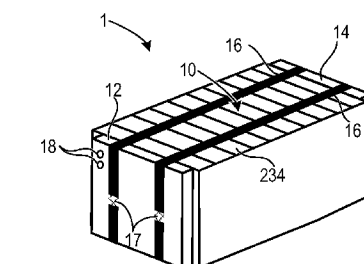


FIG. 1

(57) Abstract: A battery module is provided. The battery module may include a battery cell stack including a plurality of sealed electrochemical cells interposing a first and a second end cover, the first end cover including a band engagement section. The battery module may further include a retention band circumnavigating the battery cell stack, first end cover, and second end cover, the retention band joined at an overlapping portion and including an engagement end mated with the band engagement section.

BATTERY MODULE HAVING RETENTION BAND AND METHOD OF ASSEMBLY

Technical Field

[0001] The present application relates to the field of battery modules and battery packs.

Background and Summary

[0002] Excess heat and/or voltage in a battery cell may cause the liquid electrolyte within the cells to change into a gaseous state. Consequently, increased pressure may build up in the cell causing the cell's packaging to distend. The distended cells may increase the size of the battery module and/or degrade operation of the battery.

[0003] Some battery modules have used a rigid housing to reduce the battery cell expansion. Other battery modules have used bands fitted with tensioning buckles to reduce cell expansion.

[0004] However, the inventors herein have recognized various shortcomings of the above approaches. For example, buckles may increase costs as well as the profile of the battery module, thereby requiring additional packaging space.

[0005] As such, various example systems and approaches are described herein, including a battery module having a battery cell stack including a plurality of sealed electrochemical cells interposing a first and a second end cover, the first end cover including a band engagement section. The battery module may further include a retention band circumnavigating the battery cell stack, first end cover, and second end cover, the retention band joined at an overlapping portion and including an engagement end mated with the band engagement section. The engagement end of the band may be formed via a crimping action to an otherwise un-modified end of the

band, such as via a crimping tool. The crimping action may form various protrusions that are shaped to mate with corresponding recesses in the band engagement section of the first end cover. In this way, standardized banding material may be cut at various lengths and used to join various sized stacks, while still achieving reliable banding and tensioning at reduced costs, such as without any buckles in one example.

[0006] Furthermore, a method for assembly a battery module including a first and a second end cover interposing a battery cell stack is provided. The method may include matting an engagement end of a retention band in a band engagement section included in the first end cover, circumnavigating a periphery of the battery module with the retention band, tensioning the retention band to a desired level, and joining a first portion of the retention band to a second portion of the retention band.

[0007] In this way, a low profile retention band may be used to reduce cell expansion during operation of the battery module, thereby increasing the battery module's performance. Additionally, the mated band engagement section and engagement end enables a desired level of tensioning to be provided to the retention band during installation.

[0008] The above advantages and other advantages, and features of the present description will be readily apparent from the following Detailed Description when taken alone or in connection with the accompanying drawings.

[0009] It should be understood that the summary above is provided to introduce in simplified form a selection of concepts that are further described in the detailed description. It is not meant to identify key or essential features of the claimed subject matter, the scope of which is defined uniquely by the claims that follow the detailed description. Furthermore, the claimed subject matter is not limited to

implementations that solve any disadvantages noted above or in any part of this disclosure.

Brief Description of the Drawings

- [0010] Fig. 1 illustrates a battery module including a battery cell stack.
- [0011] Fig. 2 shows an exploded view of a portion of the battery cell stack shown in Fig. 1.
- [0012] Figs. 3-5 show multiple views of an engagement end of a retention band.
- [0013] Fig. 6 shows a side view of an end cover that may be included in the battery module shown in Fig. 1.
- [0014] Figs. 7-11 show an assembly process for the battery module.
- [0015] Fig. 12 shows a method for assembly of a battery module.
- [0016] Fig. 13 shows an illustration of a vehicle in which the battery module shown in Fig. 1 may be used.

Detailed Description of the Depicted Embodiments

- [0017] Fig. 1 shows a battery module 1 including a battery cell stack 10 interposed between a first end cover 12 and a second end cover 14. The battery cell stack may include a plurality of stacked and sealed electrochemical cells. The stacked arrangement allows the battery cells to be densely packed in the battery module, described in more detail herein with regard to Fig. 2.
- [0018] Retention bands 16 may circumnavigate an exterior of battery module 1. As depicted the retention bands extend down the sides of the battery cell stack in a longitudinal direction and wrap around the first and second end covers in a vertical direction. However, it will be appreciated that other retention band arrangements are

possible. For example, the retention bands may wrap around the end covers in a lateral direction and extend longitudinally down the sides of the battery cell stack. Furthermore, it will be appreciated that an alternate number of retention bands may be used in other embodiments. For example, a single retention band may be used.

[0019] The retention bands may exert opposing compressive forces on the battery module to maintain the cell stack together, and may further operate to maintain the shape of the pack when the battery cells are distended due high temperature and/or high voltage conditions. The retention bands may limit, and in some cases substantially inhibit, expansion of the cells within the battery module, thereby improving the battery module's efficiency.

[0020] It will be appreciated that the opposing compressive forces may be exerted on the end covers in a longitudinally inward direction. In this way, the compression force may be distributed to battery cell stack via the end covers, enabling the compression force to be evenly distributed to the battery cell stack. Additionally, the opposing compressive forces may also be exerted on the battery cells stack in a vertically inward direction. Furthermore, opposing compressive forces may also be exerted on the battery module to secure the end covers to the battery cell stack while the cells are not experiencing elevated pressures. The desired amount of compressive force may be applied during assembly of the battery module when the retention bands are joined together, described in greater detail herein with regard to Figs. 7-11.

[0021] The retention bands may be welded together at overlapping portions 17. However other techniques may be used to join the retention bands, such as adhesive bonding. It will be appreciated that the welded retention bands have a low profile and increase the compactness of the battery module, when compared to other coupling devices, such as buckles.

[0022] An engagement end of each retention band may be mated with a corresponding band engagement section in the one and/or both of the first and second end covers. This attachment form allows the retention bands to be coupled to, and retained by, the first end cover during installation and tensioning. Specifically, the mating of the retention bands with the first end cover may reduce slipping of the retention bands during tensioning. The retention bands and corresponding installation process are discussed in greater detail herein with regard to Figs. 3-11.

[0023] Continuing with Fig. 1, the battery module may further include terminals 18, enabling energy or current to be provided to and extracted from battery module 1. In this way the battery module may be discharged and recharged.

[0024] Although any single battery pack has a given number of cells, different packs for different applications may have different numbers of cells. For example, system requiring increase charge capacity may have a greater number of cells interposed between the end covers than systems with less capacity. Thus, the length of the bands may vary from application to application, yet due to the attachment structure described herein, it is possible to simply cut the various lengths from a single roll of banding material.

[0025] Fig. 2 shows an exploded view of a portion of an exemplary battery cell stack 200. As shown the battery cell stack is assembled in the order of a housing heat sink 210, battery cell 212, compliant pad 214, battery cell 216, and so on. However, it will be appreciated that other arrangement are possible. For example, the battery cell stack may be built in the order of a housing heat sink, battery cell, housing heat sink, etc. Further in some examples, the housing heat sink may be integrated into the battery cells.

[0026] Battery cell 212 includes cathode 218 and anode 220 for connecting to a bus (not shown). The bus routes charge from a plurality of battery plates to terminals of a battery module and is coupled to bus bar support 222. Battery cell 212 further includes prismatic cell 224 that contains electrolytic compounds, such as a lithium ion compounds. Prismatic cell 224 is coupled to cell heat sink 226. Cell heat sink 226 may be formed of a metal plate with the edges bent up 90 degrees on one or more sides to form a flanged edge. In the example of Fig. 2, two opposing sides include a flanged edge. However, other geometries are possible. Battery cell 212 is substantially identical to battery cell 216. Therefore similar parts are labeled accordingly. Battery cells 212 and 216 are arranged with their terminals in alignment and exposed. Compliant pad 214 is interposed between battery cell 212 and battery cell 216. However, in other examples the compliant pad may not be included in the battery cell stack.

[0027] Housing heat sink 210 may be formed by a metal plate having a base 228 with the edges bent up 90 degrees on one or more sides to form a flanged edge. In Fig. 2, longitudinally aligned edge 230 and vertically aligned edges 232 are bent flanged edges. However, it will be appreciated that other configurations are possible. As depicted the housing heat sink is sized to receive one or more battery cells. In other words, one or more battery cells may be positioned within base 228. Thus, the flanged edges of the battery cells may be in contact with housing heat sink and underside 229 of battery cell 212 may be in contact with the base of the housing heat sink, facilitating heat transfer. However it will be appreciated that other arrangements are possible in other embodiments.

[0028] One of the longitudinally aligned edges 232 of the housing heat sink 210 may form a portion of the top side 234 of battery module 1, as shown in Fig. 1.

Similarly, one of the longitudinally aligned edges 232 may form a portion of the bottom side of the battery module. However it will be appreciated that other arrangements are possible in other embodiments. Furthermore, the housing heat sink may not be included in the battery cell stack in other embodiments.

[0029] Figs. 3-5 show various views of an engagement end 310 of a retention band 300. The engagement end is shaped via a crimping process, as described herein. It will be appreciated that retention band 300 may be one of the retention bands 16, shown in Fig. 1. In particular Fig. 3 shows a side view of an engagement end 310 of a retention band, Fig. 4 shows a top view of the engagement end of the retention band, and Fig. 5 shows a front view of the retention band. FIGS 3-6 are drawn approximately to scale, although alternative relative dimensions of the engagement end may be used, if desired.

[0030] The retention band may be formed from a shipping band, such as a metal shipping band, a plastic band, etc. Thus, the retention band may be cut from a simple roll, enabling increased production efficiency and length variability when assembling a plurality of battery modules, thereby decreasing the manufacturing cost. However, in other embodiments the retention band may be cut and formed prior to assembly. The engagement end may be configured to mate with a band engagement section included in the first end cover, shown in Fig. 6. Continuing with Figs. 3-5, the engagement end may include a slot engagement portion 312 including a protruding bent end and a pocket engagement portion including two outer-edge protrusions 316. The two outer-edge protrusion each are formed from a cut and bent portion of the strip itself. While FIG. 3 shows each protrusion longer than it is wide, the shape of each protrusion can be adjusted. Also, while FIG. 3 shows two protrusions, one a single protrusion on one side, or in the center, of the strip may be used. Further while

FIG. 3 shows the protrusions positioned each aligned in the longitudinal direction, the protrusions may be positioned one behind another in the longitudinal direction, and optionally on opposite sides of the strip thus positioned diagonally. Further yet, more than two protrusions may be used, if desired.

[0031] As shown in Fig. 3 the protrusions 316 form an angle 318 with the retention band that is less than 90 degrees. In one example, the angle may be between 30 and 60 degrees, and more specifically, between 40 and 50 degrees. The angled protrusions, when coupled with the band engagement section of an end cover, enable the retention band to remain in place and held by the end cover while the retention band is wrapped around the stack tensioned during assembly, discussed in greater detail herein.

[0032] In some examples the engagement end may be formed using a crimping tool that cuts and deforms the end of the band to form the engagement end illustrated herein.

[0033] Fig. 6 shows an exemplary first end cover 12. As shown, the end cover includes a band engagement section 600 configured to mate with the engagement end of the retention band, shown in Figs. 3-5. Continuing with Fig. 6, in the depicted embodiment the band engagement section includes a slot recess 602 and a two pocket recesses 604. As shown, the slot recess is a lateral slot, while the pocket recesses are vertical slots. The pocket recesses and slot recess are shaped and positioned corresponding to the protrusions and the bent end, respectively. For example, if two diagonally positioned protrusions are provided, then two diagonally positioned pocket recesses are provided in the end cover.

[0034] As shown, the end cover may include banding tracks 606, enabling the retention bands to remain in a desired position during assembly of the battery module.

It will be appreciated that the banding tracks are recessed and sized to accept the retention band. The recessed tracks increase the compactness of the battery module.

[0035] Figs. 7-11 show an assembly process for installing a retention band in the battery module. Cross-sectional views of the battery module are shown in Figs. 8-11 to reveal band engagement section 600 of the first end cover 12. Although a single retention band is shown, it will be appreciated that the assembly process may be carried out for a plurality of retention bands.

[0036] Fig. 7 shows battery module 1 secured to a holding fixture 700. The holding fixture allows the battery module to be fixed in a desired position so that the effect of the tensioning process on the battery module's size and shape may be diminished.

[0037] Fig. 8 shows the engagement end 310 of retention band 300 mated with the band engagement section 600 of the first end cover 12. As shown, protrusion 316 is mated with pocket recess 604 and slot engagement portion 312 is mated with slot recess 602. In this way, an end of the retention band may be secured to the battery module during installation of the retention band, and resist slipping with respect to the cover to enable a desired level of tension in the bands. Because the protrusion 316 is angled in a direction partially in the direction of the tension forces, it is forced into engagement with the end cover with a self-locking action, in that the greater the tension force in the band, the greater the protrusion is forced further into a wall of the pocket recess. Thus, the band can thereby be retained by the end cover during tensioning.

[0038] After the retention band is attached to the battery module, the retention band may be wrapped around the battery module, as shown in Fig. 9. Then, the retention band may be tensioned to a desired level via a tensioning tool. As noted

above, the matting of engagement end 310 of the retention band 300 with band engagement section 600 reduces slippage of the retention band relative to the cover during tensioning.

[0039] Next, overlapping portions 17 of the retention band are welded together while the desired tension is maintained, as shown in Fig. 10. It will be appreciated that in other embodiments the retention band may be joined together via another suitable technique, such as adhesives. Subsequently, the retention band may be cut to a desired length to remove excess material, as shown in Fig. 11.

[0040] It will be appreciated that the process depicted in Figs. 7-11 may be quickly and efficiently implemented with low cost materials, thereby decreasing the cost of production of the battery module when compared to other banding systems which may utilize banding buckles or other coupling device to attach and tension the bands to the battery module.

[0041] Fig. 12 shows a method 1200 for assembly of a battery module, such as illustrated in FIGS. 8-11, including a first and a second end cover retaining a battery cell stack. Method 1200 may be implemented via the systems and components described above.

[0042] First, at 1202 the method includes forming an engagement end of a retention band. Next, at 1204 the method includes securing the battery module in place. At 1206 the method includes matting the engagement end of the retention band with a band engagement section included in the first end cover. At 1208 the method includes circumnavigating a periphery the battery module with the retention band. Circumnavigating a periphery of the battery module with the retention band may include wrapping the retention band around the first and second end covers. Next, at 1210 the method includes tensioning the retention band to a desired level. It will be

appreciated that the desired level may be selected based on one or more of the following parameters; anticipated operating temperature range, electrolytic material used in the battery cells, and number of cells included in the battery module. For example, with increased numbers of cells, increased tensioning may be provided in the bands.

[0043] At 1212 the method includes joining a first portion of the retention band to a second portion of the retention band. In some examples, the first portion and the second portion may be overlapping. Next, at 1214 the method may include cutting the retention band to a desired length.

[0044] Turning to Fig. 13, a schematic view of a non-limiting application of the battery module is shown. In particular, battery module 1 is installed in a vehicle 1300 for the purpose of supplying energy to propel vehicle 1300 by way of electric motor 1302. Vehicle controller 1304 may facilitate communication between battery module 1 and motor 1302. In one embodiment, vehicle 1300 may be propelled solely by electric motor 1302. In another embodiment, vehicle 1300 may be a hybrid vehicle that may be propelled by an electric motor and an internal combustion engine. It will be appreciated that the battery module may be used in a number of other environments such as in commercial or residential energy storage systems, industrial applications, portable electronic device, etc.

[0045] The subject matter of the present disclosure includes all novel and nonobvious combinations and subcombinations of the various systems and configurations, and other features, functions, and/or properties disclosed herein.

[0046] The following claims particularly point out certain combinations and subcombinations regarded as novel and nonobvious. These claims may refer to “an” element or “a first” element or the equivalent thereof. Such claims should be

understood to include incorporation of one or more such elements, neither requiring nor excluding two or more such elements. Other combinations and subcombinations of the disclosed features, functions, elements, and/or properties may be claimed through amendment of the present claims or through presentation of new claims in this or a related application. Such claims, whether broader, narrower, equal, or different in scope to the original claims, also are regarded as included within the subject matter of the present disclosure.

Claims:

1. A battery module comprising:

a battery cell stack including a plurality of sealed electrochemical cells interposed between a first and a second end cover, the first end cover including a band engagement section; and

a retention band circumnavigating the battery cell stack, first end cover, and second end cover, the retention band joined at an overlapping portion of the band and including an engagement end mated with the band engagement section.
2. The battery module of claim 1, wherein the engagement end includes at least one protrusion configured to mate with a recess included in the band engagement section.
3. The battery module of claim 2, wherein the protrusion extends from the retention band at an angle less than 90 degrees.
4. The battery module of claim 1, wherein the engagement end includes a bent portion configured to mate with a recess included in the band engagement section.
5. The battery module of claim 1, wherein the first and second end covers include recessed banding channel in which the retention band is positioned.
6. The battery module of claim 1, wherein the retention band is welded together at the overlapping section.

7. The battery module of claim 1, wherein the battery is coupled in a vehicle.
8. A method for assembly a battery module including a first and a second end cover interposing a battery cell stack, the method comprising:
matting an engagement end of a retention band in a band engagement section included in the first end cover;
circumnavigating a periphery of the battery module with the retention band;
tensioning the retention band to a desired level; and
joining a first portion of the retention band to a second portion of the retention band.
9. The method of claim 8, wherein the periphery of the battery module includes the first and second end covers and the battery cell stack.
10. The method of claim 8, wherein circumnavigating the battery module includes wrapping the retention band around the second end cover.
11. The method of claim 8, wherein the first and second portions of the retention band are overlapping.
12. The method of claim 11, wherein the retention band is metal and joining the overlapping portion of the retention band includes welding the overlapping portion of the retention band together.

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FIG. 1

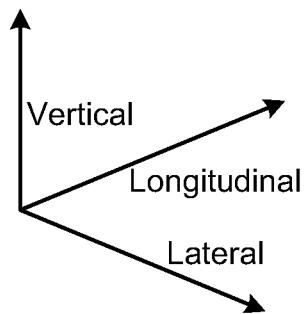
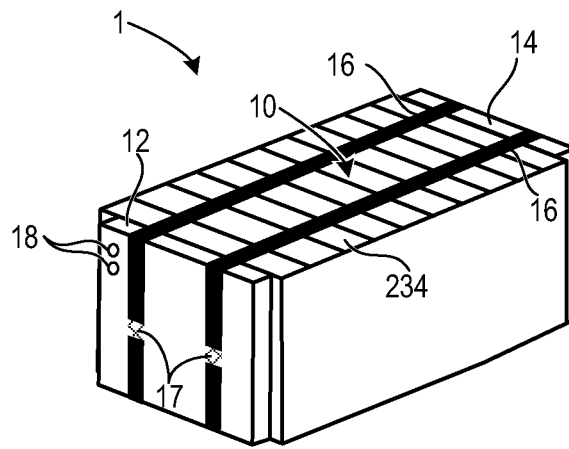


FIG. 5

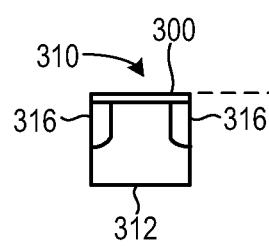


FIG. 3

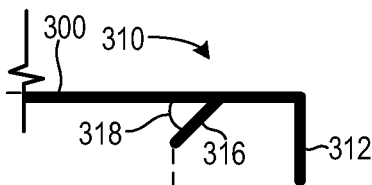


FIG. 4

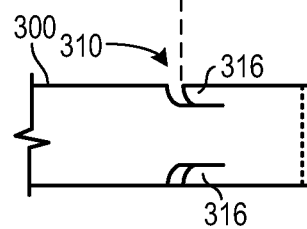
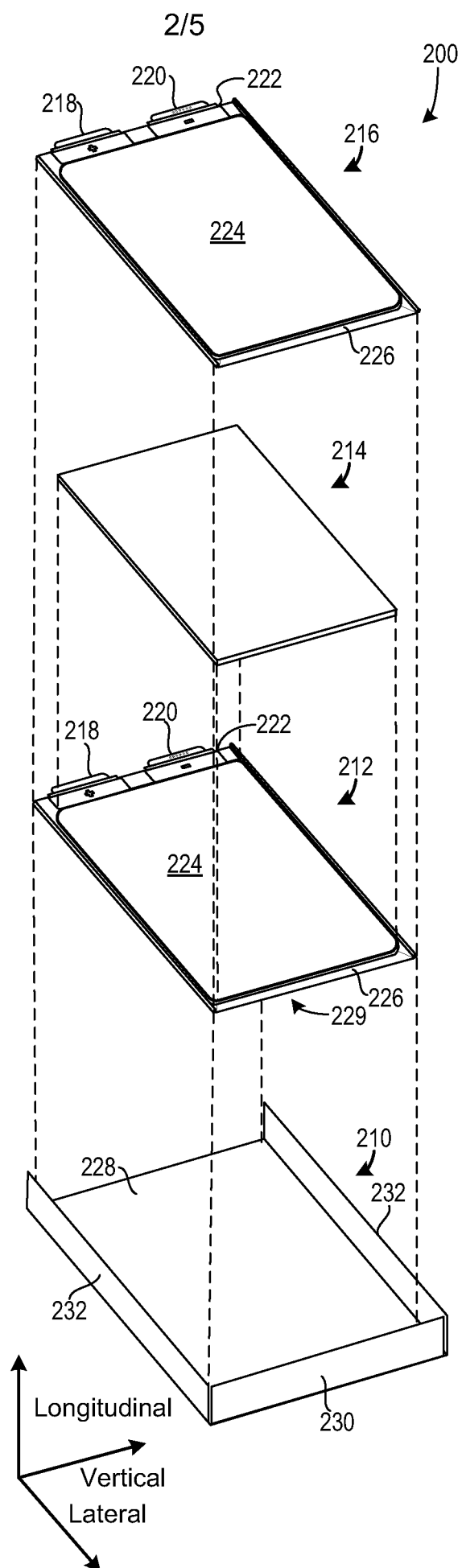
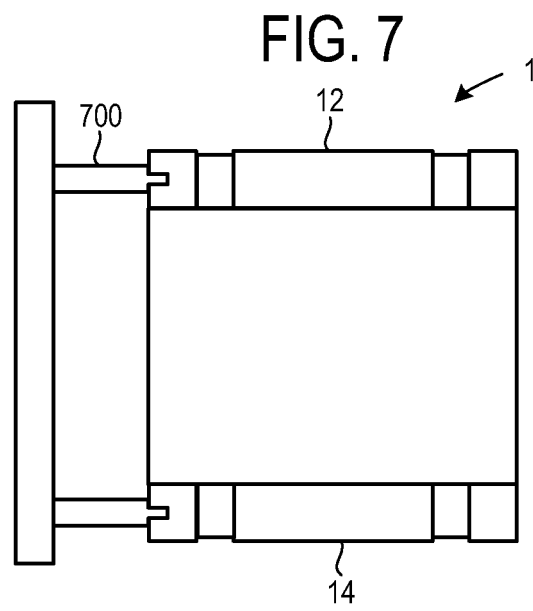
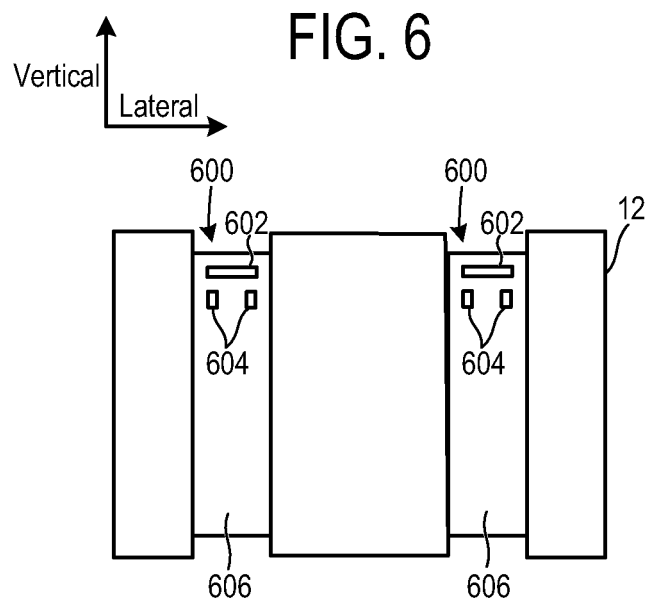


FIG. 2



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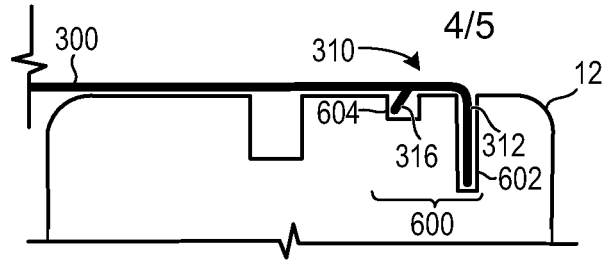


FIG. 8

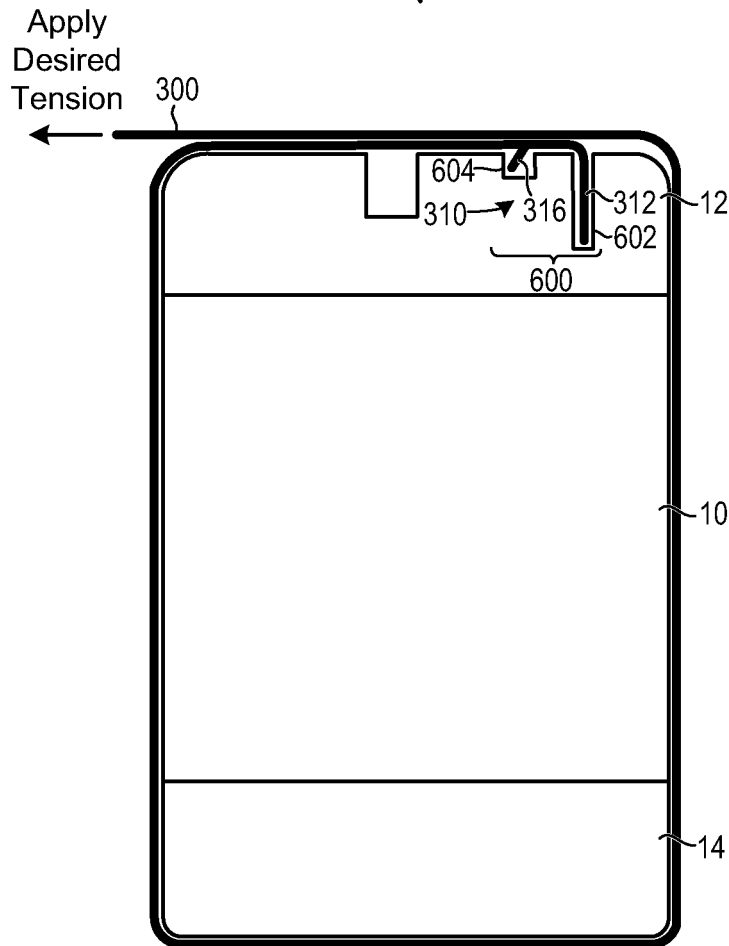


FIG. 9

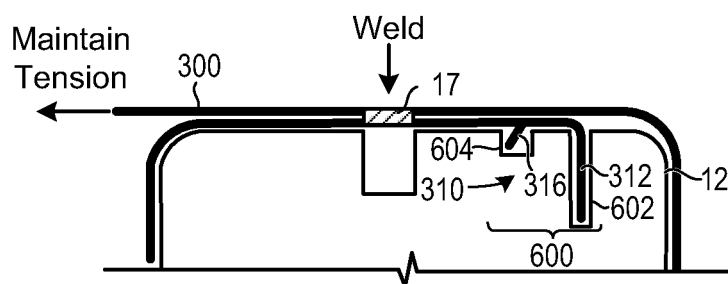


FIG. 10

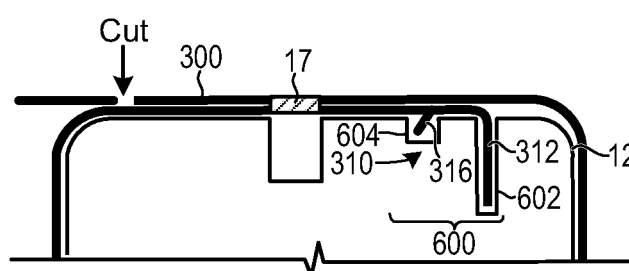


FIG. 11

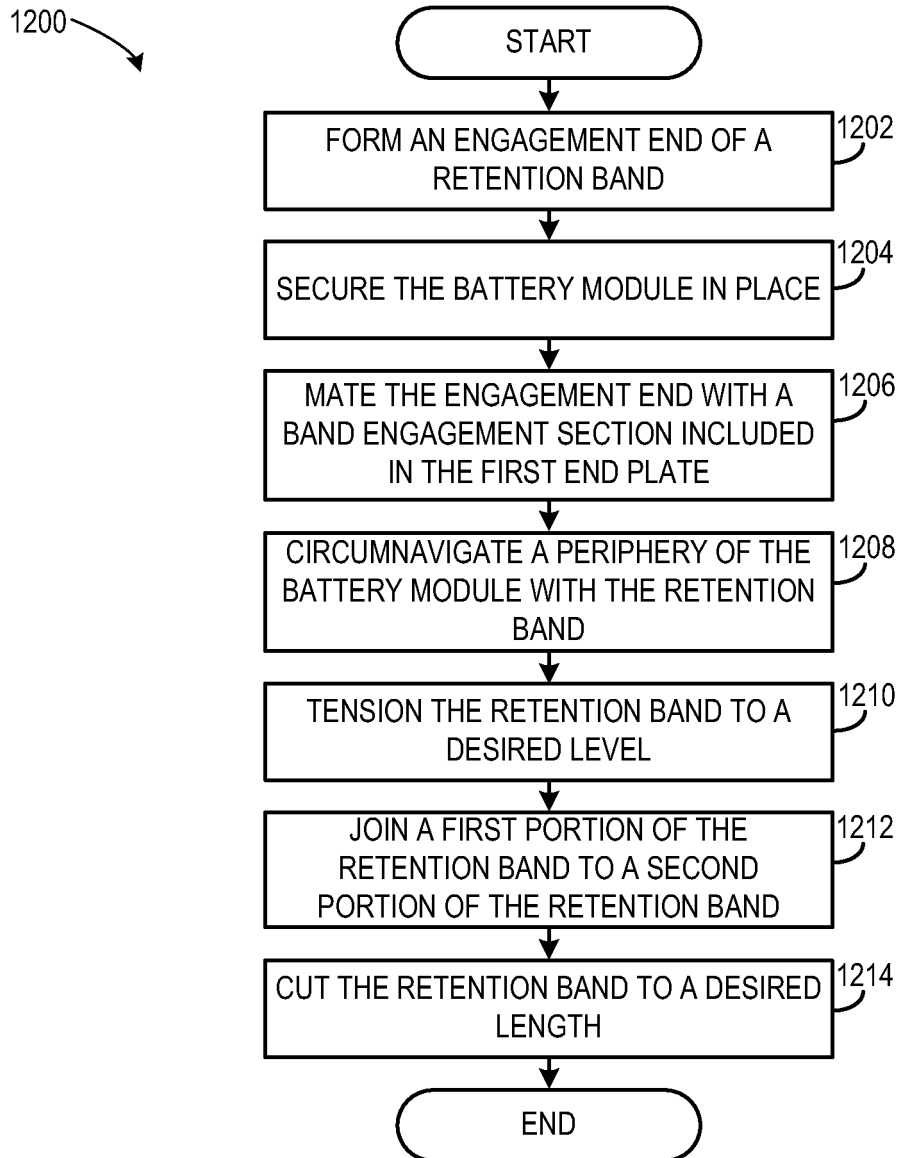
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FIG. 12

FIG. 13

