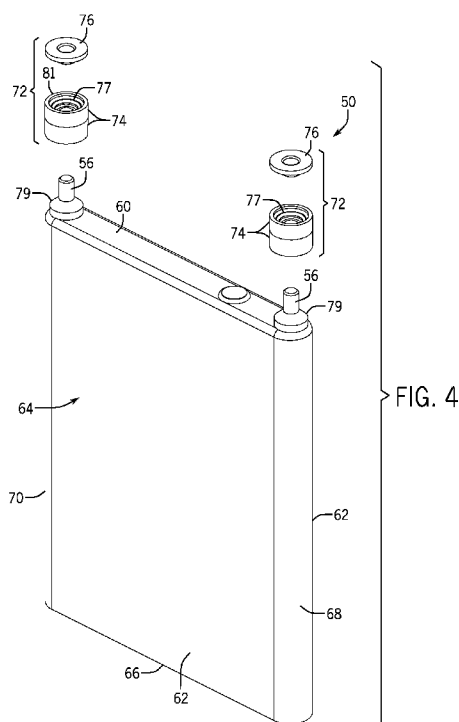




- (51) **International Patent Classification:**
H01M 10/60 (2014.01) *H01M 10/6551* (2014.01)
H01M 10/65 (2014.01) *H01M 2/30* (2006.01)
- (21) **International Application Number:**
PCT/US2016/013745
- (22) **International Filing Date:**
16 January 2016 (16.01.2016)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
62/100,001 5 January 2015 (05.01.2015) US
14/673,740 30 March 2015 (30.03.2015) US
- (71) **Applicant:** JOHNSON CONTROLS TECHNOLOGY COMPANY [US/US]; 915 East 32nd Street, Holland, Michigan 49423 (US).
- (72) **Inventors:** TYLER, Matthew R.; 9484 North 45th Street, Brown Deer, Wisconsin 53223 (US). TRESTER, Dale B.; 3045 North 89th Street, Milwaukee, Wisconsin 53222 (US). BONIN, Christopher M.; 605 Aspen Street, South Milwaukee, Wisconsin 53172 (US).
- (74) **Agents:** MORGAN, Rejean, A. et al.; 100 S. Saunders Road, Suite 150, Lake Forest, Illinois 60045 (US).
- (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, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, 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, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, 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).

[Continued on next page]

- (54) **Title:** WASHERS FOR A LITHIUM ION BATTERY CELL TERMINAL



(57) **Abstract:** The present disclosure relates to washers for lithium ion battery cell terminals. A lithium ion battery module includes a housing, a first battery cell disposed in the housing and having a cell terminal protruding from a surface of a casing of the first battery cell, where the cell terminal is configured to enable electrical connection to the battery cell, and a washer stack disposed about the cell terminal. The washer stack has an electrically insulative washer and an electrically conductive washer. The electrically conductive washer is disposed adjacent to the electrically insulative washer such that the electrically insulative washer is positioned between the electrically conductive washer and the surface of the casing, and the electrically conductive washer is configured to enable electrical connection to the cell terminal.

**Declarations under Rule 4.17:**

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| — | <i>as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))</i> | — | <i>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))</i> |
| — | <i>as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))</i> | — | <i>the filing date of the international application is within two months from the date of expiration of the priority period (Rule 26bis.3)</i> |

Published:

- *with international search report (Art. 21(3))*

WASHERS FOR A LITHIUM ION BATTERY CELL TERMINAL

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] *This application claims priority from and the benefit of U.S. Provisional Application Serial No. 62/100,001, entitled "MECHANICAL AND ELECTRICAL ASPECTS OF LITHIUM ION BATTERY MODULE WITH VERTICAL AND HORIZONTAL CONFIGURATIONS," filed January 5, 2015, and U.S. Application 14/673,740, entitled "WASHERS FOR A LITHIUM ION BATTERY CELL TERMINAL," filed March 30, 2015, both of which are hereby incorporated by reference, in their entirety for all purposes.*

BACKGROUND

[0002] The present disclosure relates generally to the field of batteries and battery modules. More specifically, the present disclosure relates to washers for a battery module.

[0003] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0004] A vehicle that uses one or more battery systems for providing all or a portion of the motive power for the vehicle can be referred to as an xEV, where the term "xEV" is defined herein to include all of the following vehicles, or any variations or combinations thereof, that use electric power for all or a portion of their vehicular motive force. For example, xEVs include electric vehicles (EVs) that utilize electric power for all motive force. As will be appreciated by those skilled in the art, hybrid electric vehicles (HEVs), also considered xEVs, combine an internal combustion engine

propulsion system and a battery-powered electric propulsion system, such as 48 Volt (V) or 130V systems. The term HEV may include any variation of a hybrid electric vehicle. For example, full hybrid systems (FHEVs) may provide motive and other electrical power to the vehicle using one or more electric motors, using only an internal combustion engine, or using both. In contrast, mild hybrid systems (MHEVs) disable the internal combustion engine when the vehicle is idling and utilize a battery system to continue powering the air conditioning unit, radio, or other electronics, as well as to restart the engine when propulsion is desired. The mild hybrid system may also apply some level of power assist, during acceleration for example, to supplement the internal combustion engine. Mild hybrids are typically 96V to 130V and recover braking energy through a belt or crank integrated starter generator. Further, a micro-hybrid electric vehicle (mHEV) also uses a "Start-Stop" system similar to the mild hybrids, but the micro-hybrid systems may or may not supply power assist to the internal combustion engine and operate at a voltage below 60V. For the purposes of the present discussion, it should be noted that mHEVs typically do not technically use electric power provided directly to the crankshaft or transmission for any portion of the motive force of the vehicle, but an mHEV may still be considered an xEV since it does use electric power to supplement a vehicle's power needs when the vehicle is idling with internal combustion engine disabled and recovers braking energy through an integrated starter generator. In addition, a plug-in electric vehicle (PEV) is any vehicle that can be charged from an external source of electricity, such as wall sockets, and the energy stored in the rechargeable battery packs drives or contributes to drive the wheels. PEVs are a subcategory of EVs that include all-electric or battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and electric vehicle conversions of hybrid electric vehicles and conventional internal combustion engine vehicles.

[0005] xEVs as described above may provide a number of advantages as compared to more traditional gas-powered vehicles using only internal combustion engines and traditional electrical systems, which are typically 12V systems powered by a lead acid battery module. For example, xEVs may produce fewer undesirable emission products

and may exhibit greater fuel efficiency as compared to traditional internal combustion vehicles and, in some cases, such xEVs may eliminate the use of gasoline entirely, as is the case of certain types of EVs or PEVs.

[0006] As technology continues to evolve, there is a need to provide improved power sources, particularly battery modules, for such vehicles and other implementations. For example, it is now recognized that terminal posts of battery cells may experience shear forces via transmission from features (e.g., bus bars) that are used to form electrical interconnections between the cell terminals and other electrically conductive elements (e.g., additional cell terminals or battery module terminals). Accordingly, it is now recognized that it may be desirable to mitigate or reduce the effect of these transmitted forces on the terminals.

SUMMARY

[0007] A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

[0008] The present disclosure relates to a lithium ion battery module that includes a housing, a first battery cell disposed in the housing and having a cell terminal protruding from a surface of a casing of the first battery cell, where the cell terminal is configured to enable electrical connection to the battery cell, and a washer stack disposed about the cell terminal. The washer stack has an electrically insulative washer and an electrically conductive washer. The electrically conductive washer is disposed adjacent to the electrically insulative washer such that the electrically insulative washer is positioned between the electrically conductive washer and the surface of the casing, and the electrically conductive washer is configured to enable electrical connection to the cell terminal.

[0009] The present disclosure also relates to a lithium ion battery module that includes a housing, a battery cell disposed in the housing and having a cell terminal protruding from a surface of a casing of the first battery cell, where the cell terminal is configured to enable electrical connection to the battery cell, and a washer stack disposed about the cell terminal. The washer stack has an electrically insulative washer and an electrically conductive washer. The electrically insulative washer is disposed adjacent to the surface of the casing and the electrically conductive washer is disposed in the washer stack such that the electrically insulative washer is positioned between the electrically conductive washer and the surface of the casing. The battery module also includes a bus bar electrically coupled to the cell terminal via the electrically conductive washer.

[0010] The present disclosure further relates to a battery module that includes a housing, a battery module terminal configured to provide an electrical output of the battery module when coupled to an electrical load, a battery cell disposed in the housing and having a cell terminal protruding from a surface of a casing of the first battery cell, where the cell terminal is configured to enable electrical connection to the first battery cell, and a washer stack disposed about the cell terminal. The washer stack has a stack of electrically insulative washers disposed adjacent to the surface of the casing and an electrically conductive washer disposed adjacent to the stack of electrically insulative washers such that the stack of electrically insulative washers are positioned between the electrically conductive washer and the surface of the casing. The battery module also includes a bus bar electrically coupled to the electrically conductive washer, wherein the bus bar is configured to establish an electrical connection between the battery cell and the battery module terminal.

DRAWINGS

[0011] Various aspects of this disclosure may be better understood upon reading the following detailed description and upon reference to the drawings in which:

[0012] FIG. 1 is a perspective view of an xEV having a battery system configured to provide power for various components of the xEV, in accordance with an aspect of the present disclosure;

[0013] FIG. 2 is a cutaway schematic view of an embodiment of the xEV that utilizes the battery system of FIG. 1, in accordance with an aspect of the present disclosure;

[0014] FIG. 3 is an exploded view of an embodiment of the lithium ion battery module having battery cells with one or more washers disposed about cell terminals, in accordance with an aspect of the present disclosure;

[0015] FIG. 4 is an exploded view of one of the battery cells of the battery module of FIG. 3, in accordance with an aspect of the present disclosure;

[0016] FIG. 5 is a perspective view of the battery cell of FIG. 4 with terminal washers disposed over battery cell terminals, in accordance with an aspect of the present disclosure;

[0017] FIG. 6 is a perspective view of an electrical connection between a bus bar and a conductive washer disposed about cell terminals, in accordance with an aspect of the present disclosure;

[0018] FIG. 7 schematically illustrates exaggerated movement of terminal washers in response to transmission of a shear force from a bus bar, in accordance with an aspect of the present disclosure;

[0019] FIG. 8 illustrates a washer stack having a conductive washer substantially aligned with a top of a cell terminal, in accordance with an aspect of the present disclosure;

[0020] FIG. 9 illustrates a cell terminal protruding beyond a conductive washer of a washer stack, in accordance with an aspect of the present disclosure;

[0021] FIG. 10 illustrates a cell terminal positioned between a top surface and a bottom surface of a conductive washer of a washer stack, in accordance with an aspect of the present disclosure;

[0022] FIGS. 11-13 depict top-down views of different shapes of the washers disposed about the cell terminals, in accordance with an aspect of the present disclosure;

[0023] FIG. 14 is a cross-sectional view of a washer stack oriented substantially parallel to a casing of a battery cell, in accordance with an aspect of the present disclosure;

[0024] FIG. 15 is a cross sectional view of a washer stack having a protrusion extending toward a casing of a battery cell, in accordance with an aspect of the present disclosure; and

[0025] FIG. 16 is a cross sectional view of a washer stack having a protrusion extending away from a casing of a battery cell, in accordance with an aspect of the present disclosure.

DETAILED DESCRIPTION

[0026] One or more specific embodiments will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0027] Battery modules, in accordance with the present disclosure, may include one or more battery cells. The battery cells may each include terminals that enable electrical interconnections to be formed between the individual battery cells, as well as between the battery cells and a module terminal. Such electrical interconnections may be created by coupling battery cell terminals of different battery cells together using a conductive component (e.g., via a bus bar). However, such components may transmit an undesirable force and/or stress to the battery cell terminals. It is now recognized that disposing one or more washers over the battery cell terminals, and coupling the bus bars to the washers, may reduce such undesirable forces and/or stresses on the battery cell terminals.

[0028] The present disclosure includes embodiments of a battery cell having washers disposed over terminals of the battery cell. The washers may include a combination of insulative (e.g., plastic or ceramic) washers and metallic (e.g., aluminum or copper) washers. To establish electrical connections between the battery cells, bus bars are disposed against (e.g., welded to) outermost surfaces of the metallic washers, where the outermost surfaces of the metallic washers are in plane with, protrude beyond, or are recessed with respect to outermost surfaces of the terminals. Utilizing washers disposed on the battery cell terminals may reduce shear forces applied to the battery cell terminals, thereby increasing the life of the battery module.

[0029] To help illustrate, FIG. 1 is a perspective view of an embodiment of a vehicle 10, which may utilize a battery system 12 that includes washers disposed over battery cell terminals, as described in the present disclosure. It is now recognized that it is desirable for the non-traditional battery system 12 (e.g., a lithium ion car battery having terminal washers) to be largely compatible with traditional vehicle designs. In this respect, present embodiments include various types of battery modules for xEVs and systems that include xEVs. Accordingly, the battery system 12 may be placed in a location in the vehicle 10 that would have housed a traditional battery system (e.g., a standard 12V lead acid battery or a 12V lithium ion battery with no terminal washers). For example, as

illustrated, the vehicle 10 may include the battery system 12 positioned similarly to a lead-acid battery of a combustion-engine vehicle (e.g., under the hood of the vehicle 10).

[0030] A more detailed view of the battery system 12 is described in FIG. 2. As depicted, the battery system 12 includes an energy storage component 14 coupled to an ignition system 16, an alternator 18, a vehicle console 20, and optionally to an electric motor 22. Generally, the energy storage component 14 may capture/store electrical energy generated in the vehicle 10 and output electrical energy to power electrical components in the vehicle 10. Additionally, the energy storage component 14 may output electrical energy to start (e.g., re-start or re-ignite) an internal combustion engine 24. For example, in a start-stop application, to preserve fuel, the internal combustion engine 24 may idle when the vehicle 10 stops. Thus, the energy storage component 14 may supply energy to re-start the internal combustion engine 24 when propulsion is demanded by the vehicle 10.

[0031] The battery system 12 may also supply power to components of the vehicle's electrical system, which may include radiator cooling fans, climate control systems, electric power steering systems, active suspension systems, auto park systems, electric oil pumps, electric super/turbochargers, electric water pumps, heated windscreen/defrosters, window lift motors, vanity lights, tire pressure monitoring systems, sunroof motor controls, power seats, alarm systems, infotainment systems, navigation features, lane departure warning systems, electric parking brakes, external lights, or any combination thereof. In the depicted embodiment, the energy storage component 14 supplies power to the vehicle console 20 and the ignition system 16, which may be used to start (e.g., crank) the internal combustion engine 24.

[0032] Additionally, the energy storage component 14 may capture electrical energy generated by the alternator 18 and/or the electric motor 22. In some embodiments, the alternator 18 may generate electrical energy while the internal combustion engine 24 is running. More specifically, the alternator 18 may convert the mechanical energy produced by the rotation of the internal combustion engine 24 into electrical energy.

Additionally, or alternatively, when the vehicle 10 includes an electric motor 22, the electric motor 22 may generate electrical energy by converting mechanical energy produced by the movement of the vehicle 10 (e.g., rotation of the wheels) into electrical energy. Thus, in some embodiments, the energy storage component 14 may capture electrical energy generated by the alternator 18 and/or the electric motor 22 during regenerative braking. As such, the alternator and/or the electric motor 22 are generally referred to herein as a regenerative braking system.

[0033] To facilitate capturing and supplying electrical energy, the energy storage component 14 may be electrically coupled to the vehicle's electric system via a bus 26. For example, the bus 26 may enable the energy storage component 14 to receive electrical energy generated by the alternator 18 and/or the electric motor 22. Additionally, the bus 26 may enable the energy storage component 14 to output electrical energy to the ignition system 16 and/or the vehicle console 20.

[0034] Additionally, as depicted, the energy storage component 14 may include multiple battery modules. For example, in the depicted embodiment, the energy storage component 14 includes a lithium ion (e.g., a first) battery module 28 and a lead acid (e.g., a second) battery module 30, which each includes one or more battery cells. Additionally, the energy storage component 14 may include any number of battery modules, all or some of which may include terminal washers configured to protect cell terminals. Although the lithium ion battery module 28 and lead-acid battery module 30 are depicted adjacent to one another, they may be positioned in different areas around the vehicle. For example, the lead-acid battery module 30 may be positioned in or about the interior of the vehicle 10 while the lithium ion battery module 28 may be positioned under the hood of the vehicle 10.

[0035] In some embodiments, the energy storage component 14 may include multiple battery modules to utilize multiple different battery chemistries. For example, when the lithium ion battery module 28 is used, performance of the battery system 12 may be improved since the lithium ion battery chemistry generally has a higher coulombic

efficiency and/or a higher power charge acceptance rate (e.g., higher maximum charge current or charge voltage) than the lead-acid battery chemistry. As such, the capture, storage, and/or distribution efficiency of the battery system 12 may be improved.

[0036] To facilitate controlling the capturing and storing of electrical energy, the battery system 12 may additionally include a control module 32 (e.g., a battery management system). More specifically, the control module 32 may control operations of components in the battery system 12, such as relays (e.g., switches) within the energy storage component 14, the alternator 18, and/or the electric motor 22. For example, the control module 32 may regulate an amount of electrical energy captured/supplied by each battery module 28 or 30 (e.g., to de-rate and re-rate the battery system 12), perform load balancing between the battery modules 28 and 30, determine a state of charge of each battery module 28 or 30, determine a temperature or voltage of each battery module 28 or 30 (e.g., via a signal received from one or more sensing components), control voltage output by the alternator 18 and/or the electric motor 22, and the like.

[0037] Accordingly, the control unit 32 may include one or more processor units 34 and one or more memory components 36. More specifically, the one or more processor units 34 may include one or more application specific integrated circuits (ASICs), one or more field programmable gate arrays (FPGAs), one or more general purpose processors, or any combination thereof. Additionally, the one or more memory components 36 may include volatile memory, such as random access memory (RAM), and/or non-volatile memory, such as read-only memory (ROM), optical drives, hard disc drives, or solid-state drives. In some embodiments, the control unit 32 may include portions of a vehicle control unit (VCU) and/or a separate battery control module. Furthermore, as depicted, the lithium ion battery module 28 and the lead-acid battery module 30 are connected in parallel across their terminals. In other words, the lithium ion battery module 28 and the lead-acid module 30 may be coupled in parallel to the vehicle's electrical system via the bus 26.

[0038] As discussed previously, washers may be disposed over terminals of battery cells of, for example, the battery module 28 to reduce or eliminate shear forces exerted on the battery cell terminals. Present embodiments may be further appreciated with reference to the battery module of FIG. 3, which is an exploded view of an embodiment of the lithium ion battery module 28 having one or more washers disposed on terminals of one or more battery cells. However, it should be noted that the battery module 28 illustrated in FIG. 3 is intended to represent any battery module configuration that may benefit from the present techniques.

[0039] As shown in FIG. 3, the lithium ion battery module 28 may include a plurality of battery cells 50. The battery cells 50 may be arranged in a first stack 52 and a second stack 54, where the battery cells 50 are positioned adjacent one another in orientations where respective terminals 56 of the battery cells 50 are positioned at the same side of the stacks 52, 54. Accordingly, adjacent battery cells 50 will have terminals 56 that are adjacent to one another in each of the first and second stacks 52, 54. As an example, the embodiment of FIG. 3 includes the first and second stacks 52, 54 in a side-by-side relationship. In other embodiments, the first and second stacks 52, 54 may be configured in another orientation (e.g., a top to bottom relationship). In still further embodiments, only one cell stack may be included in the battery module 28, or more than two cell stacks may be included (e.g., 3, 4, 5, 6, 7, 8, 9, 10, or more cell stacks).

[0040] As shown in FIG. 3, the battery module 28 may include a module housing 57 constructed of any appropriate material, such as an amide-based polymer, a polyolefin (e.g., polypropylene), or any other material. The module housing 57 includes a cell receptacle region 58, where the battery cell stacks 52 and 54 are positioned within the battery module housing 57. In the illustrated embodiment, the battery cells 50 are positioned into the cell receptacle region 58 “bottom first,” where the terminals 56 of each battery cell 50 point outwardly toward an opening 59 of the receptacle region 58.

[0041] To facilitate discussion of the present embodiments, FIG. 4 illustrates an exploded view of one of the battery cells 50 having terminal washers in accordance with

an embodiment of the present disclosure. In a prismatic cell configuration, as shown in FIG. 4, the battery cell 50 includes a top surface 60 having at least one cell terminal 56 (the illustrated embodiment has two cell terminals 56 extending from the top surface 60).

[0042] The illustrated battery cell of FIG. 4 also includes faces 62, corresponding to the broadest part of a casing 64 of the battery cell 50. A bottom surface 66 is substantially opposite the top surface 60. The faces 62 extend between the top surface 60 and bottom surface 66 and are coupled by first 68 and second 70 sides, which may be straight, rounded, or any other suitable geometry. The casing 64 (e.g., housing) of the battery cell 50, which houses the active electrochemical elements of the cell 50, may be polymeric, metallic, composite, or any other suitable material. Further, it should be noted that the present embodiments are not limited to battery modules having prismatic battery cells, but are also intended to include embodiments where the battery cells 50 are pouch battery cells, cylindrical battery cells, and so forth. Furthermore, while described in the context of the lithium ion battery module 28 having lithium ion battery cells 50, the present disclosure is applicable to other battery chemistries that may benefit from the washers disclosed herein.

[0043] As shown in FIG. 4, in accordance with embodiments of the present disclosure, the terminal 56 may have a post configuration and may protrude from the top surface 60 of the casing 64 to facilitate an electrical connection with, for instance, another terminal 56 of another battery cell 50 using electrical connecting features (e.g., bus bars). In other embodiments, the terminal 56 may protrude from the bottom surface 66 of the casing 64. In embodiments where the battery cell 50 includes protruding terminals 56, it is now recognized that terminal washers, shown generally as a washer stack 72, may provide additional structural support to the terminals 56. For example, the illustrated washer stack 72 may be fitted over the terminals 56 of the battery cells 50. The washer stack 72, in a general sense, provides additional structural support to the terminals 56 and reduces the transmission of forces to a protruding terminal 56 from other components (e.g., the bus bar) to which the terminal 56 is connected.

[0044] The washer stack 72 may include one or more insulative (e.g., plastic) washers 74 and one or more conductive (e.g., metallic) washers 76. As shown, the washer stack 72 may include two insulative washers 74 and one conductive washer 76. In other embodiments, the battery cell 50 may include only one insulative washer 74, no insulative washers 74, or more than two insulative washers 74 (e.g., 3, 4, 5, 6, 7, 8, 9, 10, or more). Similarly, in other embodiments, the battery cell 50 may have more than one conductive washer 76 (e.g., 2, 3, 4, 5, 6, 7, 8, 9, 10, or more) or no conductive washers 76.

[0045] The insulative washers 74 of FIG. 4 may also include a recess 77 that may be configured to receive one or more of the conductive washers 76. As such, the insulative washers 74 may be positioned between the conductive washer 76 and the surface 66 of the casing 64, thereby preventing any interference caused by the casing 64. In certain embodiments, the recess 77 may fully receive the conductive washer 76, such that the face 78 of the washer is flush with a top 81 of the recess 77. The recess 77 may also enable the insulative washer 74 adjacent to the surface 66 (e.g., directly adjacent to the surface 66) of the casing 64 to fit completely over protrusions 79 of the cell terminals 56. The recess 77 may then enable the washer stack 72 to fit securely over the cell terminals 56.

[0046] FIG. 5 illustrates a perspective view of the battery cell 50 of FIG. 4 with the terminal washers disposed over the cell terminals 56. As shown in the illustrated embodiment, one washer stack 72 is fitted over each of the terminals 56 of the battery cell 50. In certain embodiments, the washer stack 72 is arranged so that the conductive washer 76 is on top of the stack 72, such that a face 78 of the conductive washer 76 is exposed to act as a terminal pad for the terminal 56. Accordingly, an electrical connection to an intermediate connecting feature (e.g., bus bars) may be established via a weld or connection, for example, between the conductive washer 76 (e.g., a weld to the face 78) and the intermediate connecting feature (e.g., a bus bar). In one embodiment, by

acting as a terminal pad, the conductive washer 76 allows electrical connection between the terminal 56 and the bus bar without a direct physical connection between them.

[0047] FIG. 6 illustrates a perspective view of an embodiment of an electrical connection formed by a weld, for example, between a bus bar 80 and one of the conductive washers 76. In certain embodiments, a direct physical connection between the bus bar 80 and the cell terminal 56 is absent. Accordingly, the bus bar 80 may only be electrically connected to the conductive washer 76 (e.g., without physical coupling). As shown in FIG. 6, the bus bar 80 and the conductive washer 76 may contact one another to form the electrical connection (e.g., the face 78 of the conductive washer 76 contacts a face of the bus bar 80). Additionally, the insulative washers 74 may be disposed between the electrically conductive washer 76 and the casing 64, such that no electrical connection may be formed between the bus bar 80 and the casing 64 (e.g., no electric current flows through the insulative washers 74 at the operating voltage of the module 28). Because the bus bar 80 is not directly physically coupled to the terminal 56, the bus bar 80 may not exert undesirable shear forces upon the battery terminals 56. Therefore, the washer stack 72 may be configured to provide protection to the cell terminals 56 by absorbing such forces, thereby enhancing the life of the battery cell 50.

[0048] An example of the protection provided by the washer stack 72 to the terminals 56 is shown schematically in FIG. 7, where movement of the washers is exaggerated for clarity. As shown in FIG. 7, a force, such as a shear force 90 (e.g., a lateral force with respect to the axial direction of the terminal), is applied to the bus bar 80. In certain embodiments, the bus bar 80 may transfer the force 90 to the washer stack 72 instead of the cell terminal 56. For example, the washer stack 72 may be configured to absorb some or all of the transferred forces 90. As shown in the illustrated embodiment of FIG. 7, the washer stack 72 may shift in response to the shear force 90, whereas the cell terminal 56 experiences little to no applied force. In other embodiments, the washer stack 72 may experience no movement. Instead, the force 90 may be absorbed and distributed through

the materials of the individual washers that make up the washer stack 72, such that little to no force may be applied to the cell terminal 56.

[0049] Indeed, the material composition of the washer stack 72 may be selected to provide a desired degree of force absorbance, and the illustrated (exaggerated) movement of the individual washers will generally depend on the number and material construction of the washer stack 72. For example, one or more washers of the washer stack 72 may include the insulative (e.g., non-conductive) washers 74 of a material composition that enables a higher degree of flexibility of the washer stack 72. Additionally, the material construction of a washer of the washer stack 72 may be selected to provide resistance against the force 90, for example by selecting a relatively hard material that may absorb the force 90. As non-limiting examples, washers with a Shore D hardness of greater than 50 or a Shore A hardness of greater than 70 may resist movement resulting from the shear forces 90. Shore A hardness values less than about 60 may provide absorbance of the shear forces 90, but may exhibit some movement. However, it should be noted that the washers of the washer stack 72 may have any hardness value or combination of values (for combinations of washers) suitable for a desired configuration of the washer stack 72.

[0050] As also shown in FIG. 7, the washer stack 72 may include a first insulative washer 92 and a second insulative washer 94 positioned about the terminal 56 and adjacent to (e.g., contacting) the top surface 60 of the battery cell 50. While the illustrated embodiment of FIG. 7 includes the two insulative washers 92 and 94, more than two insulative washers 74 may be included in the washer 72, or less than two insulative washers 74 may be included in the washer stack 72. The first 92 and second 94 insulative washers may, for example, reduce the likelihood of a short between the terminal 56 of a particular battery cell 50 and a terminal 56 of an adjacent battery cell 50. The electrically insulative washers 92 and 94 are preferably located closest, within the washer stack 72, to the top surface 60 of the cell casing 64, so that the terminal 56 and the conductive washer 76 remain electrically insulated from the casing 64. In addition, as

described above, it may be desirable for there to be multiple electrically insulative washers 92 and 94 to provide increased flexibility in the washer stack 80.

[0051] By way of non-limiting example, the electrically insulative washers 74 (e.g., the first washer 92 and the second washer 94) may include an electrically insulative polymeric material, an electrically insulative composite material, electrically insulative ceramics, and the like. Whether the material is electrically insulative may be determined based on the desired degree of electrical separation between the terminal post of the terminal 56 and other external, electrically conductive features of the battery module 28, such as an adjacent battery cell 50 and its associated terminals 56. For example, the electrically insulative washers may generally be configured to resist or impede parasitic current draw from the terminals 56 by way of contact with other electrically conductive features (e.g., the bus bar 80) of the module 28, and may be configured to prevent a short circuit from being formed by way of inadvertent electrical pathway formation (e.g., with an adjacent terminal 56).

[0052] In addition, the conductive washer 76 of the washer stacks 72 may include a suitable amount of conductive material. The amount of conductive material will generally be an amount suitable to provide a desired degree of conductivity between the cell terminals 56 and the interconnecting features (e.g., the bus bars 80). In certain embodiments, the conductive washers may be metallic, such as aluminum, copper, or the like. The conductive washers 76, in certain embodiments, may serve as an electrical interface with the bus bar 80, as shown in FIGS. 6 and 7. Again, this may result in a reduced amount of shear forces being placed on the terminal 56 of the battery cells 50, which may prolong the life of the battery cells 50 and reduce the likelihood of a compromised battery cell casing 64.

[0053] In certain embodiments, the washer stack 72 may be such that the conductive washer 76 is substantially aligned with a top 96 of the cell terminal 56, as shown in FIG. 8. In certain embodiments, aligning the top 96 of the cell terminal 56 with the face 78 of the electrically conductive washer 76 may enable a strong electrical connection between

the cell terminal 56 and the bus bar 80, while reducing or eliminating exertion of the shear force 90 on the cell terminal 56. For example, configuring the washer stack 72 such that the face 78 of the electrically conductive washer 76 is substantially flush with the top 96 of the cell terminal 56 may enable a direct electrical connection between the cell terminal 56 and the bus bar 80 because the two components may contact one another. Moreover, because of the presence of the washer stack 72, the cell terminal 56 may not be physically attached to the bus bar 80 (e.g., welded together). This lack of a physical attachment may prevent or reduce damage to the cell terminal 56 from the shear forces 90 exerted on the bus bar 80. Additionally, configuring the washer stack 72 such that the conductive washer 76 is substantially aligned with the top 96 of the cell terminal 56 may also facilitate the coupling (e.g., welding) of the electrically conductive washer 76 and the bus bar 80. For example, because the cell terminal 56 does not protrude beyond the face 78 of the electrically conductive washer 76 (e.g., as shown in FIG. 9) the weld between the washer 76 and the bus bar 80 may be performed without physical interference because of the lack an obstacle impeding access to the washer face 78.

[0054] In other embodiments, the washer stack 72 may be configured such that the top 96 of the terminal 56 protrudes beyond the conductive washer 76, as shown in FIG. 9. This configuration may be desirable in embodiments where the bus bar 80 has an opening configured to receive the terminal 56. In still further embodiments, the washer stack 72 may be such that the top 96 of the terminal 56 is recessed within the conductive washer 76, as shown in FIG. 10 (e.g., between the face 78 of the electrically conductive washer 76 and the second face of the electrically conductive washer 76). Such a configuration may be desirable to provide physical displacement between the bus bar 80 and the terminal 56.

[0055] While the embodiments set forth above include round shapes (e.g., from a top-down view of the cell terminal 56) for the electrically insulative 74 and electrically conductive 76 washers making up the washer stack 72, the washers and/or the washer stack 72 may have other geometries. For example, the washers (e.g., the conductive 76

and/or insulative washers 74) may be square, hexagonal, or any other suitable geometry, as shown in FIGS. 11-13. Additionally, the cell terminal 56 may also have other geometries (e.g., square, hexagonal). Specifically, FIGS. 11-13 may be considered to be a top-down view of different embodiments of the washers disposed about the terminal 56.

[0056] The washers may also have various cross-sectional geometries having particular configurations. For example, the washers shown in FIGS. 3-13 may have the cross-sectional geometry shown in FIG. 14. As shown in the cross-sectional side view of FIG. 14, a washer 100 is oriented substantially parallel to the top surface 60 of the casing 64.

[0057] However, other embodiments of the washer 100, such as those shown in FIGS. 15 and 16, include cross-sectional geometries that are not oriented parallel, but instead include a first portion 102 and a second portion 104 that are oriented crosswise relative to one another. Specifically, the first portion 102 may be oriented substantially parallel relative to the casing 64, while the second portion 104 (e.g., a protrusion) may extend toward (e.g., in FIG. 15) or away from (e.g., in FIG. 16) the casing 64. The second portion 104 (e.g., protrusions) of the washer 100, as shown in FIGS. 15 and 16, may be configured to prevent displacement of the terminal 56, such as lateral displacement of the top portion 96 of the terminal 56. In this way, the second portion 104 (e.g., protrusions) of the washer 100 may provide additional blocking of the shear forces 90 (e.g., as shown in FIG. 7) from causing movement of the terminal 56. While specific embodiments are shown in FIGS. 14-16, the washer 100 may have other cross-sectional geometries not explicitly illustrated, such as geometries with rounded portions, multiple protrusions, recesses, and so forth.

[0058] One or more of the disclosed embodiments, alone or in combination, may provide one or more technical effects including reducing shear forces applied to a terminal post of a battery cell by disposing one or more washers over the battery cell terminal post. The stack of washers may resist or absorb the forces, thereby reducing the forces applied to the terminal post and extending the life of the battery cell as well as the

overall battery module. The technical effects and technical problems in the specification are exemplary and are not limiting. It should be noted that the embodiments described in the specification may have other technical effects and can solve other technical problems.

[0059] The specific embodiments described above have been shown by way of example, and it should be understood that these embodiments may be susceptible to various modifications and alternative forms. It should be further understood that the claims are not intended to be limited to the particular forms disclosed, but rather to cover all modifications, equivalents, and alternatives falling within the spirit and scope of this disclosure.

CLAIMS:

1. A lithium ion battery module, comprising:
 - a housing;
 - a first battery cell disposed in the housing and having a cell terminal protruding from a surface of a casing of the first battery cell, wherein the cell terminal is configured to enable electrical connection to the battery cell; and
 - a washer stack disposed about the cell terminal, comprising an electrically insulative washer and an electrically conductive washer; and
 - wherein the electrically conductive washer is disposed adjacent to the electrically insulative washer such that the electrically insulative washer is positioned between the electrically conductive washer and the surface of the casing, and wherein the electrically conductive washer is configured to enable electrical connection to the cell terminal.
2. The lithium ion battery module of claim 1 wherein the electrically conductive washer is welded to a bus bar such that the bus bar is electrically connected to the cell terminal, and wherein a physical connection between the bus bar and the cell terminal is absent.
3. The lithium ion battery module of claim 1, wherein the electrically conductive washer has a top surface and a bottom surface, and wherein the bottom surface is adjacent to the electrically insulative washer and the top surface is adjacent to a bus bar.
4. The lithium ion battery module of claim 3, wherein the top surface is substantially aligned with the cell terminal.
5. The lithium ion battery module of claim 3, wherein the cell terminal protrudes beyond the top surface.

6. The lithium ion battery module of claim 3, wherein an upper surface of the cell terminal is positioned between the top surface and the bottom surface.

7. The lithium ion battery module of claim 1, wherein a washer of the washer stack comprises a cross section with a length that is oriented substantially parallel to the surface of the casing.

8. The lithium ion battery module of claim 1, wherein a washer of the washer stack comprises a protrusion extending away from the surface of the casing.

9. The lithium ion battery module of claim 1, wherein a washer of the washer stack comprises a protrusion extending toward the surface of the casing.

10. The lithium ion battery module of claim 1, wherein one or both of the electrically insulative washer and the electrically conductive washer comprise a round shape, a square shape, a polygonal shape, or any combination thereof.

11. The lithium ion battery module of claim 1, wherein the electrically insulative washer comprises a polymeric material

12. The lithium ion battery module of claim 11, wherein the polymeric material comprises a Shore D hardness of greater than 50.

13. The lithium ion battery module of claim 11, wherein the polymeric material comprises a Shore A hardness of greater than 70.

14. The lithium ion battery module of claim 1, wherein the electrically conductive washer comprises copper.

15. The lithium ion battery module of claim 1, wherein the electrically conductive washer comprises aluminum.

16. The lithium ion battery module of claim 1, wherein the electrically insulative washer is disposed adjacent to the surface of the casing.

17. A lithium ion battery module, comprising:
a housing;
a battery cell disposed in the housing and having a cell terminal protruding from a surface of a casing of the first battery cell, wherein the cell terminal is configured to enable electrical connection to the battery cell;
a washer stack disposed about the cell terminal, comprising an electrically insulative washer and an electrically conductive washer;
wherein the electrically insulative washer is disposed adjacent to the surface of the casing;
wherein the electrically conductive washer is disposed in the washer stack such that the electrically insulative washer is positioned between the electrically conductive washer and the surface of the casing; and
a bus bar electrically coupled to the cell terminal via the electrically conductive washer.

18. The lithium ion battery module of claim 17, wherein the electrically conductive washer is welded to the bus bar such that the bus bar is electrically connected to the cell terminal, and wherein a physical connection between the bus bar and the cell terminal is absent.

19. The lithium ion battery module of claim 17, comprising an additional electrically insulative washer positioned in the stack between the electrically insulative

washer and the electrically conductive washer, wherein the electrically insulative washer and the additional electrically insulative washer each comprise a polymeric material.

20. The lithium ion battery module of claim 19, wherein the additional electrically insulative washer comprises a recess configured to receive at least a portion of the electrically conductive washer.

21. A battery module, comprising:

- a housing;
- a battery module terminal configured to provide an electrical output of the battery module when coupled to an electrical load;
- a battery cell disposed in the housing and having a cell terminal protruding from a surface of a casing of the first battery cell, wherein the cell terminal is configured to enable electrical connection to the first battery cell;
- a washer stack disposed about the cell terminal, comprising a stack of electrically insulative washers disposed adjacent to the surface of the casing and an electrically conductive washer disposed adjacent to the stack of electrically insulative washers such that the stack of electrically insulative washers are positioned between the electrically conductive washer and the surface of the casing; and
- a bus bar electrically coupled to the electrically conductive washer, wherein the bus bar is configured to establish an electrical connection between the battery cell and the battery module terminal.

22. The battery module of claim 21, wherein the electrically conductive washer is welded to the bus bar such that the bus bar is electrically connected to the cell terminal, and wherein a physical connection between the bus bar and the cell terminal is absent.

23. The battery module of claim 21, wherein the stack of electrically insulative washers comprises electrically insulative ceramic material, electrically

insulative polymeric material, electrically insulative composite material, or any combination thereof.

24. The battery module of claim 21, wherein the electrically conductive washer comprises copper or aluminum.

25. The battery module of claim 21, wherein the bus bar is welded to the electrically conductive washer.

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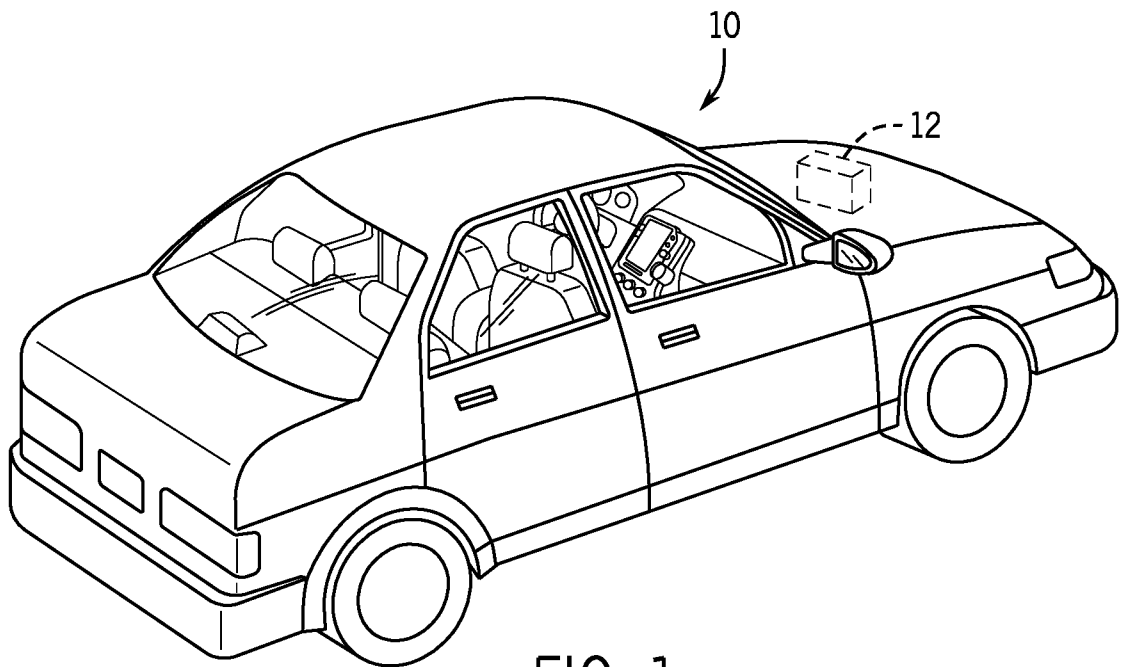


FIG. 1

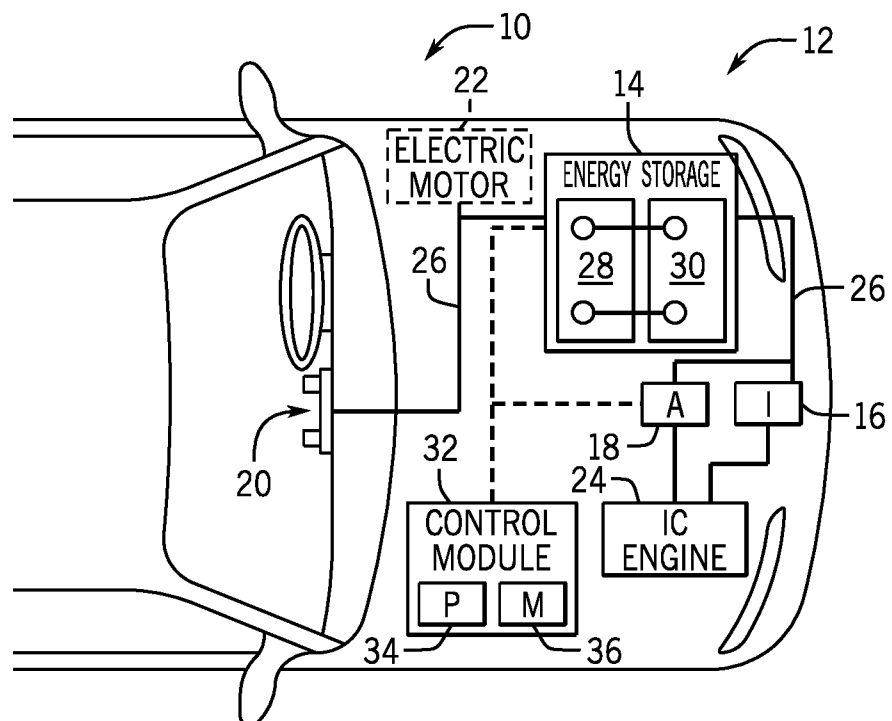


FIG. 2

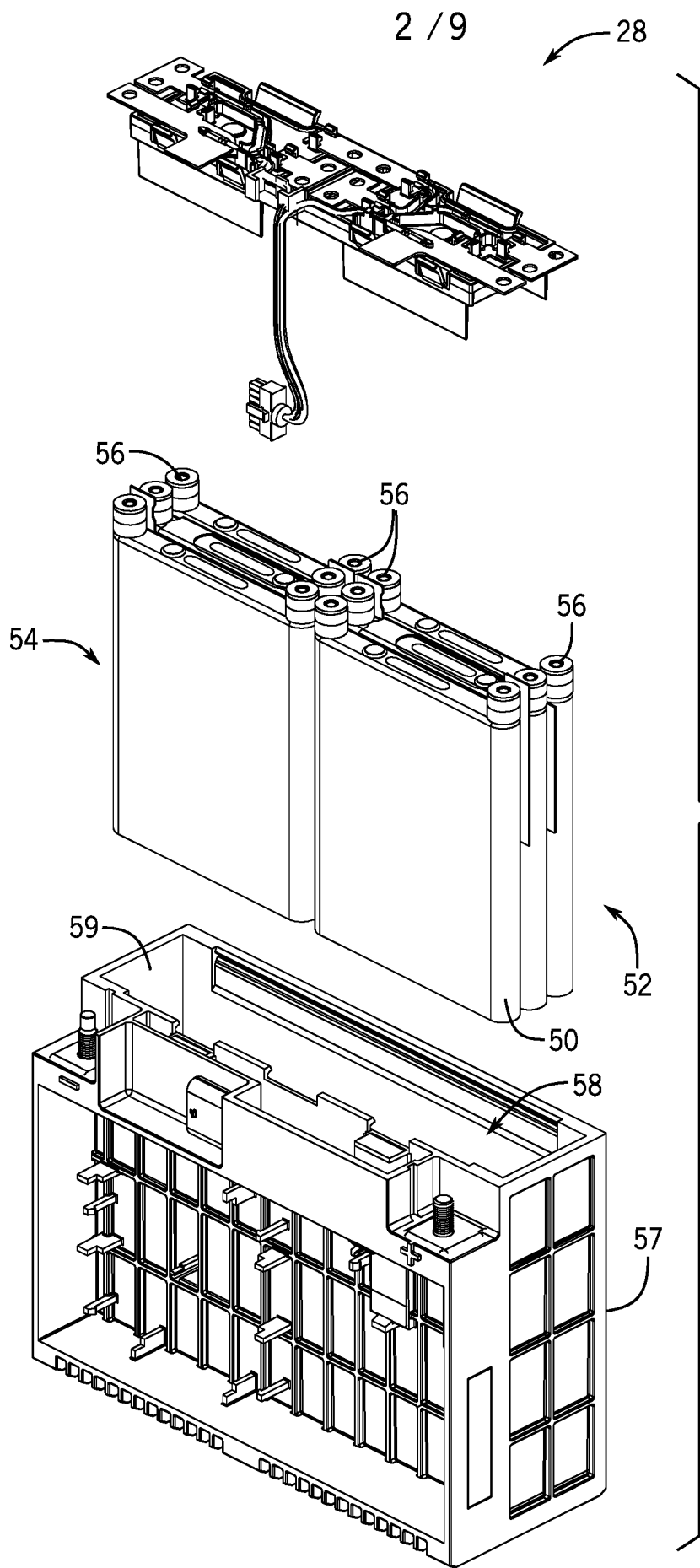
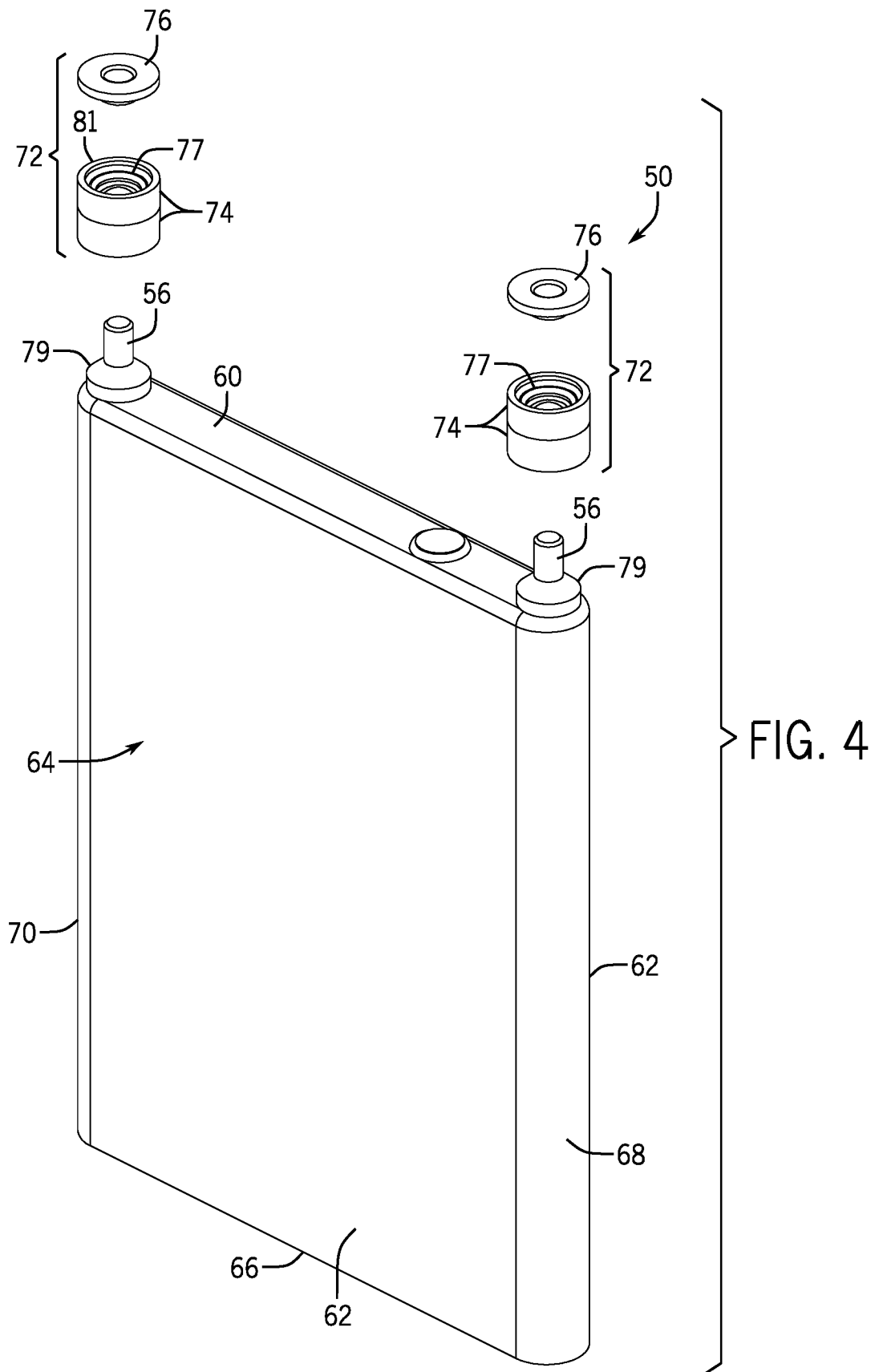


FIG. 3

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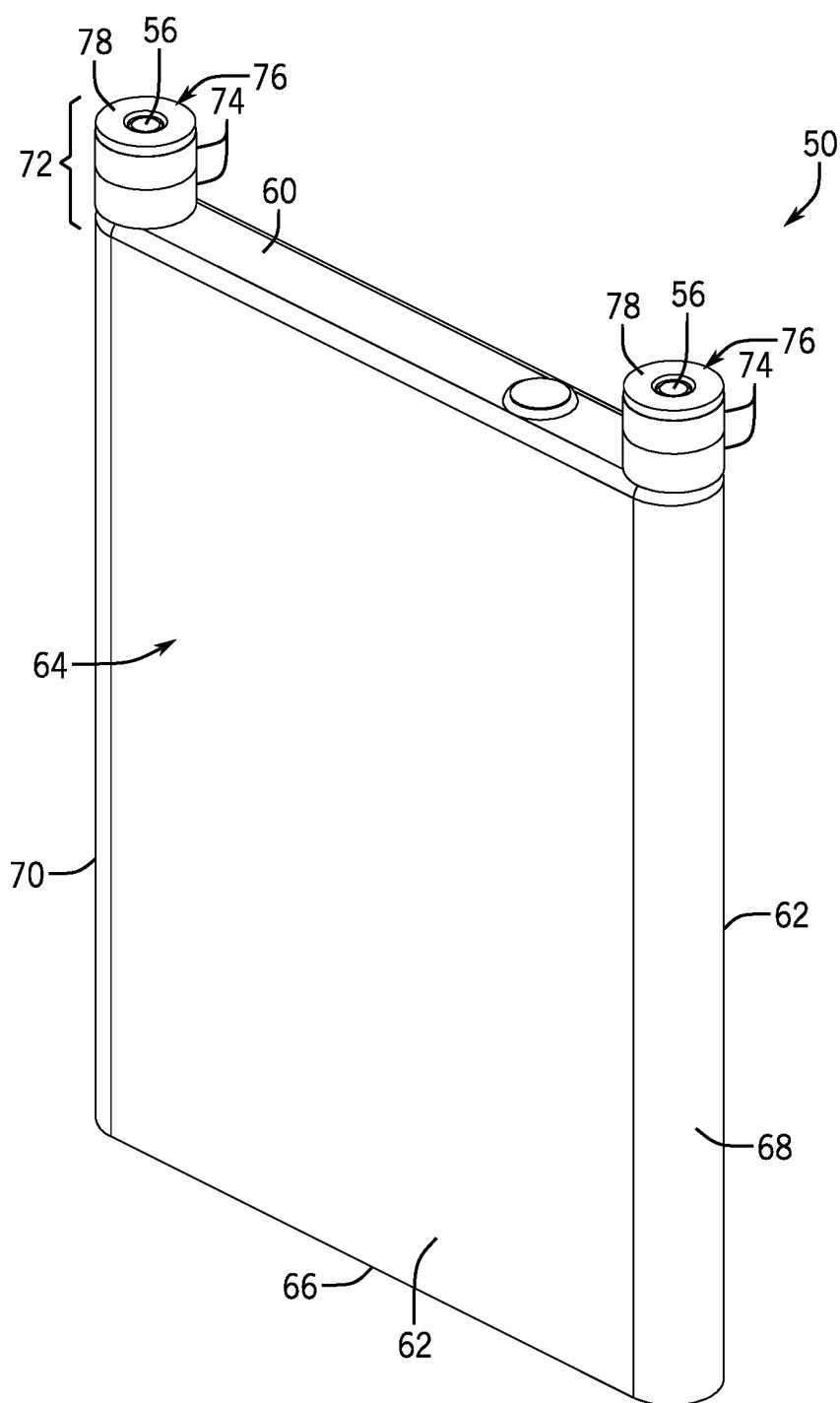


FIG. 5

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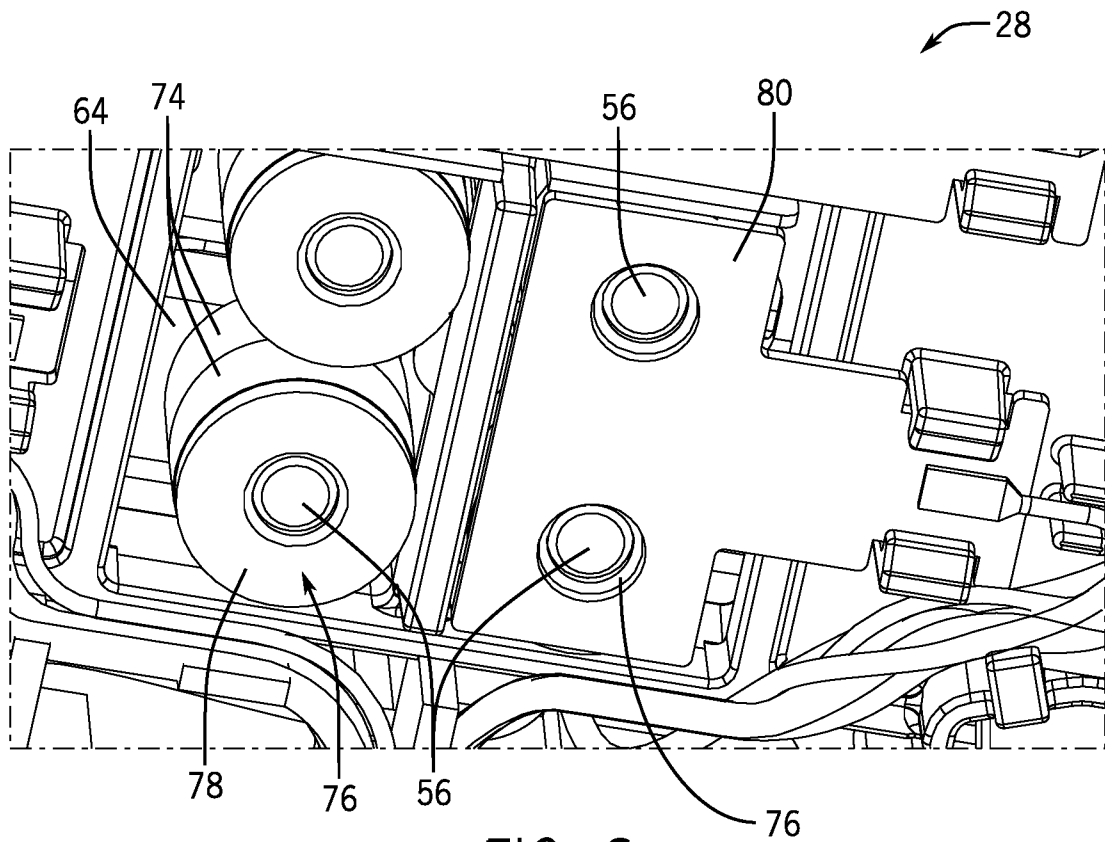
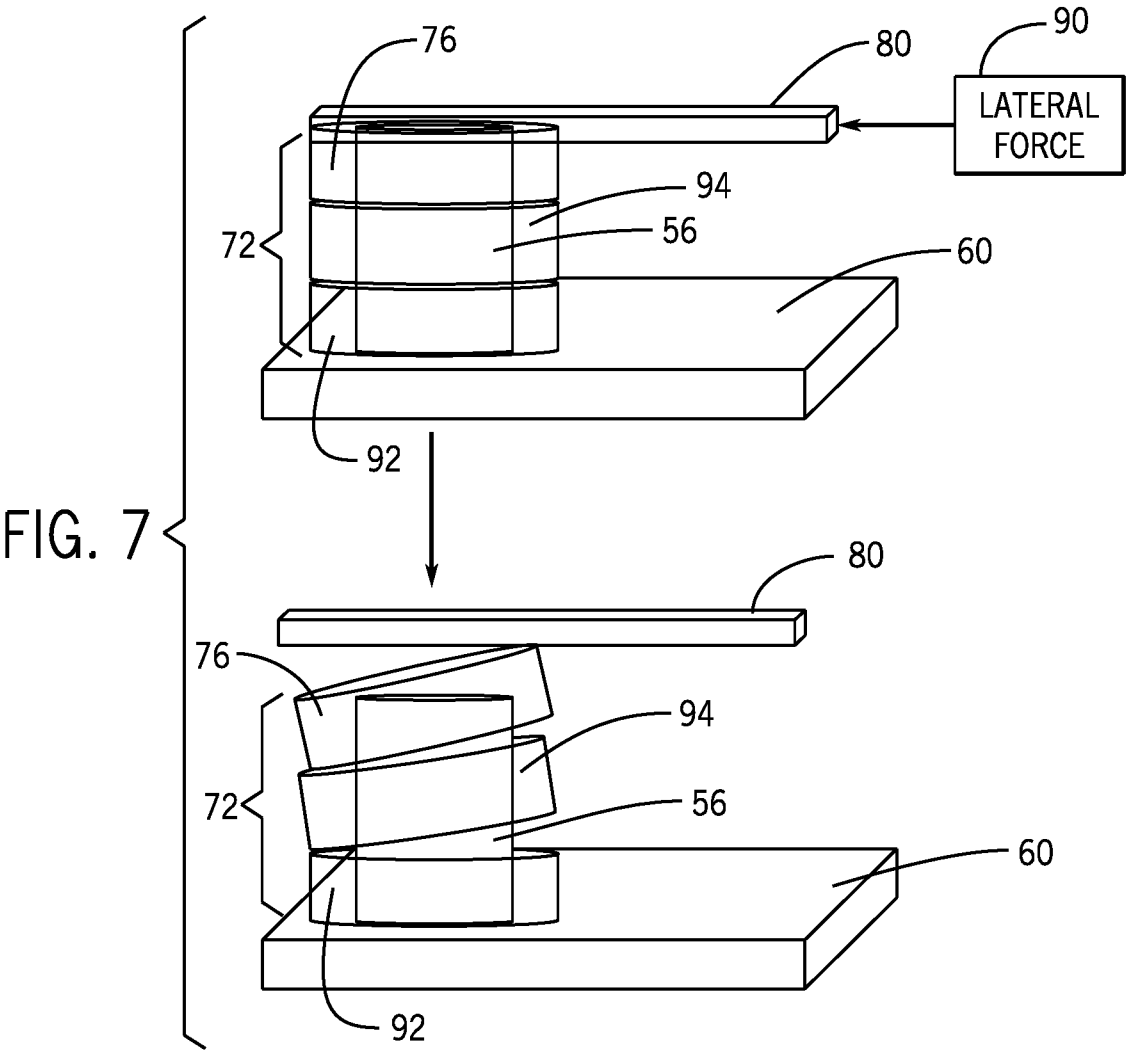


FIG. 6



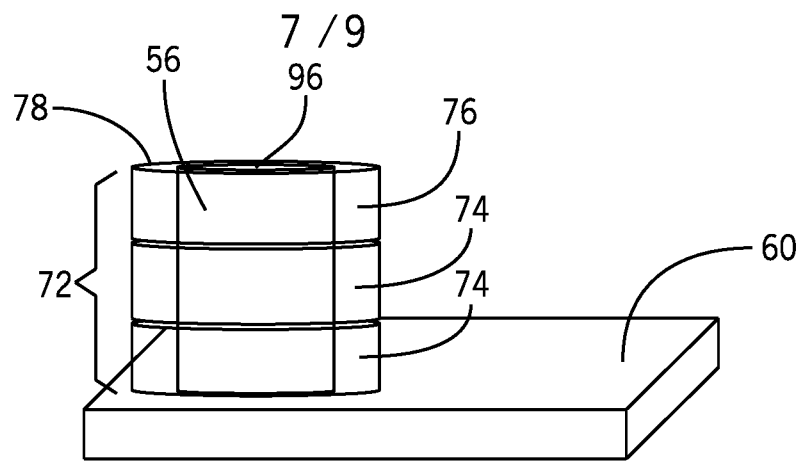


FIG. 8

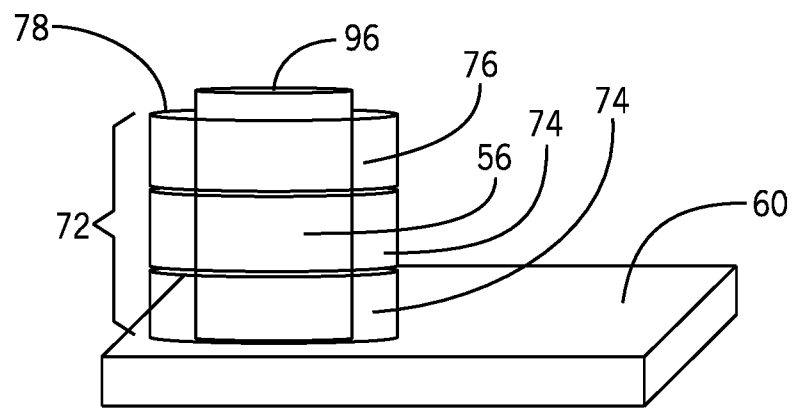


FIG. 9

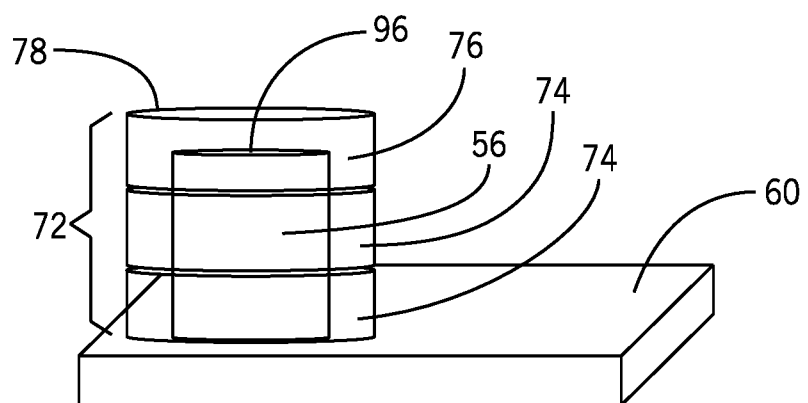
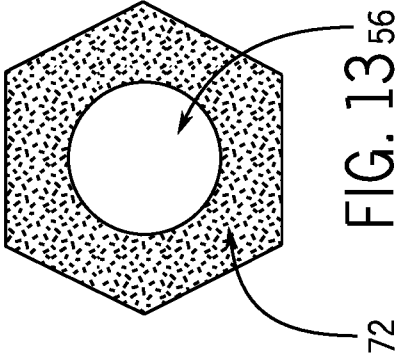
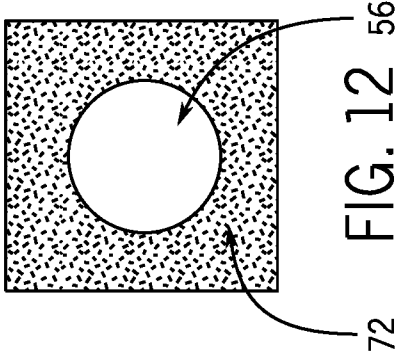


FIG. 10

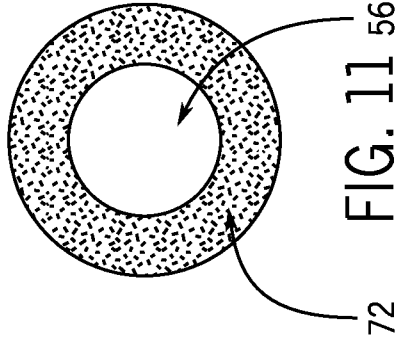
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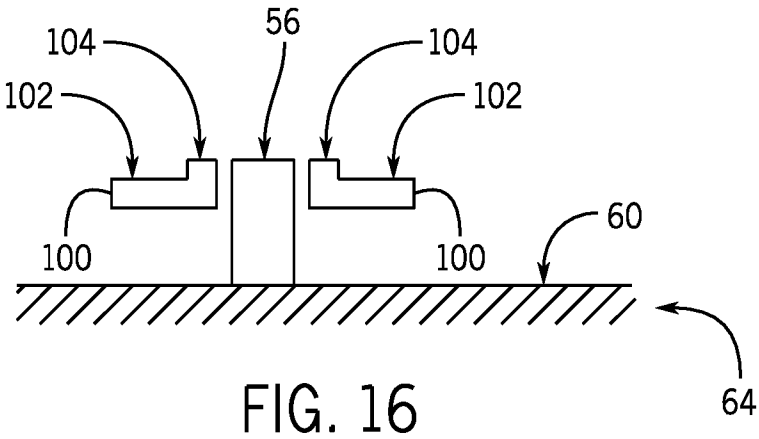
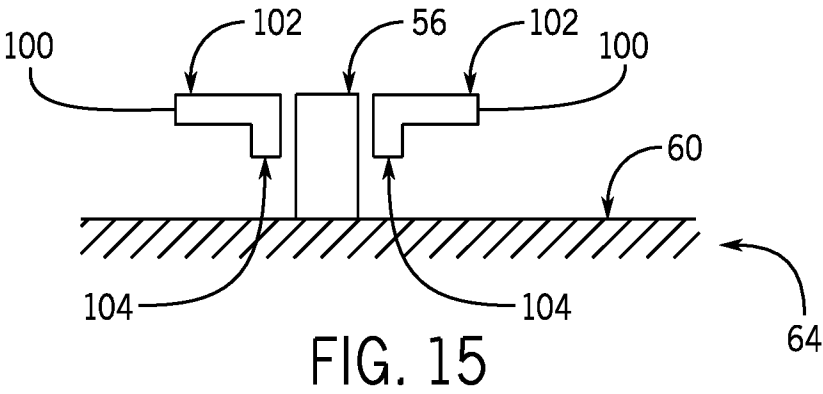
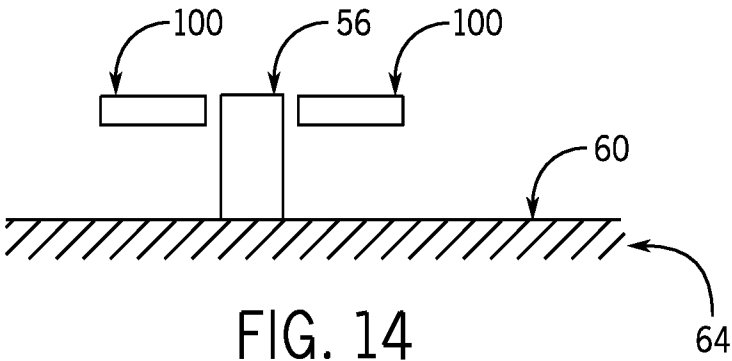


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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/013745

A. CLASSIFICATION OF SUBJECT MATTER INV. H01M10/60 H01M10/65 H01M10/6551 H01M2/30 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 A X	EP 2 620 993 A1 (SHIN KOBE ELECTRIC MACHINERY [JP]) 31 July 2013 (2013-07-31) the whole document ----- JP 2003 086151 A (JAPAN STORAGE BATTERY CO LTD) 20 March 2003 (2003-03-20) abstract -----	1-3,5, 7-25 4,6 1,5,7,16
☐ 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	
11 April 2016	19/05/2016	
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 Cappadonia, Marcella	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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