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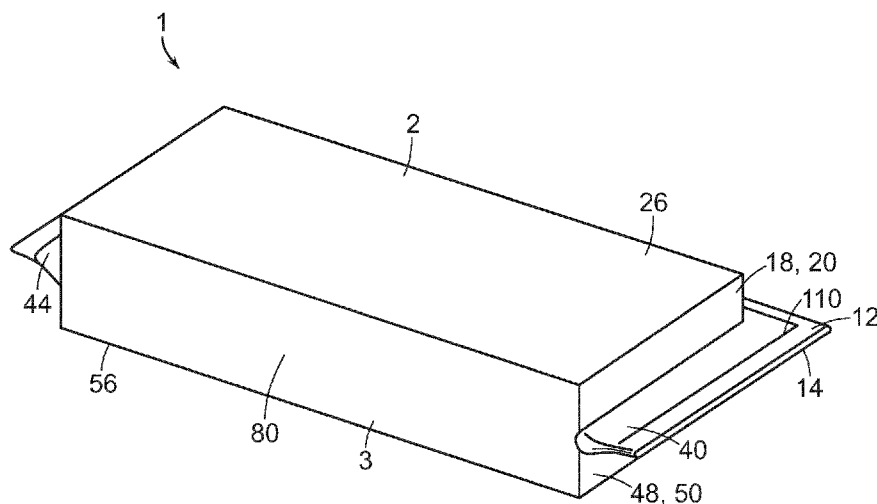


FIG. 1

(57) Abstract: An electrochemical pouch cell includes a pouch cell housing and an electrode assembly disposed in the housing. The housing is formed of a single blank that is drawn to form recesses in the sheet, and then folded so that the recesses are aligned and open facing each other. In addition, the recesses are joined along one side thereof by a connecting region of the sheet. The connecting region serves to space the recesses apart in both the pre-folded and post-folded configurations. The electrode assembly is disposed in the space defined within and between the recesses, and flange portions of the material surrounding the recesses are sealed together to form a sealed electrochemical cell. By providing the connecting region between the recesses, the height of the cell may be greater than twice the draw depth of the metal foil laminate material.



POUCH CELL AND METHOD OF MANUFACTURING SAME

BACKGROUND

[001] Lithium-ion battery cells are provided in various cell types that address the space requirements of a very wide variety of installation situations, and the most common types used in automobiles are cylindrical cells, prismatic cells, and pouch cells. The cells of different types each have substantially the same internal construction, including an anode, a cathode, a separator membrane that separates the cathode space from the anode space, an electrolyte/solvent, and lithium source, but they can differ appreciably in terms of their general dimensions, cell housing, and volumetric energy efficiency.

[002] With respect to the cell housing, for example, the cylindrical cells and prismatic cells each typically have a rigid housing, usually made of metal or plastic, whereas the pouch cell is surrounded only by a flexible outer envelope made of a metal foil laminate material which seals off the actual battery space from the environment. Pouch cell housings may be formed using a drawing process which produces tray-like case halves that are subsequently sealed together. However, the maximum draw depth of the metal laminated film used to form the pouch cell is limited by the material properties of the metal layer of the metal foil laminate material. For example, some aluminum metal foil laminate materials have a maximum draw depth of about 6 mm to 8 mm, and drawing to greater depths can result in tearing of the aluminum layer in the corners of the case half due to material overstress and stretching in this region. The forming process including the drawing step thus limits the overall height of the pouch cell that can be formed to about 12 mm to 16 mm, where a cell height h of 16 mm is obtained by sandwiching the active material between two drawn films, where the cell height h corresponds to the draw direction of the material used to form the pouch. This height limit, which is typically less than twice the draw depth of the metal foil laminate material, in turn limits the amount of active material that can be stored within the pouch cell. Such conventional pouch cells having drawn cell housings are typically formed with plates having a large area (e.g., length and width dimensions) to achieve acceptable energy outputs. That is, the aspect ratio of cell height to length or width is very small (for example, less than 0.1). In order to form battery pouch cells having a greater power storage capacity, it is desirable to form pouch cells having a greater overall height.

SUMMARY

[003] In some aspects, an electrochemical cell includes a pouch cell housing and an electrode assembly disposed in the housing. The electrode assembly includes a positive electrode, a negative electrode and a separator disposed between the positive electrode and the negative electrode. The positive electrode, the separator and the negative electrode are stacked along a stack axis. The housing includes a single sheet of a metal foil laminate material, and the sheet includes a first sheet surface, a second sheet surface that is opposed to the first sheet surface, and a sheet peripheral edge that extends between the first sheet surface and the second sheet surface. The sheet includes a first recess formed in the first sheet surface. The first recess is shaped and dimensioned to receive a first portion of the electrode assembly. The first recess includes a first sidewall arranged to form a closed loop. The first sidewall has a first surface edge at the first sheet surface and a first endwall edge that is spaced apart from the first sheet surface. The first recess includes a first endwall that is surrounded by the first sidewall, and a peripheral edge of the first endwall is integral with the first endwall edge. The sheet includes a second recess formed in the first sheet surface. The second recess is shaped and dimensioned to receive a second portion of the electrode assembly. The second recess includes a second sidewall arranged to form a closed loop. The second sidewall has a second surface edge at the first sheet surface and a second endwall edge that is spaced apart from the first sheet surface. The second recess includes a second endwall that is surrounded by the second sidewall, and a peripheral edge of the second endwall is integral with the second endwall edge. In addition, the sheet includes a connecting region that is disposed between the first recess and the second recess. The connecting region has a first side that coincides with a portion of the first surface edge, and a second side that is parallel to the first side. The second side coincides with a portion of the second surface edge. The first surface edge defines a first recess opening, and the second surface edge defines a second recess opening. The first recess opening faces the second recess opening, and the first recess opening is spaced apart from the second recess opening by a distance corresponding to a width of the connecting region. The width of the connecting region corresponds to a distance between the first side and the second side.

[004] In some embodiments, the connecting region is coplanar with both a portion of the first sidewall and a portion of the second sidewall.

[005] In some embodiments, the connecting region defines a plane that is parallel to the stack axis.

[006] In some embodiments, the sheet includes a first flange portion that comprises an area that is bordered by the first recess, the sheet peripheral edge and the connecting region first side. In addition, the sheet includes a second flange portion that comprises an area that is bordered by the second recess, the sheet peripheral edge and the connecting region second side. The first flange portion is joined to the second flange portion along a seal line.

[007] In some embodiments, the first and second recesses each have a rectangular shape, and the seal line is a continuous line that extends along three sides of the first and second recesses.

[008] In some embodiments, the housing includes a first pleat formed in the first and second flange portions at a location corresponding to one end of the connecting region, and the housing includes a second pleat formed in the first and second flange portions at a location corresponding to an opposed end of the connecting region, where the opposed end is opposed to the one end. The first pleat includes a first portion of the connecting region that is folded back on the first flange portion at the one end of the connecting region and a second portion of the connecting region that is folded back on the second flange portion at the one end of the connecting region. The first portion and the second portion are disposed between the first flange portion and the second flange portion. In addition, the second pleat includes a third portion of the connecting region that is folded back on the first flange portion at the opposed end of the connecting region and a fourth portion of the connecting region that is folded back on the second flange portion at the opposed end of the connecting region. The third portion and the fourth portion are disposed between the first flange portion and the second flange portion.

[009] In some embodiments, the seal line extends across both the first pleat and the second pleat.

[0010] In some embodiments, the first recess is oriented relative to the second recess in such a way that the first end wall and the second end wall are parallel to each other and such that the

first surface edge and the second surface edge are between the first end wall and the second end wall.

[0011] In some embodiments, the pouch cell housing has a housing height that is greater than twice the draw depth of the material used to form the pouch cell housing, where the housing height corresponds to a distance between the first endwall and the second endwall.

[0012] In some embodiments, the first sidewall and the second sidewall each define a rectangular loop.

[0013] In some embodiments, the metal foil laminate material comprises an aluminum foil layer that is sandwiched between polymer layers.

[0014] In some aspects, a method of forming an electrochemical cell having a pouch cell housing is provided. The method includes providing a sheet of a metal foil laminate material, the sheet including a first sheet surface, a second sheet surface that is opposed to the first sheet surface, and a sheet peripheral edge that extends between the first sheet surface and the second sheet surface. The method includes forming a first recess in the sheet at a location spaced apart from the peripheral edge, where the first recess includes a first sidewall arranged to form a closed loop. The first sidewall has a first surface edge at the first sheet surface and a first endwall edge that is spaced apart from the first sheet surface. The first recess includes a first endwall that is surrounded by the first sidewall, and a peripheral edge of the first endwall is integral with the first endwall edge. The method includes forming a second recess in the sheet at a location spaced apart from the peripheral edge and from the first recess, whereby a connecting region is provided that is disposed between the first recess and the second recess. The second recess includes a second sidewall arranged to form a closed loop. The second sidewall has a second surface edge at the first sheet surface and a second endwall edge that is spaced apart from the first sheet surface. The second recess including a second endwall that is surrounded by the second sidewall, and a peripheral edge of the second endwall is integral with the second endwall edge. The connecting region includes a first side that coincides with a portion of the first surface edge, and a second side that is parallel to the first side. The second side coincides with a portion of the second surface edge. The method includes folding the sheet in a first direction along a first fold line until a portion of the first sidewall is aligned with the connecting region, where the first fold line overlies the first side. The method includes folding the sheet in a second direction

along a second fold line until a portion of the second sidewall is aligned with the connecting region and the first recess is aligned with the second recess. The second fold line overlies the second side, and the second direction is opposed to the first direction. The method includes joining a first flange portion of the sheet to the second flange portion of the sheet along a seal line so as to provide a closed sealed space within the cell. The first flange portion includes an area that is bordered by the first recess, the sheet peripheral edge and the connecting region first side, and the second flange portion includes an area that is bordered by the second recess, the sheet peripheral edge and the connecting region second side.

[0015] In some embodiments, the method also includes forming a first pleat in the first and second flange portions at a location corresponding to one end of the connecting region, where the first pleat includes a first portion of the connecting region that is folded back on the first flange portion at the one end of the connecting region and a second portion of the connecting region that is folded back on the second flange portion at the one end of the connecting region. The first portion and the second portion are disposed between the first flange portion and the second flange portion. In addition, a second pleat is formed in the first and second flange portions at a location corresponding to an opposed end of the connecting region, where the opposed end is opposed to the one end and where the second pleat includes a third portion of the connecting region that is folded back on the first flange portion at the opposed end of the connecting region and a fourth portion of the connecting region that is folded back on the second flange portion at the opposed end of the connecting region. The third portion and the fourth portion are disposed between the first flange portion and the second flange portion.

[0016] In some embodiments, the step of joining a first flange portion of the sheet to the second flange portion of the sheet along a seal line includes extending the seal line across both first pleat and the second pleat.

[0017] In some embodiments, the method also includes providing an electrode assembly that includes a positive electrode, a negative electrode and a separator disposed between the positive electrode and the negative electrode. The positive electrode, the separator and the negative electrode are stacked along a stack axis. Prior to the step of joining a first flange portion of the sheet to the second flange portion of the sheet along a seal line, the method includes disposing

the electrode assembly within an interior space of the cell defined between the first recess and the second recess.

[0018] In some embodiments, the connecting region serves to space the first recess apart from the second recess both before and after the steps of folding the sheet in a first direction along a first fold line and folding the sheet in a second direction along a second fold line.

[0019] In some aspects, an electrochemical pouch cell includes a pouch cell housing and an electrode assembly disposed in the housing. The pouch cell housing is formed of a single sheet (e.g., a blank) of a metal foil laminate material that is drawn to form recesses in the sheet, and then folded so that the recesses are aligned and open facing each other. In addition, the recesses are joined along one side thereof by a connecting region of the sheet. The connecting region serves to space the recesses apart in both the pre-folded and post-folded configurations. The electrode assembly is disposed in the space defined within and between the recesses, and flange portions of the material surrounding the recesses are sealed together to form a sealed electrochemical cell. By providing the connecting region between the recesses, the height of the cell may be greater than twice the draw depth of the metal foil laminate material.

[0020] Since both the first recess and the second recess are formed in the same blank, the area of the blank is large relative to a blank that is used to form a single recess (for example, for pouch cell housings formed of two blanks, each blank drawn to form a half shell). Since the draw depth is greater for a blank of a greater size, the pouch cell formed of a single blank that is sized to accommodate two recesses may have a greater draw depth than a pouch cell formed of two blanks, each blank sized to accommodate a single recess. For example, for pouch cells formed of an aluminum foil laminate material, the pouch cell formed of a single blank that is sized to accommodate two recesses may have a draw depth of 11 millimeters as compared to some pouch cells formed of two blanks, each blank sized to accommodate a single recess and having a draw depth of 6 millimeters.

[0021] In addition to having a cell height that is greater than some conventional pouch cells formed of the same material, the pouch cell housing described herein has a side that is free of pouch flanges and a corresponding seal line. The flange-free side of the housing provides a flat surface that can allow good thermal contact with a cell thermal management device such as a cooling plate, whereby the temperature of the cell can be efficiently and easily controlled.

Moreover, since the flange-free side of the cell housing includes the connecting region, the area corresponding to the flange-free side that contacts the cooling plate is large relative to a pouch cell that does not include a connecting region, further increasing the efficiency of the thermal management of the cell.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Fig. 1 is a perspective view of a pouch cell.

[0023] Fig. 2 is another perspective view of the pouch cell of Fig. 1.

[0024] Fig. 3 is a schematic cross sectional view of the pouch cell of Fig. 1.

[0025] Fig. 4 is a perspective view of a sheet of material including the first and second recess formed therein.

[0026] Fig. 5 is a detail view of a portion of Fig. 4 as indicated by the broken circle in Fig. 4.

[0027] Fig. 6 is a top plan view of the sheet of material of Fig. 4, in which the first flange portion, the connecting region, and the second flange portion are identified using corresponding cross-hatching, fold lines are shown in broken lines and folding directions are indicated using arrows.

[0028] Fig. 7 is a schematic side view of the assembled pouch cell housing.

[0029] Fig. 8 is a flow chart illustrating a method of forming the pouch cell of Fig. 1.

[0030] Fig. 9 is an illustration of the sheet following a folding operation.

[0031] Fig. 10 is an illustration of the sheet following a portion of the sealing operation.

[0032] Fig. 11 is an illustration of a portion the sheet following a pleating operation.

[0033] Fig. 12 is an enlarged view of the pleat of Fig. 11.

[0034] Fig. 13 is an illustration of the sheet following completion of the pleating and sealing operations.

[0035] Fig. 14 is an illustration of the pouch cell housing as formed by the method and following completion of a trimming operation.

DETAILED DESCRIPTION

[0036] Referring to Figs. 1-4, a lithium ion electrochemical pouch cell 1 includes a pouch-type housing 2 and an electrode assembly 120 that is sealed within the housing 2 along with an electrolyte. The housing 2 is formed of a single sheet (e.g., a blank) 4 of a flexible metal foil laminate material. In a method described in detail below, the sheet 4 is drawn to form first and second recesses 18, 48 that are spaced apart along the sheet surface 6. The region between the first recess 18 and the second recess 48 is referred to as the connecting region 80, and the first and second recesses 18, 48 are each joined along one side thereof to the connecting region 80. The drawn sheet 4 is folded so that the recesses 18, 48 are aligned and open facing each other. In this configuration, the recesses 18, 48 are spaced apart a distance corresponding to a width of the connecting region 80. The electrode assembly 120 is disposed in the space defined within and between the first and second recesses 18, 48. In addition, flange portions 12, 14 corresponding to the sheet material surrounding the first and second recesses 18, 48 are sealed together to form a sealed electrochemical cell 1. Since the connecting region 80 serves to space the first and second recesses 18, 48 apart, a pouch cell 1 is provided in which the cell height may be greater than twice the draw depth of the metal foil laminate material, as described in detail below.

[0037] Referring to Fig. 3, the electrode assembly 120 comprises at least one positive electrode 122, at least one negative electrode 124 and a separator 126 that is disposed between each pair of the positive electrode 122 and the negative electrode 124. Each of the positive electrodes 122, the negative electrodes 124 and the separators 126 are thin plates, and each of the positive and negative electrodes 122, 124 have a layered structure to facilitate insertion and/or movement of lithium-ions. For example, the positive electrodes 122 may include a first substrate formed of a first electrically-conductive material such as copper, and a first active material such as a graphite coating that is disposed on one or both sides of the first substrate. In addition, negative electrodes 124 may include a second substrate formed of a second electrically-conductive material such as aluminium, and a second active material such as a lithiated metal oxide coating that is disposed on one or both sides of the second substrate. The substrates used to form the positive and negative electrodes 122, 124 are very thin (e.g., having a thickness on the order of

about 0.04 to 0.15 mm) compared to the overall cell height (e.g. having a height of about 35 mm) and thus are illustrated schematically and not to scale in the figures.

[0038] The separator 126 is a permeable membrane that functions to keep the positive and negative electrodes 122, 124 apart to prevent electrical short circuits while also allowing passage of ionic charge carriers provided in the electrolyte and that are needed to close the circuit during the passage of current within the cell 1. The separator 126 is formed of an electrically insulating material such as a tri-layer polypropylene-polyethylene-polypropylene membrane.

[0039] The positive electrodes 122 and negative electrodes 124 are arranged in a stacked or layered configuration in which a separator 126 is disposed (e.g., sandwiched) between each pair of the positive and negative electrodes 122, 124. A stack axis 128 of the electrode assembly 120 extends through a center of the electrode assembly 120 in a direction parallel to the stacking direction. In the stacked configuration, the positive electrodes 122, the negative electrodes 124 and the separators 126 are stacked along the stack axis 128. In some embodiments, the peripheral edges of each of the electrodes 122, 124 and separators 126 are aligned in a direction parallel to the direction of the stack axis 128 (shown), while in other embodiments (not shown), the peripheral edges of the positive electrodes 122 are offset to one side of the stack axis 128, while the peripheral edges of the negative electrodes 124 are offset to an opposed side of the stack axis 128. The particular alignment of the peripheral edges facilitates connection of the electrodes 122, 124 to respective terminals (not shown) of the cell 1, and is determined based on whether current collectors are used, and the type of current collector used.

[0040] Referring to Figs. 3-5, the electrode assembly 120 is sealed within the housing 2. The housing 2 is formed of a single sheet 4 of a relatively flexible metal foil laminate material. For example, in some embodiments, the sheet 4 is a multi-layer material that includes a central layer of an aluminium foil 7 that is sandwiched between a layer of polyamide 5 and a layer of polypropylene 9. The sheet 4 includes a first sheet surface 6, a second sheet surface 8 that is opposed to the first sheet surface 6, and a sheet peripheral edge 10 that extends between the first sheet surface 6 and the second sheet surface 8.

[0041] The first recess 18 is formed in the first sheet surface 6 at a location that is spaced apart from the sheet peripheral edge 10. The first recess 18 is shaped and dimensioned to receive a first portion 130 of the electrode assembly 120, where the first portion 130 includes, for example,

one end of the electrode assembly 120. The first recess 18 includes a first endwall 26 that is offset from the first sheet surface 6, and a first sidewall 20 that is arranged to form a closed loop around the peripheral edge 28 of the first endwall 26. In the illustrated embodiment, the first sidewall 20 forms a rectangular closed section having four first sidewall portions 20(1), 20(2), 20(3), 20(4), but it is understood that the first sidewall 20 can have other shapes, including non-rectangular polygons and or curved shapes, as required by the application. The first sidewall 20 includes a first surface edge 22 at the first sheet surface 6 (e.g., the first surface edge 22 is common to both the first sidewall 20 and the first sheet surface 6). The first surface edge 22 defines a rectangular opening of the first recess 18. The first sidewall 20 also includes a first endwall edge 24 that is spaced apart from the first sheet surface 6, and is common to both the first sidewall 20 and the first endwall 26.

[0042] The second recess 48 is formed in the first sheet surface 6 at a location that is spaced apart from the sheet peripheral edge 10. The second recess 48 is shaped and dimensioned to receive a second portion 132 of the electrode assembly 120, where the second portion 132 includes, for example, an opposed end of the electrode assembly 120 relative to that of the first portion 130. The second recess 48 includes a second endwall 56 that is offset from the first sheet surface 6, and a second sidewall 50 that is arranged to form a closed loop around the peripheral edge 58 of the second endwall 56. In the illustrated embodiment, the second sidewall 50 forms a closed section having the same shape as that of the first sidewall 20. Thus, in the illustrated embodiment, the second sidewall 50 forms a rectangular closed section having four second sidewall portions 50(1), 50(2), 50(3), 50(4). The second sidewall 50 includes a second surface edge 52 at the first sheet surface 6 (e.g., the second surface edge 52 is common to both the second sidewall 50 and the first sheet surface 6). The second surface edge 52 defines a rectangular opening of the second recess 48. The second sidewall 50 also includes a second endwall edge 54 that is spaced apart from the first sheet surface 6, and is common to both the second sidewall 50 and the second endwall 56.

[0043] Referring also to Figs. 6 and 7, during the drawing process (discussed further below), the first and second recesses 18, 48 are formed in the sheet 4 in an aligned, side-by-side arrangement in which the first recess 18 is spaced apart from the second recess 48 such that a gap exists between the first recess 18 and the second recess 48. The connecting region 80 is disposed between and joins the first recess 18 to the second recess 48. In addition, the portion of the sheet

4 that is bordered by the first recess 18, the sheet peripheral edge 10 and a first side 81 of the connecting region 80 is referred to herein as a first flange portion 12, and the portion of the sheet 4 that is bordered by the second recess 48, the sheet peripheral edge 10 and a second side 82 of the connecting region 80 is referred to herein as the second flange portion 14.

[0044] The connecting region 80 is rectangular in shape, and thus includes four sides 81, 82, 83, 84. The first side 81 extends between opposed peripheral edges 10 of the sheet 4 and coincides with a portion of the first surface edge 22 of the first recess 18, e.g. the portion of the first surface edge 22 that abuts the connecting region 80. The second side 82 is parallel to the first side 81, extends between opposed peripheral edges of the sheet 4 and coincides with a portion of the second surface edge 52 of the second recess 48, e.g. the portion of the second surface edge 52 that abuts the connecting region 80. The third and fourth sides 83, 84 coincide with the sheet peripheral edge 10 on opposed ends of the connecting region 80. A width of the connecting region 80 corresponds to a distance between the first side 81 and the second side 82.

[0045] In the assembled housing 2, the first recess 18 is oriented relative to the second recess 48 in such a way that the recesses 18, 48 are aligned with each other along the stack axis 128, and open facing each other (Fig. 7). In this configuration, the first end wall 26 and the second end wall 56 are parallel to each other, and the first surface edge 22 and the second surface edge 52 are between the first end wall 26 and the second end wall 56. In addition, the connecting region 80 is coplanar with both a portion of the first sidewall 20 (e.g., the fourth sidewall portion 20(4) of the first sidewall 20) and a portion of the second sidewall 50 (e.g., the second sidewall portion 50(2) of the second sidewall 50). As a result, the connecting region is generally parallel with the stacking axis 128. In addition, the first recess 18 is spaced apart from the second recess 48 in a direction perpendicular to the first and second endwalls 26, 56 by a distance corresponding to the width of the connecting region 80. Due to the presence of the connecting region 80 between the first and second recesses 18, 48, the pouch cell housing 2 has a housing height h that is greater than twice the draw depth of the material sheet 4 used to form the pouch cell housing 2. As used herein, the housing height h corresponds to a distance between the first endwall 26 and the second endwall 56.

[0046] In the assembled housing 2, a first pleat 40 is formed in the first and second flange portions 12, 14 at the third side 83 of the connecting region 80. In addition, a second pleat 44 is

formed in the first and second flange portions 12, 14 at an opposed end of the connecting region 80 with respect to the location of the first pleat 40, that is, at the fourth side 84 of the connecting region 80. The first pleat 40 includes end portions of the connecting region 80 that are folded back onto the flange portions 12, 14 at the third side 83 of the connecting region 80. For example, a first end portion 91 of the connecting region 80 is located in an inside corner defined by the connecting regions first and third sides 81, 83. In addition, a second end portion 92 of the connecting region 80 is located in an inside corner defined by the connecting regions second and third sides 82, 83. The first end portion 91 is folded back on the first flange portion 12 at the connecting region third side 83 (to a location referred to as 91' in Fig. 6), and the second end portion 92 of the connecting region 80 is folded back on the second flange portion 14 at the at the connecting region third side 83 (to a location referred to as 92' in Fig. 6). In the first pleat 40, the first end portion 91 and the second end portion 92 are disposed between the first flange portion 12 and the second flange portion 14.

[0047] Like the first pleat 40, the second pleat 44 includes end portions of the connecting region 80 that are folded back onto the flange portions 12, 14. In the second pleat 44, the end portions are located at the fourth side 84 of the connecting region 80. For example, a third end portion 93 of the connecting region 80 is located in an inside corner defined by the connecting regions first and fourth sides 81, 84. In addition, a fourth end portion 94 of the connecting region 80 is located in an inside corner defined by the connecting regions second and fourth sides 82, 84. The third end portion 93 is folded back on the first flange portion 12 at the connecting region fourth side 84 (to a location referred to as 93' in Fig. 6), and the fourth end portion 94 of the connecting region 80 is folded back on the second flange portion 14 at the at the connecting region fourth side 84 (to a location referred to as 94' in Fig. 6). In the second pleat 44, the third end portion 93 and the fourth end portion 94 are disposed between the first flange portion 12 and the second flange portion 14.

[0048] The first and second pleats 40, 44 tuck away excess material along the sheet peripheral edge associated with the connecting region 80 that would otherwise protrude across a plane P defined by the connecting region 80.

[0049] In the assembled housing 2, the first flange portion 12 is joined to the second flange portion 14 along a continuous seal line 110 that extends along three sides of the first and second

recesses 18, 48, e.g., the three sides that do not correspond to the connecting region 80. Since the first and second pleats 40, 44 are formed in the first and second flange portions 12, 14, the seal line 110 extends across both the first pleat 40 and the second pleat 44.

[0050] Referring to Figs. 4 and 6-14, a method of manufacturing an electrochemical cell 1 having a pouch-type housing that is formed from a single blank or sheet 4 of housing material will now be described.

[0051] In an initial step (step 200), the sheet 4 of a metal foil laminate material is provided. In the illustrated embodiment, the material is a flexible, three-layer, metal laminated film having a polypropylene layer, an aluminium foil layer, and a polyethylene layer. However, it is understood that the material is not limited to this construction.

[0052] The first recess 18 is then formed in the first surface 6 of the sheet 4 at a location that is spaced apart from the sheet peripheral edge 10 (step 202), and the second recess 48 is formed in the first surface 6 of the sheet 4 at a location spaced apart from the sheet peripheral edge 10 and from the first recess 18 (step 204, Figs. 4 and 6). The first and second recesses 18, 48 may be formed simultaneously in a drawing process, for example using a single punch tool with two protrusions that is advanced once, or alternatively may be formed sequentially in a drawing process, for example using a single punch tool having a single protrusion that is advanced twice and moved between advances. Since the second recess 48 is formed in the sheet 4 at a location spaced apart from the first recess 18, the connecting region 80 is provided between the first recess 18 and the second recess 48.

[0053] Following formation of the first and second recesses 18, 48, the sheet 4 is folded in a first direction along a first fold line 112 until the fourth wall portion 20(4) of the first sidewall 20 is aligned with the connecting region 80 (step 206). The first fold line 112 overlies or coincides with both the connecting portion first side 81 and a portion of the first surface edge 22. In addition, the sheet 4 is folded in a second direction along a second fold line 114 until a second wall portion 50 (2) of the second sidewall 50 is aligned with the connecting region 80 (step 208). The second fold line 114 overlies or coincides with both the connecting portion second side 82 and a portion of the second surface edge 52. The second direction is opposed to the first direction, so that the folding operations of steps 206 and 208 result in the sheet 4 being folded generally into a U-shape in which the first recess 18 is aligned with the second recess 48, where

the “base” of the U corresponds to the connecting region, and the “legs” of the U correspond to the first and second flange portions 12, 14 (Fig. 9).

[0054] Optionally, following the folding operations of steps 206 and 208, the first and second pleats 40, 44 may be formed (steps 210, 212). This step is used for applications in which it is desirable to have a pouch cell 1 in which one end 3 of the cell 1 is free of flange material. The flange-free end 3 provides a stable cell support surface, as well as a surface through which the thermal conditions of the cell 1 can be efficiently managed. For applications in which having flange material that protrudes beyond the one end 3 of the cell has no negative consequences, steps 210, 212 may be omitted.

[0055] The first pleat 40 is formed in the first and second flange portions 12, 14 at a location corresponding to the third side 83 of the connecting region 80 (step 210). In particular, the first end portion 91 of the connecting region 80 is folded back on the first flange portion 12 at the connecting region third side 83, and the second end portion 92 of the connecting region 80 is folded back on the second flange portion 14 at the at the connecting region third side 83 in such a way that the first end portion 91 and the second end portion 92 are disposed between the first flange portion 12 and the second flange portion 14 (Figs. 11 and 12).

[0056] The second pleat 44 is formed in the first and second flange portions 12, 14 at a location corresponding to the fourth side 84 of the connecting region 80 (step 212). In particular, the third end portion 93 of the connecting region 80 is folded back on the first flange portion 12 at the connecting region fourth side 84, and the fourth end portion 94 of the connecting region 80 is folded back on the second flange portion 14 at the at the connecting region fourth side 84 in such a way that the third end portion 93 and the fourth end portion 94 are disposed between the first flange portion 12 and the second flange portion 14.

[0057] Following the pleat forming operations of steps 210 and 212, the first flange portion 12 is joined to the second flange portion along the seal line 110 so as to provide a closed sealed space within the cell 1 (step 214). The seal line 110 is formed by application of heat to one or both of the first and second flange portions 12, 14, and may be achieved, for example, by using by using a heat sealing device, welding, or other appropriate joining technique. In some embodiments, sealing is achieved in three linear sealing steps, one for each side of the recesses 18, 48 except side corresponding to the connecting portion 80. For example, a first sealing step (step 214a)

includes sealing a side of the housing that is opposed to the connecting portion 80, following by second and third sealing steps that include sealing the sides of the housing 2 that are perpendicular to the connecting portion 80 (sealing steps 214b, 214c). In some embodiments, the first sealing step 214a, in which the side of the housing opposed to the connecting portion 80 is sealed, may be performed prior to forming the pleats 40, 44 (Fig. 10), and the second and third sealing steps 214b, 214c are performed subsequent to forming the pleats (Fig. 13).

[0058] Since the sheet 4 is folded generally into a U-shape following the folding operations of steps 206 and 208, the first and second flange portions 12, 14 are generally aligned but spaced apart. Thus the sealing operation serves as a continuation of the sheet forming process since it serves to close the gap between the first and second flange portions 12, 14.

[0059] When the pleat forming operations are performed, the step of joining a first flange portion 12 to the second flange portion 14 includes extending the seal line 110 across both first pleat 40 and the second pleat 44. The resulting seal line 110 extends partially surrounds the housing 2. In some embodiments excess flange material (e.g., flange material disposed between the seal line and the case half peripheral edge) may be trimmed off (Fig. 14).

[0060] Prior to the joining and sealing operation described in step 214, the method includes providing the electrode assembly 120 (step 216) and disposing the electrode assembly 120 within an interior space of the cell housing 2 defined between the first recess 18 and the second recess 48. The electrode assembly is oriented within the cell housing 2 so that the stack axis 128 extends through the first and second endwalls 26, 56 of the recesses 18, 48 (Fig. 7).

[0061] In the assembled pouch cell 1, the electrode assembly 120 and an electrolyte are sealed within the interior space defined between the first and second recesses 18, 48. Other ancillary components and features, including current collectors, terminals, etc. that may also be included in the cell 1 are well known in the art and not described here.

[0062] Although the material used to form a pouch cell 1 is described as a flexible, three-layer, metal laminated film having a polypropylene layer, an aluminium foil layer, and a polyethylene layer, the material used to form the pouch cell 1 may have a greater or fewer number of layers and/or use different materials to form the layers. In one example, some batteries that are used in cell phones employ a pouch cell housing that has the following three layers which are joined by a thin adhesive between adjacent layers: oriented nylon/aluminium foil/polypropylene. In another

example, some batteries that are used in electric vehicles employ a pouch cell housing that has the following four layers which are joined by a thin adhesive between adjacent layers: polyethylene terephthalate/oriented nylon/aluminium foil/polypropylene.

[0063] Although the cells 20 are described herein as being lithium-ion cells, the cells 2 are not limited to having a lithium-ion chemistry. For example, the cells 2 may have other chemistries, including aluminum-ion, alkaline, nickel-cadmium, nickel metal hydride, or other appropriate chemistry.

[0064] In the illustrated embodiment, the positive electrodes 6, separators 8 and negative electrodes 10 are arranged in a stacked or layered configuration. It is understood, however, that the arrangement of the positive electrodes 6, separators 8 and negative electrodes 10 is not limited to a stacked configuration. For example, the positive electrodes 6, separators 8 and negative electrodes 10 may be provided in a Z-folded configuration, a rolled and flattened configuration, a cross-woven configuration, or any other suitable configuration.

[0065] Selective illustrative embodiments of the apparatus and method are described above in some detail. It should be understood that only structures considered necessary for clarifying the apparatus and method have been described herein. Other conventional structures, and those of ancillary and auxiliary components of the apparatus and method, are assumed to be known and understood by those skilled in the art. Moreover, while working examples of the apparatus and method have been described above, the apparatus and/or method is not limited to the working examples described above, but various design alterations may be carried out without departing from the devices as set forth in the claims.

We claim,

1. An electrochemical cell comprising a pouch cell housing and an electrode assembly disposed in the housing, wherein

the electrode assembly comprises a positive electrode, a negative electrode and a separator disposed between the positive electrode and the negative electrode, and the positive electrode, the separator and the negative electrode are stacked along a stack axis, and

the housing comprises a single sheet of a metal foil laminate material, and the sheet includes

a first sheet surface, a second sheet surface that is opposed to the first sheet surface, and a sheet peripheral edge that extends between the first sheet surface and the second sheet surface,

a first recess formed in the first sheet surface, the first recess being shaped and dimensioned to receive a first portion of the electrode assembly, the first recess including a first sidewall arranged to form a closed loop, the first sidewall having a first surface edge at the first sheet surface and a first endwall edge that is spaced apart from the first sheet surface, the first recess including a first endwall that is surrounded by the first sidewall, a peripheral edge of the first endwall being integral with the first endwall edge,

a second recess formed in the first sheet surface, the second recess being shaped and dimensioned to receive a second portion of the electrode assembly, the second recess including a second sidewall arranged to form a closed loop, the second sidewall having a second surface edge at the first sheet surface and a second endwall edge that is spaced apart from the first sheet surface, the second recess including a second endwall that is surrounded by the second sidewall, a peripheral edge of the second endwall being integral with the second endwall edge,
and

a connecting region disposed between the first recess and the second recess, the connecting region having

a first side that coincides with a portion of the first surface edge,
and

a second side that is parallel to the first side, the second side coinciding with a portion of the second surface edge,

and wherein

the first surface edge defines a first recess opening, the second surface edge defines a second recess opening,

the first recess opening faces the second recess opening,

the first recess opening is spaced apart from the second recess opening by a distance corresponding to a width of the connecting region, the width of the connecting region corresponding to a distance between the first side and the second side.

2. The electrochemical cell of claim 1, wherein the connecting region is coplanar with both a portion of the first sidewall and a portion of the second sidewall.

3. The electrochemical cell of claim 1, wherein the connecting region defines a plane that is parallel to the stack axis.

4. The electrochemical cell of claim 1, wherein the sheet includes a first flange portion that comprises an area that is bordered by the first recess, the sheet peripheral edge and the connecting region first side, and a second flange portion that comprises an area that is bordered by the second recess, the sheet peripheral edge and the connecting region second side, and wherein the first flange portion is joined to the second flange portion along a seal line.

5. The electrochemical cell of claim 4, wherein the first and second recesses each have a rectangular shape, and the seal line is a continuous line that extends along three sides of the first and second recesses.

6. The electrochemical cell of claim 4, wherein

the housing comprises a first pleat formed in the first and second flange portions at a location corresponding to one end of the connecting region,

the housing comprises a second pleat formed in the first and second flange portions at a location corresponding to an opposed end of the connecting region, where the opposed end is opposed to the one end,

the first pleat includes a first portion of the connecting region that is folded back on the first flange portion at the one end of the connecting region and a second portion of the connecting region that is folded back on the second flange portion at the one end of the connecting region, where the first portion and the second portion are disposed between the first flange portion and the second flange portion, and

the second pleat includes a third portion of the connecting region that is folded back on the first flange portion at the opposed end of the connecting region and a fourth portion of the connecting region that is folded back on the second flange portion at the opposed end of the connecting region, where the third portion and the fourth portion are disposed between the first flange portion and the second flange portion.

7. The electrochemical cell of claim 6, wherein the seal line extends across both the first pleat and the second pleat.

8. The electrochemical cell of claim 1, wherein the first recess is oriented relative to the second recess in such a way that the first end wall and the second end wall are parallel to each other and such that the first surface edge and the second surface edge are between the first end wall and the second end wall.

9. The electrochemical cell of claim 1, wherein the pouch cell housing has a housing height that is greater than twice the draw depth of the material used to form the pouch cell housing, where the housing height corresponds to a distance between the first endwall and the second endwall.

10. The electrochemical cell of claim 1, wherein the first sidewall and the second sidewall each define a rectangular loop.

11. The electrochemical cell of claim 1, wherein the metal foil laminate material comprises an aluminum foil layer that is sandwiched between polymer layers.

12. A method of forming an electrochemical cell having a pouch cell housing, the method steps comprising

providing a sheet of a metal foil laminate material, the sheet including a first sheet surface, a second sheet surface that is opposed to the first sheet surface, and a sheet peripheral edge that extends between the first sheet surface and the second sheet surface,

forming a first recess in the sheet at a location spaced apart from the peripheral edge, the first recess including a first sidewall arranged to form a closed loop, the first sidewall having a first surface edge at the first sheet surface and a first endwall edge that is spaced apart from the first sheet surface, the first recess including a first endwall that is surrounded by the first sidewall, a peripheral edge of the first endwall being integral with the first endwall edge,

forming a second recess in the sheet at a location spaced apart from the peripheral edge and from the first recess, whereby a connecting region is provided that is disposed between the first recess and the second recess, the second recess including a second sidewall arranged to form a closed loop, the second sidewall having a second surface edge at the first sheet surface and a second endwall edge that is spaced apart from the first sheet surface, the second recess including a second endwall that is surrounded by the second sidewall, a peripheral edge of the second endwall being integral with the second endwall edge, the connecting region including a first side that coincides with a portion of the first surface edge, and a second side that is parallel to the first side, the second side coinciding with a portion of the second surface edge,

folding the sheet in a first direction along a first fold line until a portion of the first sidewall is aligned with the connecting region, where the first fold line overlies the first side,

folding the sheet in a second direction along a second fold line until a portion of the second sidewall is aligned with the connecting region and the first recess is aligned with the second recess, where the second fold line overlies the second side, and the second direction is opposed to the first direction, and

joining a first flange portion of the sheet to the second flange portion of the sheet along a seal line so as to provide a closed sealed space within the cell, where the first flange portion comprises an area that is bordered by the first recess, the sheet peripheral edge and the

connecting region first side, and the second flange portion comprises an area that is bordered by the second recess, the sheet peripheral edge and the connecting region second side.

13. The method of claim 12, comprising the steps of

forming a first pleat in the first and second flange portions at a location corresponding to one end of the connecting region, where the first pleat includes a first portion of the connecting region that is folded back on the first flange portion at the one end of the connecting region and a second portion of the connecting region that is folded back on the second flange portion at the one end of the connecting region, where the first portion and the second portion are disposed between the first flange portion and the second flange portion, and

forming a second pleat in the first and second flange portions at a location corresponding to an opposed end of the connecting region, where the opposed end is opposed to the one end and where the second pleat includes a third portion of the connecting region that is folded back on the first flange portion at the opposed end of the connecting region and a fourth portion of the connecting region that is folded back on the second flange portion at the opposed end of the connecting region, where the third portion and the fourth portion are disposed between the first flange portion and the second flange portion.

14. The method of claim 13, wherein the step of joining a first flange portion of the sheet to the second flange portion of the sheet along a seal line comprises extending the seal line across both first pleat and the second pleat.

15. The method of claim 12, comprising the steps of

providing an electrode assembly that comprises a positive electrode, a negative electrode and a separator disposed between the positive electrode and the negative electrode, and the positive electrode, the separator and the negative electrode are stacked along a stack axis, and

prior to the step of joining a first flange portion of the sheet to the second flange portion of the sheet along a seal line, disposing the electrode assembly within an interior space of the cell defined between the first recess and the second recess.

16. The method of claim 12, wherein the connecting region serves to space the first recess apart from the second recess both before and after the steps of folding the sheet in a first direction along a first fold line and folding the sheet in a second direction along a second fold line.

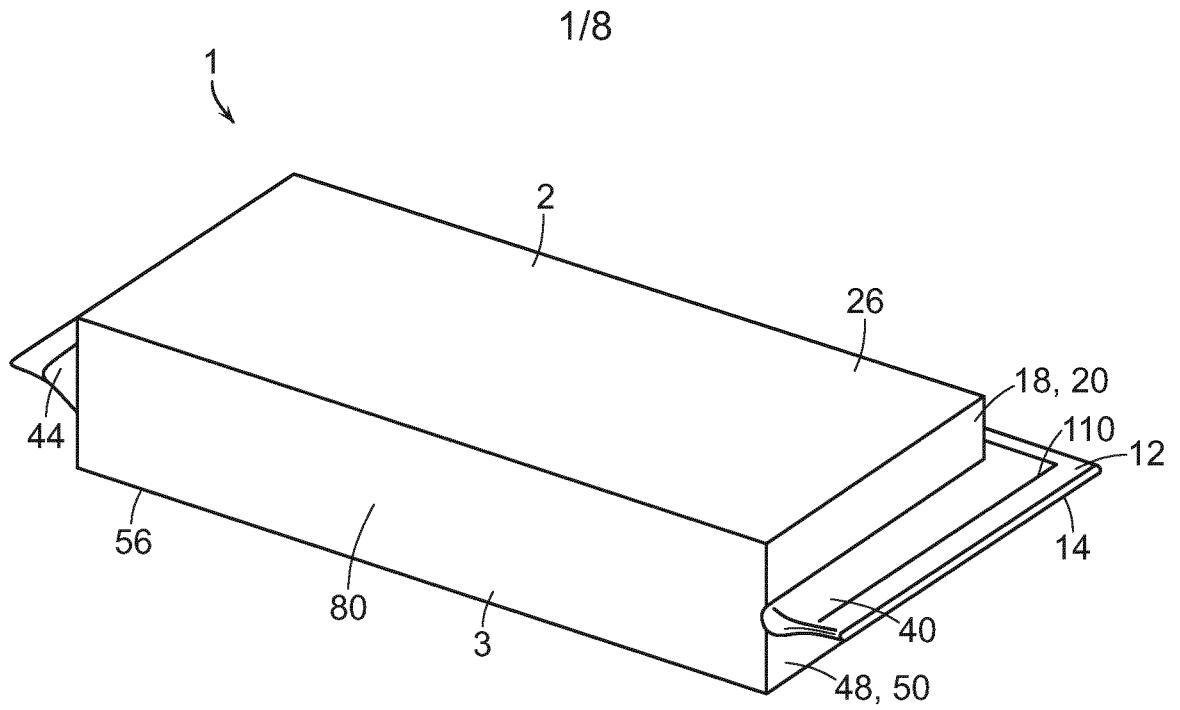


FIG. 1

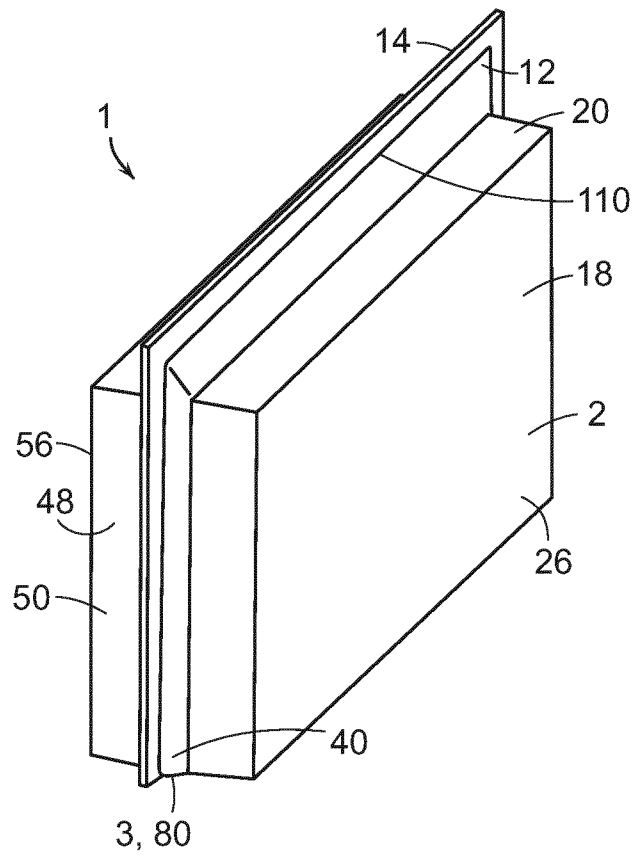


FIG. 2

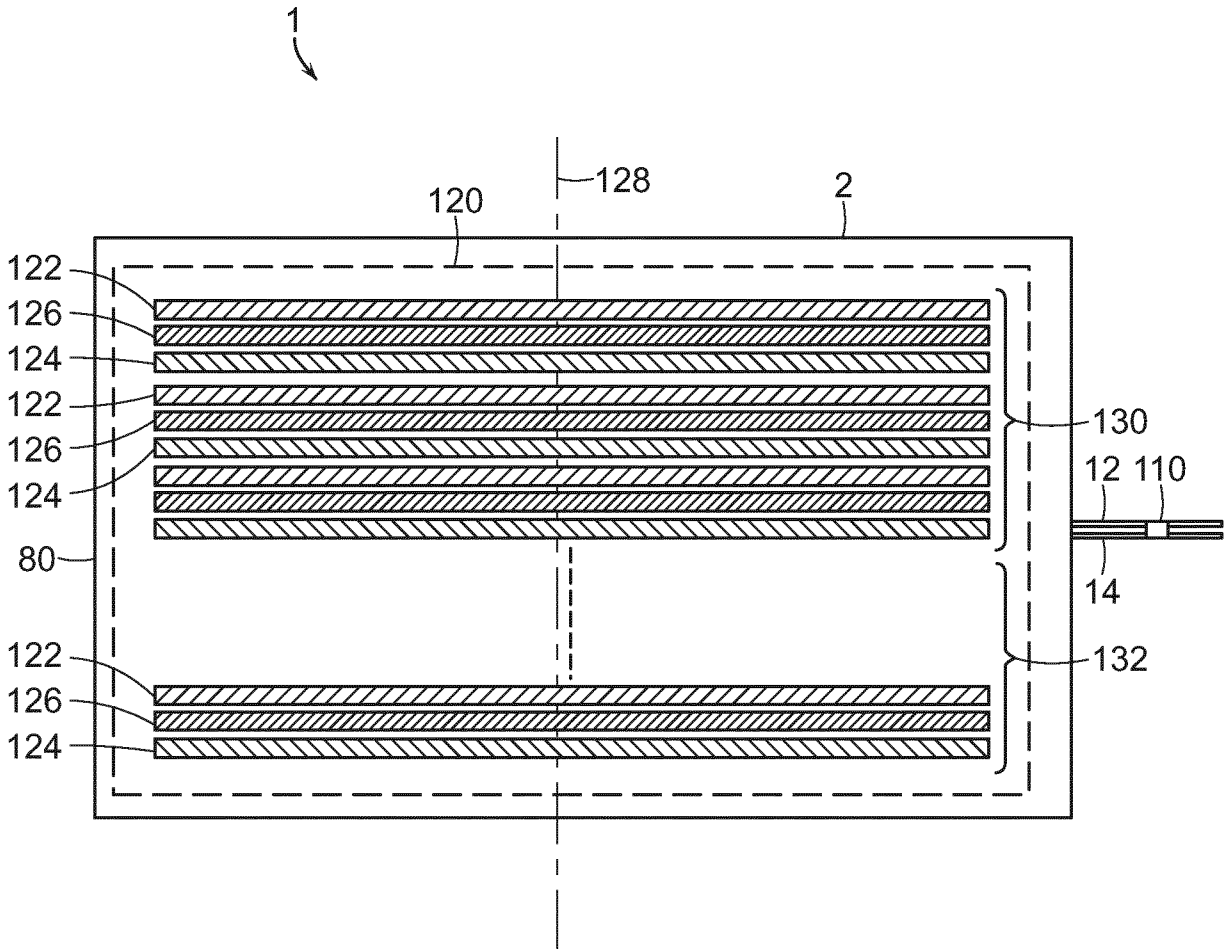


FIG. 3

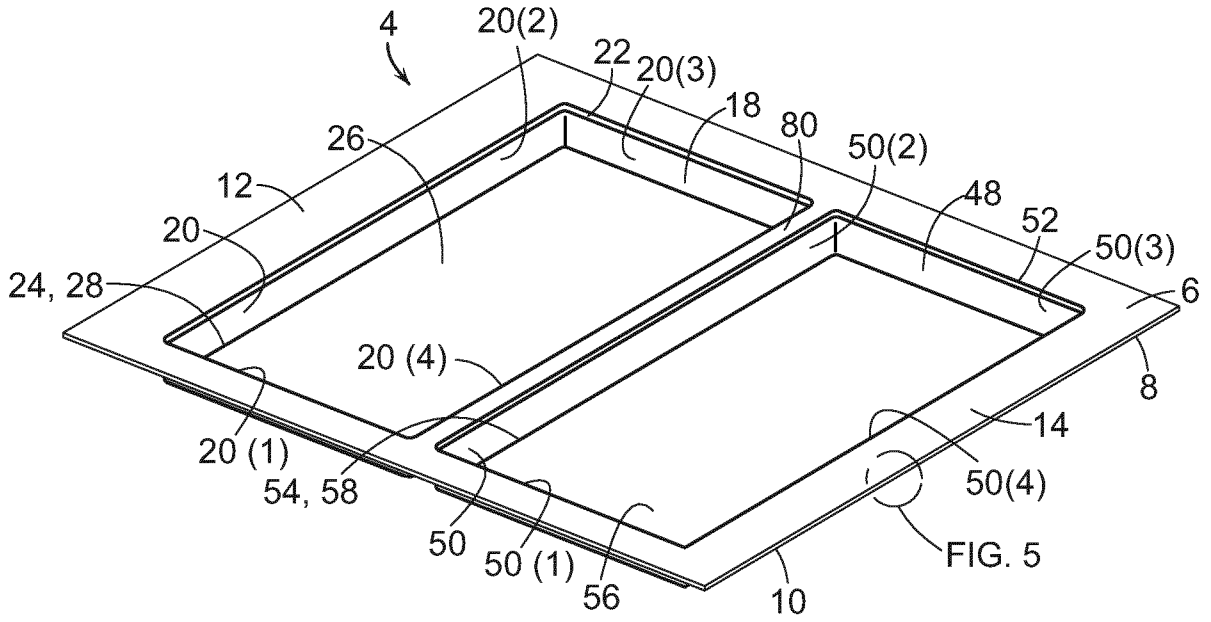


FIG. 4

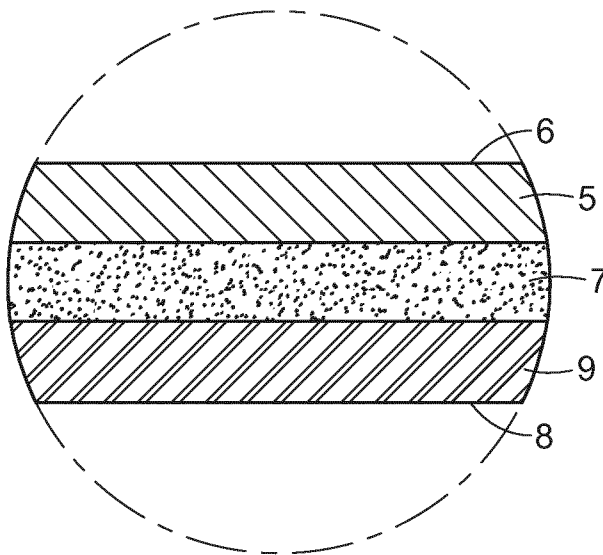


FIG. 5

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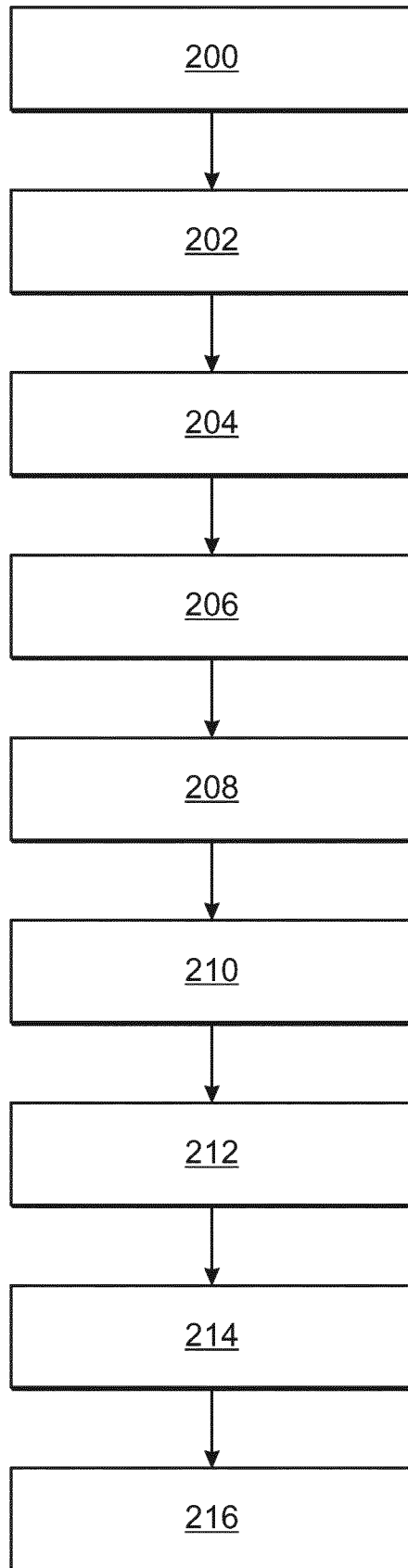


FIG. 8

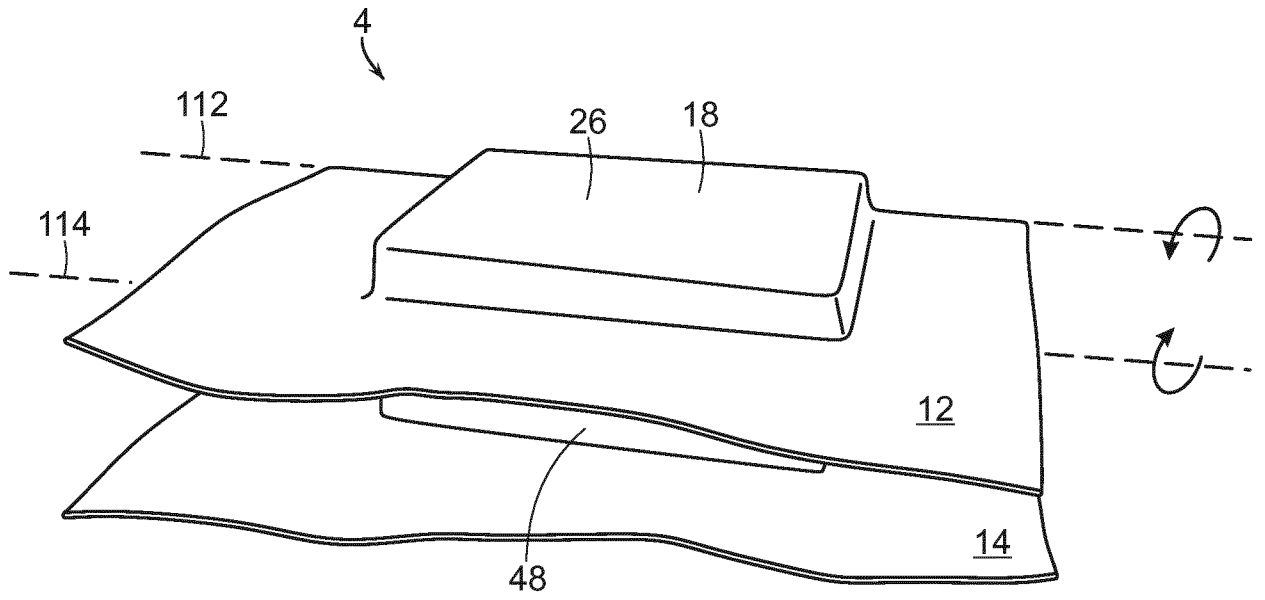


FIG. 9

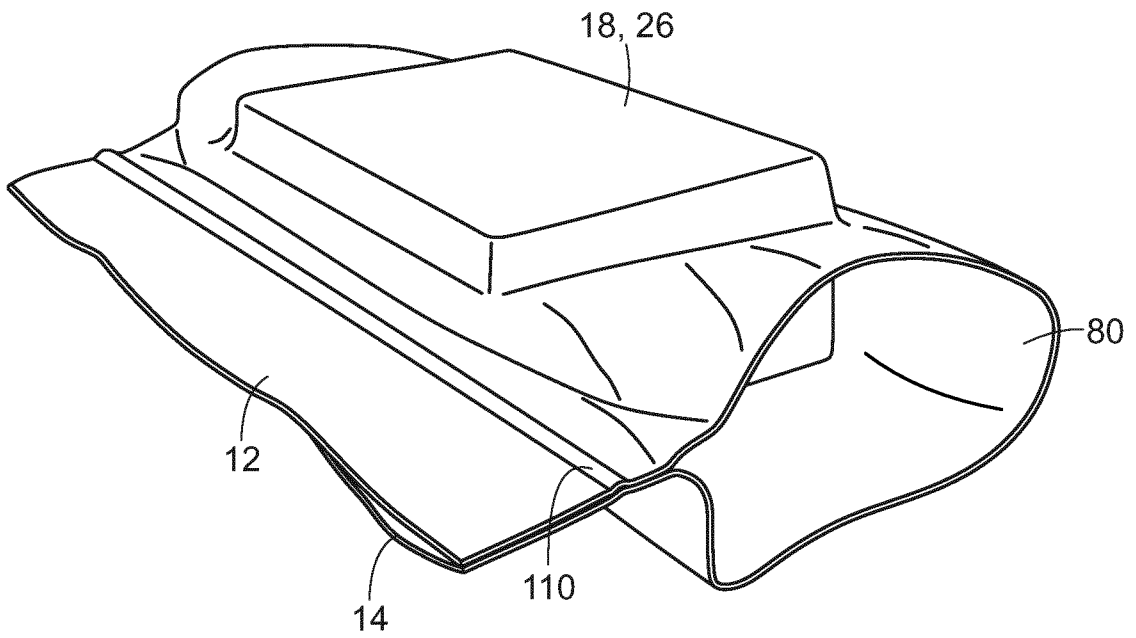


FIG. 10

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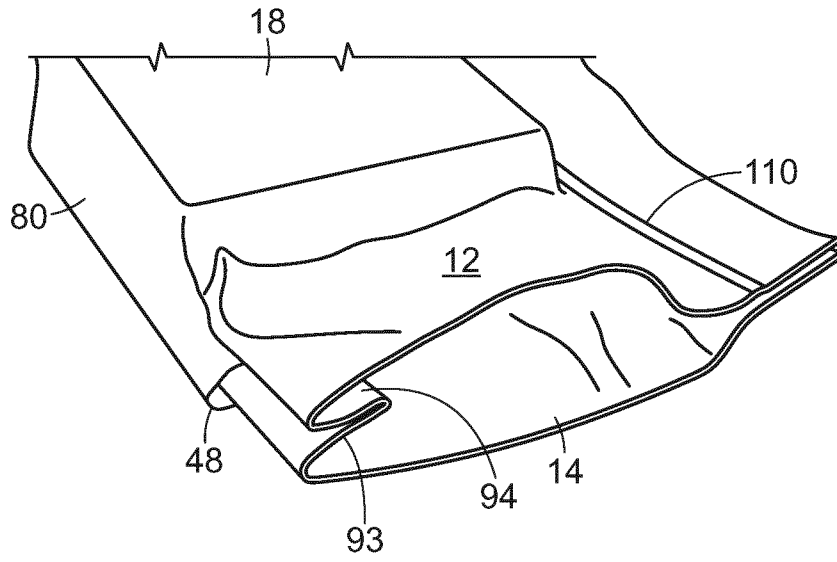


FIG. 11

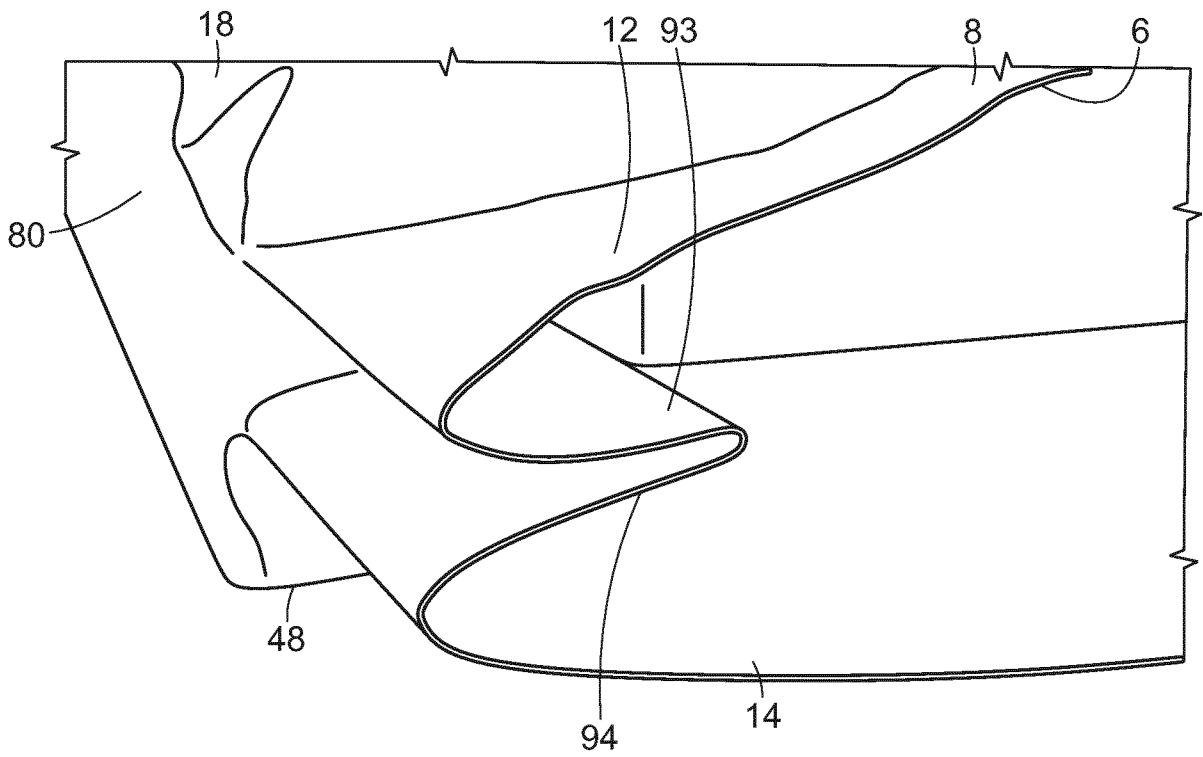


FIG. 12

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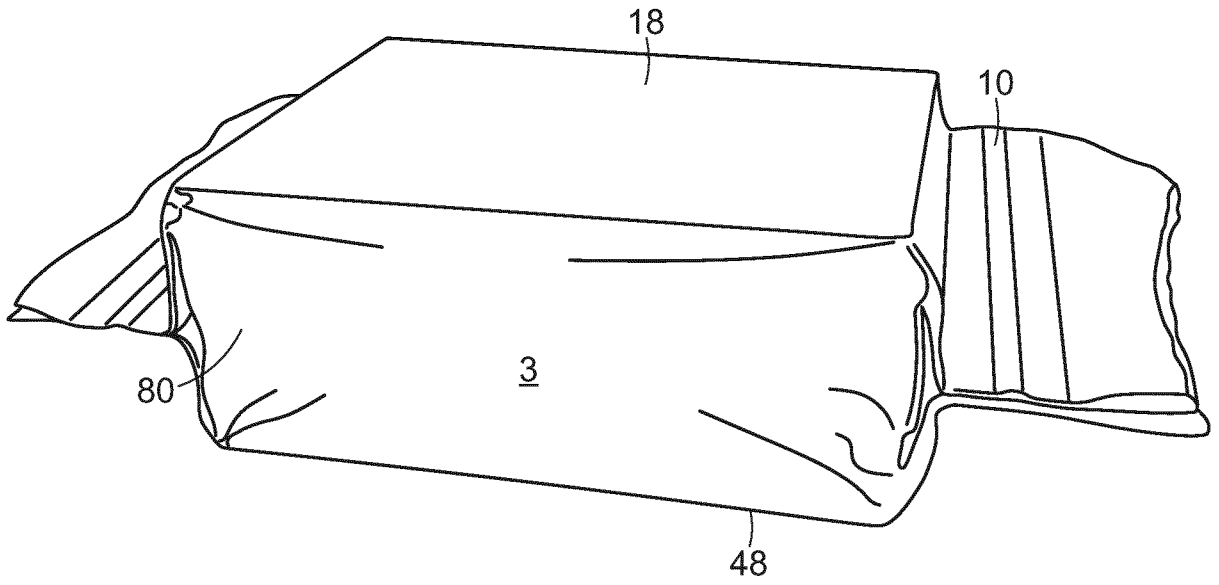


FIG. 13

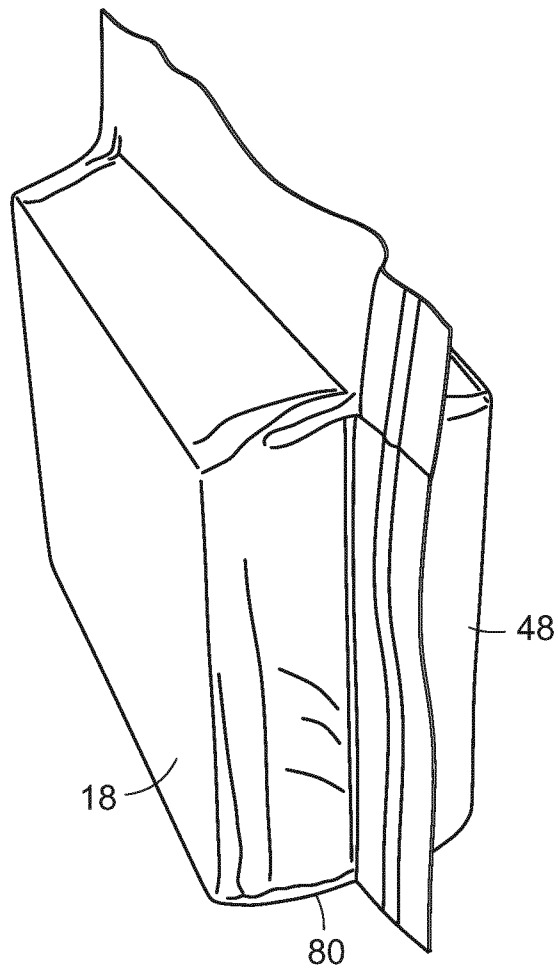


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/084790

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M2/02
ADD.

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

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/101894 A1 (BABA MAMORU [JP] ET AL) 25 April 2013 (2013-04-25)	1-5, 8-12,15, 16
Y	the whole document	6,7,13, 14
Y	----- US 2 998 178 A (JACKE RAYMOND E) 29 August 1961 (1961-08-29) figures 4,6,10 -----	6,7,13, 14

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
6 February 2019

Date of mailing of the international search report
15/02/2019

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Cappadonia, Marcella

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2018/084790

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013101894	A1	CN 103066218 A	24-04-2013
		US 2013101894 A1	25-04-2013

US 2998178	A	NONE	
