

What is claimed is:

1. ~~1.~~ 4. A secondary battery for cycling between a charged and a discharged state, the secondary battery comprising a battery enclosure ~~and~~, an electrode assembly, and carrier ions, ~~and electrode and counter-electrode busbars for collecting current from the electrode assembly~~ within the battery enclosure, and a set of electrode constraints, wherein:

\_\_\_\_\_ (a) the electrode assembly has mutually perpendicular transverse, longitudinal and vertical axes corresponding to the x, y and z axes, respectively, of an imaginary three-dimensional cartesian coordinate system, a first longitudinal end surface and a second longitudinal end surface separated from each other in the longitudinal direction, and a lateral surface surrounding an electrode assembly longitudinal axis  $A_{EA}$  and connecting the first and second longitudinal end surfaces, the lateral surface having opposing first and second regions on opposite sides of the longitudinal axis and separated in a first direction that is orthogonal to the longitudinal axis, the electrode assembly having a maximum width  $W_{EA}$ —measured in the longitudinal direction, a maximum length  $L_{EA}$  bounded by the lateral surface and measured in the transverse direction, and a maximum height  $H_{EA}$  bounded by the lateral surface and measured in the vertical direction, wherein the maximum length  $L_{EA}$  and/or maximum width  $W_{EA}$  is greater than the maximum height  $H_{EA}$ ,

\_\_\_\_\_ (b) the electrode assembly further comprises a population of electrode structures, a population of electrode current collectors, a population of separators that are ionically permeable to the carrier ions, a population of counter-electrode structures, a population of counter-electrode collectors, and a population of unit cells wherein

\_\_\_\_\_ (i) members of the electrode and counter-electrode structure populations are arranged in an alternating sequence in the longitudinal direction,

\_\_\_\_\_ (ii) each member of the population of electrode structures comprises a layer of an electrode active material having a length  $L_E$ —that corresponds to the Feret diameter of the electrode active material layer as measured in the transverse direction between first and second opposing transverse end surfaces of the electrode active material layer, and a height  $H_E$ — $H_{EA}$  that corresponds to the Feret diameter of the electrode active material layer as measured in the vertical direction between first and second opposing vertical end surfaces of the electrode active

material layer, and a width  $W_E$  that corresponds to the Feret diameter of the electrode active material layer as measured in the longitudinal direction between first and second opposing surfaces of the electrode active material layer, and each member of the population of counter-electrode structures comprises a layer of a counter-electrode active material having a length  $L_C$  that corresponds to the Feret diameter of the counter-electrode active material layer as measured in the transverse direction between first and second opposing transverse end surfaces of the counter-electrode active material layer, and a height  $H_C$  that corresponds to the Feret diameter of the counter-electrode active material layer as measured in the vertical direction between first and second opposing vertical end surfaces of the counter-electrode active material layer, and a width  $W_C$  that corresponds to the Feret diameter of the counter-electrode active material layer as measured in the longitudinal direction between first and second opposing surfaces of the counter-electrode active material layer,

\_\_\_\_\_ (iii) each unit cell comprises a unit cell portion of a first member of the electrode current collector ~~of the electrode current collector population, a first electrode active material layer of one member of the electrode population, a member of the separator population that is ionically permeable to the carrier ions, a first ~~counter-electrode active material layer of one member of the counter-electrode population, and~~ a unit cell portion of a first member of the counter-electrode current collector ~~of the population and a first counter-electrode current collector~~ active material layer of one member of the counter-electrode population, wherein (aa) the first electrode active material layer is proximate a first side of the separator and the first counter-electrode material layer is proximate an opposing second side of the separator, ~~and~~ (bb) the separator electrically isolates the first electrode active material layer from the first counter-electrode active material layer, and carrier ions are primarily exchanged between the first electrode active material layer and the first counter-electrode active material layer via the separator of each such unit cell during cycling of the battery between the charged and discharged state, ~~(ee and (cc) within each unit cell,~~~~

\_\_\_\_\_ a. the first vertical end surfaces of the electrode and the counter-electrode active material layers are on the same side of the electrode assembly, a 2D map of the median vertical position of the first opposing vertical end surface of the electrode active material in the X-Z plane, along the length  $L_E$  of the electrode active material layer, traces a first vertical end surface plot,  $E_{VP1}$ , a 2D map of the median vertical position of the first opposing vertical end surface of the counter-

electrode active material layer in the X-Z plane, along the length  $L_C$  of the counter-electrode active material layer, traces a first vertical end surface plot,  $CE_{VP1}$ , wherein for at least 60% of the length  $L_C$  of the first counter-electrode active material layer (i) the absolute value of a separation distance,  $S_{Z1}$ , between the plots  $E_{VP1}$  and  $CE_{VP1}$  measured in the vertical direction is  $1000\text{ }\mu\text{m} \geq |S_{Z1}| \geq 5\text{ }\mu\text{m}$ , and (ii) as between the first vertical end surfaces of the electrode and counter-electrode active material layers, the first vertical end surface of the counter-electrode active material layer is inwardly disposed with respect to the first vertical end surface of the electrode active material layer.

b. the second vertical end surfaces of the electrode and counter-electrode active material layer are on the same side of the electrode assembly, and oppose the first vertical end surfaces of the electrode and counter-electrode active material layers, respectively, a 2D map of the median vertical position of the second opposing vertical end surface of the electrode active material layer in the X-Z plane, along the length  $L_E$  of the electrode active material layer, traces a second vertical end surface plot,  $E_{VP2}$ , a 2D map of the median vertical position of the second opposing vertical end surface of the counter-electrode active material layer in the X-Z plane, along the length  $L_C$  of the counter-electrode active material layer, traces a second vertical end surface plot,  $CE_{VP2}$ , wherein for at least 60% of the length  $L_C$  of the counter-electrode active material layer (i) the absolute value of a separation distance,  $S_{Z2}$ , between the plots  $E_{VP2}$  and  $CE_{VP2}$  as measured in the vertical direction is  $1000\text{ }\mu\text{m} \geq |S_{Z2}| \geq 5\text{ }\mu\text{m}$ , and (ii) as between the second vertical end surfaces of the electrode and counter-electrode active material layers, the second vertical end surface of the counter-electrode active material layer is inwardly disposed with respect to the second vertical end surface of the electrode active material layer.

(c) the set of electrode constraints comprises a primary constraint system comprising first and second primary growth constraints and at least one primary connecting member, the first and second primary growth constraints separated from each other in the longitudinal direction, and the at least one primary connecting member connecting the first and second primary growth constraints, wherein the primary constraint system restrains growth of the electrode assembly in the longitudinal direction such that any increase in the Feret diameter of the electrode assembly in the longitudinal direction over 20 consecutive cycles of the secondary battery is less than 20%.

2. The secondary battery according to claim 1, wherein within each unit cell,

c. the first transverse end surfaces of the electrode and counter-electrode active material layers are on the same side of the electrode assembly, a 2D map of the median transverse position of the first opposing transverse end surface of the electrode active material layer in the X-Z plane, along the height  $H_{EA}$  of the electrode active material layer, traces a first transverse end surface plot,  $E_{TP1}$ , a 2D map of the median transverse position of the first opposing transverse end surface of the counter-electrode in the X-Z plane, along the height  $H_C$  of the counter-electrode active material layer, traces a first transverse end surface plot,  $CE_{TP1}$ , wherein for at least 60% of the height  $H_C$  of the counter electrode active material layer (i) the absolute value of a separation distance,  $S_{X1}$ , between the plots  $E_{TP1}$  and  $CE_{TP1}$  measured in the transverse direction is  $1000\ \mu\text{m} \geq |S_{X1}| \geq 5\ \mu\text{m}$ , and (ii) as between the first transverse end surfaces of the electrode and counter-electrode active material layers, the first transverse end surface of the counter-electrode active material layer is inwardly disposed with respect to the first transverse end surface of the electrode active material layer, and

d. the second transverse end surfaces of the electrode and counter-electrode active material layers are on the same side of the electrode assembly, and oppose the first transverse end surfaces of the electrode and counter-electrode active material layers, respectively, a 2D map of the median transverse position of the second opposing transverse end surface of the electrode active material layer in the X-Z plane, along the height  $H_E$  of the electrode active material layer, traces a second transverse end surface plot,  $E_{TP2}$ , a 2D map of the median transverse position of the second opposing transverse end surface of the counter-electrode in the X-Z plane, along the height  $H_C$  of the counter-electrode active material layer, traces a second transverse end surface plot,  $CE_{TP2}$ , wherein for at least 60% of the height  $H_C$  of the counter-electrode active material layer (i) the absolute value of a separation distance,  $S_{X2}$ , between the plots  $E_{TP2}$  and  $CE_{TP2}$  measured in the transverse direction is  $1000\ \mu\text{m} \geq |S_{X2}| \geq 5\ \mu\text{m}$ , and (ii) as between the second transverse end surfaces of the electrode and counter-electrode active material layers, the second transverse end surface of the counter-electrode active material layer is inwardly disposed with respect to the second transverse end surface of the electrode active material layer.

3. The secondary battery according to claim 1, wherein the electrode assembly further comprises one or more carrier ion insulating material layers, each electrode current collector of the population is electrically isolated from each counter-electrode active material layer of the population, and each counter-electrode current collector of the population is electrically isolated from each electrode active material layer of the population, and within each unit cell,

the one or more carrier ion insulating material layers have an ionic conductance of carrier ions that does not exceed 10% of the ionic conductance of the separator of carrier ions during cycling of the battery, and ionically insulate at least a portion of a surface of the electrode current collector layer from the electrolyte that is proximate to one or more of the first and second vertical end surfaces of the electrode active material layer.

4. The secondary battery according to claim 1, wherein the electrode assembly further comprises one or more carrier ion insulating material layers,

each electrode current collector of the population is electrically isolated from each counter-electrode active material layer of the population, and each counter-electrode current collector of the population is electrically isolated from each electrode active material layer of the population, and

within each unit cell,

the one or more carrier ion insulating material layers have an ionic conductance of carrier ions that does not exceed 10% of the ionic conductance of the separator of carrier ions during cycling of the battery, and ionically insulate at least a portion of a surface of the electrode current collector layer from the electrolyte that is proximate to one or more of and within a distance  $D_{CC}$  of (i) the first and second transverse end surfaces surface of the electrode active material layer.

5. The secondary battery according to claim 1, wherein:

(d) for each unit cell, (i) the first member of the electrode current collector population extends at least partially along the length  $L_E$  of the electrode active material layer in the transverse direction and comprises an electrode current collector end that extends past the first transverse end surface of the counter-electrode active material layer of each such unit cell, and (ddii) the counter-electrode current collector extends at least partially along the length  $L_C$  of the counter-electrode active material layer in the transverse direction and comprises a counter-electrode current collector end that extends past the second transverse end surface of the electrode active material layer in the transverse direction of each such unit cell, and

(e) the secondary battery further comprises at least one of:

\_\_\_\_\_ (e)(i) ~~the~~an electrode busbar ~~comprises~~comprising at least one conductive segment configured to electrically connect to the population of electrode current collectors, and extending in the longitudinal direction of the electrode assembly, the conductive segment comprising a first side having an interior surface facing the first transverse end surfaces of the counter-electrode active material layers, and an opposing second side having an exterior surface, the conductive segment optionally comprising a plurality of apertures spaced apart on along the longitudinal direction, the conductive segment of the electrode bus bar being arranged with respect to the electrode current collector ends such that the electrode current collector ends extend at least partially past a thickness of the conductive segment, to electrically connect thereto, the thickness of the conductive segment being measured between the interior and exterior surfaces, and

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\_\_\_\_\_ (e)(ii) ~~the~~a counter-electrode busbar ~~comprises~~comprising at least one conductive segment configured to electrically connect to the population of counter-electrode current collectors, and extending in the longitudinal direction of the electrode assembly, the conductive segment comprising a first side having an interior surface facing the second transverse end surfaces of the electrode active material layers, and an opposing second side having an exterior surface, the conductive segment optionally comprising a plurality of apertures spaced apart on along the longitudinal direction, the conductive segment of the counter-electrode bus bar being arranged with respect to the counter-electrode current collector ends such that the counter-electrode current collector ends extend at least partially past a thickness of the conductive segment, to electrically connect thereto, the thickness of the conductive segment being measured between the interior and exterior surfaces.

2.

6. \_\_\_\_\_ The secondary battery according to- claim 5, wherein in the case of the electrode busbar (i) the conductive segment comprises a plurality of apertures spaced apart along the longitudinal direction, wherein each of the plurality of apertures are configured to allow one or more electrode current collector ends to extend at least partially therethrough to electrically connect the one or more electrode current collector ends to the electrode busbar, and wherein in the case of the counter-electrode busbar (ii) the conductive segment comprises a plurality of apertures spaced apart along the longitudinal direction, wherein each of the plurality of apertures are configured to allow one or more counter-electrode current collector ends to extend at least partially therethrough to electrically connect the one or more counter-electrode current collector ends to the counter-electrode busbar.

7. The secondary battery according to claim 1, further comprising a wherein the electrode structures of the population of electrode structures comprise negative electrodes, and the counter-electrode structures of the population of counter-electrode structures comprise positive electrodes.
8. The secondary battery according to claim 1, wherein the electrode the electrode structures of the population of electrode structures comprise positive electrodes, and the counter-electrode structures of the population of counter-electrode structures comprise negative electrodes.
9. The secondary battery according to claim 1, wherein the set of electrode constraints, wherein the set of electrode constraints further comprises a primarysecondary constraint system comprising first and second primarysecondary growth constraints separated in a second direction and connected by at least one primarysecondary connecting member, wherein the secondary constraint system at least partially restrains growth of the electrode assembly in the second direction upon cycling of the secondary battery, the second direction being orthogonal to the longitudinal direction.
10. The secondary battery according to claim 9, wherein the first and second primarysecondary growth constraints are separated from each other in the longitudinalvertical direction, and connected by the at least one primarysecondary connecting member connecting, and wherein the secondary constraint system at least partially restrains growth of the electrode assembly in the vertical direction upon cycling of the secondary battery.
11. The secondary battery according to claim 9, wherein the first and second primary growthsecondary growth constraints are separated in the transverse direction and connected by the at least one secondary connecting member, and wherein the secondary constraint system at least partially restrains growth of the electrode assembly in the transverse direction upon cycling of the secondary battery.
12. The secondary battery according to claim 9, wherein the electrode active material has the capacity to accept more than one mole of carrier ion per mole of electrode active material when the secondary battery is charged from the discharged state to the charged state, and wherein the

at least one secondary member maintains the first and second secondary constraints in tension with each other, the at least one secondary member comprising a portion of one or more electrode current collectors of the electrode current collector population.

13. The secondary battery according to claim 9, wherein the primary electrode active material has the capacity to accept more than one mole of carrier ion per mole of electrode active material when the secondary battery is charged from the discharged state to the charged state, and wherein the at least one secondary member maintains the first and second secondary constraints in tension with each other, the at least one secondary member comprising a portion of one or more counter-electrode current collectors of the counter-electrode current collector population.
14. The secondary battery according to claim 9, wherein the electrode active material has the capacity to accept more than one mole of carrier ion per mole of electrode active material when the secondary battery is charged from the discharged state to the charged state, and wherein the at least one secondary member maintains the first and second secondary constraints in tension with each other, the at least one secondary member comprising a portion of one or more electrode current collectors of the electrode current collector population, one or more counter-electrode current collectors of the counter-electrode current collector population, and one or more separators of the population of separators.
15. The secondary battery according to claim 9, wherein the at least one secondary member connecting the first and second secondary growth constraints inhibits buckling of the first and second secondary growth constraints upon cycling of the secondary battery.
16. The secondary battery according to claim 9, wherein the electrode current collector and/or counter-electrode current collector comprise attachment sections configured to secure the electrode current collector and/or counter-electrode current collector to a portion of the electrode constraint system that is configured to constrain growth of the electrode assembly in the vertical direction, and wherein the attachment sections of at least one of the electrode and counter-electrode current collectors comprise a portion of a secondary connecting member of the electrode constraint system that attaches to the first and second secondary growth constraints to at least partially restrain growth of the electrode assembly in the vertical direction, and wherein the attachment sections each comprise any one or combination of a textured surface, openings

extending through the vertical ends in the longitudinal direction, grooves, protrusions, and indentations.

17. The secondary battery according to claim 9, wherein the secondary growth constraint system restrains growth of the electrode assembly in the longitudinalsecond direction such that any increase in the Feret diameter of the electrode assembly in the longitudinalsecond direction over 20 consecutive cycles upon repeated cycling of the secondary battery is less than 20%.

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18. The secondary battery according to ~~any preceding~~ claim 9, wherein ~~each~~the secondary constraint system restrains growth of the electrode assembly in the vertical direction with a restraining force of greater than 1000 psi and a skew of less than 0.2 mm/m.

19. The secondary battery according to claim 9, wherein members of the population of unit cellcells of the unit-cell population comprises a carrier ionsecondary battery further comprise:

electrically insulating and non-ionically permeable insulators between the first and second vertical surfaces of the counter-electrode active material layer, ~~having an ionic conductance that does not exceed 10% of and the ionic conductance of the separator of carrier ions during cycling of the~~first and second secondary growth constraints.

20. The secondary battery, ~~and~~ according to claim 1, wherein the secondary battery comprises a carrier ion insulating material layer that ionically insulates a surface of the electrode current collector layer from the electrolyte, and wherein the carrier ion insulating material comprises at least one of a ceramic, polymer, glass, adhesive, and combinations and/or composites thereof.

4.

21. The secondary battery according to claim 1, wherein the ratio of each of  $L_{EA}$  and  $W_{EA}$  to  $H_{EA}$  is at least 2:1, respectively.

22. The secondary battery according to claim 1, wherein the electrode active material layer comprises anode active material selected from the group consisting of graphite, tin, lead, magnesium, aluminum, boron, gallium, silicon, Si/C composites, Si/graphite blends, SiOx, porous Si, intermetallic Si alloys, indium, zirconium, germanium, bismuth, cadmium, antimony, silver,

zinc, arsenic, hafnium, yttrium, lithium, sodium, graphite, carbon, lithium titanate, palladium, and mixtures thereof.

23. The secondary battery according to claim 1, wherein the secondary battery comprises an insulator extending over the first and second transverse surfaces of the counter-electrode active material layer.

24. The secondary battery according to claim 1, wherein the secondary battery comprises a carrier ion insulating material comprising (i) a coating that at least partially covers surfaces adjacent vertical ends of the electrode and/or counter-electrode current collectors that extend vertically past the first and/or second vertical end surfaces of adjacent electrode and/or counter-electrode active material layers, to ionically insulate the surfaces from electrolyte, and/or (ii) a coating that at least partially covers surfaces adjacent transverse ends of the electrode and/or counter-electrode current collectors that extend in a transverse direction past the first and/or second transverse end surfaces of adjacent electrode and/or counter-electrode active material layers, to ionically insulate the surfaces electrolyte.

25. A secondary battery for cycling between a charged and a discharged state, the secondary battery comprising a battery enclosure, an electrode assembly, and carrier ions within the battery enclosure, and a set of electrode constraints, wherein

\_\_\_\_\_ (a) the electrode assembly has mutually perpendicular transverse, longitudinal and vertical axes corresponding to the x, y and z axes, respectively, of an imaginary three-dimensional cartesian coordinate system, a first longitudinal end surface and a second longitudinal end surface separated from each other in the longitudinal direction, and a lateral surface surrounding an electrode assembly longitudinal axis  $A_{EA}$  and connecting the first and second longitudinal end surfaces, the lateral surface having opposing first and second regions on opposite sides of the longitudinal axis and separated in a first direction that is orthogonal to the longitudinal axis, the electrode assembly having a maximum width  $W_{EA}$ —measured in the longitudinal direction, a maximum length  $L_{EA}$  bounded by the lateral surface and measured in the transverse direction, and a maximum height  $H_{EA}$  bounded by the lateral surface and measured in the vertical direction, wherein the maximum length  $L_{EA}$  and/or the maximum width  $W_{EA}$  is greater than the maximum height  $H_{EA}$ .

\_\_\_\_\_ (b) the electrode assembly further comprises a population of electrode structures, a population of electrode current collectors, a population of separators that are ionically permeable to the carrier ions, a population of counter-electrode structures, a population of counter-electrode collectors, and a population of unit cells wherein

\_\_\_\_\_ (i) members of the electrode and counter-electrode structure populations are arranged in an alternating sequence in the longitudinal direction,

\_\_\_\_\_ (ii) each member of the population of electrode structures comprises a layer of an electrode active material having a length  $L_E$  that corresponds to the Feret diameter of the electrode active material layer as measured in the transverse direction between first and second opposing transverse end surfaces of the electrode active material layer, and a height  $H_E$  that corresponds to the Feret diameter of the electrode active material layer as measured in the vertical direction between first and second opposing vertical end surfaces of the electrode active material layer, and a width  $W_E$  that corresponds to the Feret diameter of the electrode active material layer as measured in the longitudinal direction between first and second opposing surfaces of the electrode active material layer, and each member of the population of counter-electrode structures comprises a layer of a counter-electrode active material having a length  $L_C$  that corresponds to the Feret diameter of the counter-electrode active material layer as measured in the transverse direction between first and second opposing transverse end surfaces of the counter-electrode active material layer, and a height  $H_C$  that corresponds to the Feret diameter of the counter-electrode active material layer as measured in the vertical direction between first and second opposing vertical end surfaces of the counter-electrode active material layer, and a width  $W_C$  that corresponds to the Feret diameter of the counter-electrode active material layer as measured in the longitudinal direction between first and second opposing surfaces of the counter-electrode active material layer,

\_\_\_\_\_ (iii) each unit cell comprises a unit cell portion of a first member of the electrode current collector population, a member of the separator population that is ionically permeable to the carrier ions, a first electrode active material layer of one member of the electrode population, a unit cell portion of a first member of the counter-electrode current collector population and a first counter-electrode active material layer of one member of the counter-electrode population, wherein (aa) the first electrode active material layer is proximate a first side of the separator and the first counter-electrode material layer is proximate an opposing second side of the separator,

(bb) the separator electrically isolates the first electrode active material layer from the first counter-electrode active material layer and carrier ions are primarily exchanged between the first electrode active material layer and the first counter-electrode active material layer via the separator of each such unit cell during cycling of the battery between the charged and discharged state, and (cc) within each unit cell,

a-           a. the first transverse end surfaces of the electrode and counter-electrode active material layers are on the same side of the electrode assembly, a 2D map of the median transverse position of the first opposing transverse end surface of the electrode active material layer in the X-Z plane, along the height  $H_E$  of the electrode active material layer, traces a first transverse end surface plot,  $E_{TP1}$ , a 2D map of the median transverse position of the first opposing transverse end surface of the counter-electrode in the X-Z plane, along the height  $H_C$  of the counter-electrode active material layer, traces a first transverse end surface plot,  $CE_{TP1}$ , wherein for at least 60% of the height  $H_C$  of the counter electrode active material layer (i) the absolute value of a separation distance,  $S_{X1}$ , between the plots  $E_{TP1}$  and  $CE_{TP1}$  measured in the transverse direction is  $1000\text{ }\mu\text{m} \geq |S_{X1}| \geq 5\text{ }\mu\text{m}$ , and (ii) as between the first transverse end surfaces of the electrode and counter-electrode active material layers, the first transverse end surface of the counter-electrode active material layer is inwardly disposed with respect to the first transverse end surface of the electrode active material layer,

b-           b. the second transverse end surfaces of the electrode and counter-electrode active material layers are on the same side of the electrode assembly, and oppose the first transverse end surfaces of the electrode and counter-electrode active material layers, respectively, a 2D map of the median transverse position of the second opposing transverse end surface of the electrode active material layer in the X-Z plane, along the height  $H_E$  of the electrode active material layer, traces a second transverse end surface plot,  $E_{TP2}$ , a 2D map of the median transverse position of the second opposing transverse end surface of the counter-electrode in the X-Z plane, along the height  $H_C$  of the counter-electrode active material layer, traces a second transverse end surface plot,  $CE_{TP2}$ , wherein for at least 60% of the height  $H_C$  of the counter-electrode active material layer (i) the absolute value of a separation distance,  $S_{X2}$ , between the plots  $E_{TP2}$  and  $CE_{TP2}$  measured in the transverse direction is  $1000\text{ }\mu\text{m} \geq |S_{X2}| \geq 5\text{ }\mu\text{m}$ , and (ii) as between the second transverse end surfaces of the electrode and counter-electrode active material layers, the second transverse end surface of the counter-electrode active material

layer is inwardly disposed with respect to the second transverse end surface of the electrode active material layer,

- ~~e. — the first vertical end surfaces of the electrode and the counter electrode active material layers are on the same side of the electrode assembly, a 2D map of the median vertical position of the first opposing vertical end surface of the electrode active material in the X-Z plane, along the length  $L_E$  of the electrode active material layer, traces a first vertical end surface plot,  $E_{VP1}$ ; a 2D map of the median vertical position of the first opposing vertical end surface of the counter electrode active material layer in the X-Z plane, along the length  $L_C$  of the counter electrode active material layer, traces a first vertical end surface plot,  $CE_{VP1}$ , wherein for at least 60% of the length  $L_C$  of the first counter electrode active material layer (i) the absolute value of a separation distance,  $S_{Z1}$ , between the plots  $E_{VP1}$  and  $CE_{VP1}$  measured in the vertical direction is  $1000\text{ }\mu\text{m} \geq |S_{Z1}| \geq 5\text{ }\mu\text{m}$ , and (ii) as between the first vertical end surfaces of the electrode and counter electrode active material layers, the first vertical end surface of the counter electrode active material layer is inwardly disposed with respect to the first vertical end surface of the electrode active material layer,~~
- ~~d. — the second vertical end surfaces of the electrode and counter electrode active material layer are on the same side of the electrode assembly, and oppose the first vertical end surfaces of the electrode and counter electrode active material layers, respectively, a 2D map of the median vertical position of the second opposing vertical end surface of the electrode active material layer in the X-Z plane, along the length  $L_E$  of the electrode active material layer, traces a second vertical end surface plot,  $E_{VP2}$ , a 2D map of the median vertical position of the second opposing vertical end surface of the counter electrode active material layer in the X-Z plane, along the length  $L_C$  of the counter electrode active material layer, traces a second vertical end surface plot,  $CE_{VP2}$ , wherein for at least 60% of the length  $L_C$  of the~~

~~counter-electrode active material layer (i) the absolute value of a separation distance,  $S_{Z2}$ , between the plots  $E_{VP2}$  and  $CE_{VP2}$  as measured in the vertical direction is  $1000\text{ }\mu\text{m} \geq |S_{Z2}| \geq 5\text{ }\mu\text{m}$ , and (ii) as between the second vertical end surfaces of the electrode and counter-electrode active material layers, the second vertical end surface of the counter-electrode active material layer is inwardly disposed with respect to the second vertical end surface of the electrode active material layer,~~

\_\_\_\_\_(c)\_\_\_\_ the set of electrode constraints comprises a primary constraint system comprising first and second primary growth constraints and at least one primary connecting member, the first and second primary growth constraints separated from each other in the longitudinal direction, and the at least one primary connecting member connecting the first and second primary growth constraints, wherein the primary constraint system restrains growth of the electrode assembly in the longitudinal direction such that any increase in the Feret diameter of the electrode assembly in the longitudinal direction over 20 consecutive cycles of the secondary battery is less than 20%.

5.

26. The secondary battery according to claim 4, ~~comprising~~ 25, wherein

(a)\_\_\_\_

the electrode assembly further comprises one or more carrier ion insulating material layers,

each electrode current collector of the population is electrically isolated from each counter-electrode active material layer of the population, and each counter-electrode current collector of the population is electrically isolated from each electrode active material layer of the population, and

within each unit cell,

the one or more carrier ion insulating material layers have an ionic conductance of carrier ions that does not exceed 10% of the ionic conductance of the separator of carrier ions during cycling of the battery, and ionically insulate at least a portion of a surface of the electrode current collector layer from the electrolyte that is proximate to one or more of the first and second vertical end surfaces of the electrode active material layer.

27. The secondary battery according to claim 25, wherein

the electrode assembly further comprises one or more carrier ion insulating material layers.

each electrode current collector of the population is electrically isolated from each counter-electrode active material layer of the population, and each counter-electrode current collector of the population is electrically isolated from each electrode active material layer of the population, and

within each unit cell,

the one or more carrier ion insulating material layers have an ionic conductance of carrier ions that does not exceed 10% of the ionic conductance of the separator of carrier ions during cycling of the battery, and ionically insulate at least a portion of a surface of the electrode current collector layer from the electrolyte that is proximate to one or more of and within a distance  $D_{cc}$  of (i) the first and second transverse end surfaces surface of the electrode active material layer.

28. The secondary battery according to claim 25, wherein:

(d) for each unit cell, (i) the first member of the electrode current collector population extends at least partially along the length  $L_E$  of the electrode active material layer in the transverse direction and comprises an electrode current collector end that extends past the first transverse end surface of the counter-electrode active material layer of each such unit cell, and (ii) the counter-electrode current collector extends at least partially along the length  $L_c$  of the counter-electrode active material layer in the transverse direction and comprises a counter-electrode current collector end that extends past the second transverse end surface of the electrode active material layer in the transverse direction of each such unit cell, and

the secondary battery further comprises at least one of:

(e) (i) an electrode busbar ~~comprises~~comprising at least one conductive segment configured to electrically connect to the population of electrode current collectors, and extending in the longitudinal direction of the electrode assembly, the conductive segment comprising a first

side having an interior surface facing the first transverse end surfaces of the counter-electrode active material layers, and an opposing second side having an exterior surface, the conductive segment optionally comprising a plurality of apertures spaced apart on along the longitudinal direction, the conductive segment of the electrode bus bar being arranged with respect to the electrode current collector ends such that the electrode current collector ends extend at least partially past a thickness of the conductive segment, to electrically connect thereto, the thickness of the conductive segment being measured between the interior and exterior surfaces, and

~~(b) the counter-electrode busbar comprises at least one conductive segment configured to electrically connect to the population of counter-electrode current collectors, and extending in the longitudinal direction of the electrode assembly, the conductive segment comprising a first side having an interior surface facing the second transverse end surfaces of the electrode active material layers, and an opposing second side having an exterior surface, the conductive segment optionally comprising a plurality of apertures spaced apart on along the longitudinal direction, the conductive segment of the counter-electrode bus bar being arranged with respect to the counter-electrode current collector ends such that the counter-electrode current collector ends extend at least partially past a thickness of the conductive segment, to electrically connect thereto, the thickness of the conductive segment being measured between the interior and exterior surfaces.~~

~~6. — The secondary battery according to claim 4 or 5, wherein each unit cell of the unit cell population comprises a carrier ion insulating material, having an ionic conductance that does not exceed 10% of the ionic conductance of the separator of carrier ions during cycling of the battery, and wherein the carrier ion insulating material layer insulates a surface of the electrode current collector layer from the electrolyte.~~

~~7. A secondary battery for cycling between a charged and a discharged state, the secondary battery comprising a battery enclosure, an electrode assembly, and carrier ions within the battery enclosure, and a set of electrode constraints, wherein~~

~~(a) the electrode assembly has mutually perpendicular transverse, longitudinal and vertical axes corresponding to the x, y and z axes, respectively, of an imaginary three dimensional cartesian coordinate system, a first longitudinal end surface and a second longitudinal end surface separated from each other in the longitudinal direction, and a lateral surface surrounding an electrode assembly longitudinal axis  $A_{EA}$  and connecting the first and second longitudinal end surfaces, the~~

~~lateral surface having opposing first and second regions on opposite sides of the longitudinal axis and separated in a first direction that is orthogonal to the longitudinal axis, the electrode assembly having a maximum width  $W_{EA}$  measured in the longitudinal direction, a maximum length  $L_{EA}$  bounded by the lateral surface and measured in the transverse direction, and a maximum height  $H_{EA}$  bounded by the lateral surface and measured in the vertical direction,~~

~~(b) the electrode assembly further comprises a population of electrode structures, a population of electrode current collectors, a population of separators that are ionically permeable to carrier ions, a population of counter electrode structures, a population of counter electrode collectors, a carrier ion insulating material layer, and a population of unit cells, wherein~~

~~(i) each electrode current collector of the population is electrically isolated from each counter-electrode active material layer of the population, and each counter-electrode current collector of the population is electrically isolated from each electrode active material layer of the population,~~

~~(ii) members of the electrode and counter-electrode structure populations are arranged in an alternating sequence in the longitudinal direction,~~

~~(iii) each member of the population of electrode structures comprises a layer of an electrode active material having a length  $L_E$  that corresponds to the Feret diameter of the electrode active material layer as measured in the transverse direction between first and second opposing transverse end surfaces of the electrode active material layer, and a width  $W_E$  that corresponds to the Feret diameter of the electrode active material layer as measured in the longitudinal direction between first and second opposing surfaces of the electrode active material layer, and a height  $H_E$  that corresponds to the Feret diameter of the electrode active material layer as measured in the vertical direction between first and second opposing vertical end surfaces of the electrode active material layer, and each member of the population of counter-electrode structures comprises a layer of a counter-electrode active material having a length  $L_C$  that corresponds to the Feret diameter of the counter-electrode active material layer as measured in the transverse direction between first and second opposing transverse end surfaces of the counter-electrode active material layer, and a width  $W_C$  that corresponds to the Feret diameter of the counter-electrode active material layer as measured in the longitudinal direction between first and second opposing~~

longitudinal end surfaces of the counter electrode active material layer, and a height  $H_C$  that corresponds to the Feret diameter of the counter electrode active material layer as measured in the vertical direction between first and second opposing vertical end surfaces of the counter electrode active material layer,

(iv) each unit cell comprises a unit cell portion of a first member of the electrode current collector population, a member of the separator population that is ionically permeable to the carrier ions, a first electrode active material layer of one member of the electrode population, a unit cell portion of a first member of the counter electrode current collector population and a first counter electrode active material layer of one member of the counter electrode population, wherein (aa) the first electrode active material layer is proximate a first side of the separator and the first counter electrode material layer is proximate an opposing second side of the separator, (bb) the separator electrically isolates the first electrode active material layer from the first counter electrode active material layer and carrier ions are primarily exchanged between the first electrode active material layer and the first counter electrode active material layer via the separator of each such unit cell during cycling of the battery between the charged and discharged state, and (cc) within each unit cell,

a. — the first transverse end surfaces of the electrode and counter electrode active material layers are on the same side of the electrode assembly, a 2D map of the median transverse position of the first opposing transverse end surface of the electrode active material layer in the X-Z plane, along the height  $H_E$  of the electrode active material layer, traces a first transverse end surface plot,  $E_{TP1}$ , a 2D map of the median transverse position of the first opposing transverse end surface of the counter electrode in the X-Z plane, along the height  $H_C$  of the counter electrode active material layer, traces a first transverse end surface plot,  $CE_{TP1}$ , and wherein an absolute value of a separation distance,  $|S_{X1}|$  is the distance as measured in the transverse direction between the plots  $E_{TP1}$  and  $CE_{TP1}$

b. — the second transverse end surfaces of the electrode and counter electrode active material layers are on the same side of the electrode assembly, and oppose the first transverse end surfaces of the electrode and counter electrode active material layers,

respectively, a 2D map of the median transverse position of the second opposing transverse end surface of the electrode active material layer in the X-Z plane, along the height  $H_E$  of the electrode active material layer, traces a second transverse end surface plot,  $E_{TP2}$ , a 2D map of the median transverse position of the second opposing transverse end surface of the counter electrode in the X-Z plane, along the height  $H_C$  of the counter electrode active material layer, traces a second transverse end surface plot,  $CE_{TP2}$ , and wherein an absolute value of a separation distance,  $|S_{X2}|$  is the distance as measured in the transverse direction between the plots  $E_{TP2}$  and  $CE_{TP2}$ ;

c. — the first vertical end surfaces of the electrode and the counter electrode active material layers are on the same side of the electrode assembly, a 2D map of the median vertical position of the first opposing vertical end surface of the electrode active material in the Y-Z plane, along the length  $L_E$  of the electrode active material layer, traces a first vertical end surface plot,  $E_{VP1}$ , a 2D map of the median vertical position of the first opposing vertical end surface of the counter electrode active material layer in the Y-Z plane, along the length  $L_C$  of the counter electrode active material layer, traces a first vertical end surface plot,  $CE_{VP1}$ , and wherein an absolute value of a separation distance,  $|S_{Z1}|$  is the distance as measured in the transverse direction between the plots  $E_{VP1}$  and  $CE_{VP1}$ ;

d. — the second vertical end surfaces of the electrode and counter electrode active material layer are on the same side of the electrode assembly, and oppose the first vertical end surfaces of the electrode and counter electrode active material layers, respectively, a 2D map of the median vertical position of the second opposing vertical end surface of the electrode active material layer in the Y-Z plane, along the length  $L_E$  of the electrode active material layer, traces a second vertical end surface plot,  $E_{VP2}$ , a 2D map of the median vertical position of the second opposing vertical end surface of the counter electrode active material layer in the Y-Z plane, along the length  $L_C$  of the counter electrode active material layer, traces a second vertical end surface plot,  $CE_{VP2}$ , and wherein an absolute value of a separation distance,  $|S_{Z2}|$  is the distance as measured in the transverse direction between the plots  $E_{VP2}$  and  $CE_{VP2}$ ;

e. ~~the carrier ion insulating material layer has an ionic conductance of carrier ions that does not exceed 10% of the ionic conductance of the separator of carrier ions during cycling of the battery, and ionically insulates a surface of the electrode current collector layer from the electrolyte that is proximate to and within a distance  $D_{CC}$  of (i) the first transverse end surface of the electrode active material layer, wherein  $D_{CC}$  equals the sum of  $2 \times W_E$  and  $|S_{X1}|$ , and/or (ii) second transverse end surface of the electrode active material layer, wherein  $D_{CC}$  equals the sum of  $2 \times W_E$  and  $|S_{X2}|$ , and/or (iii) the first vertical end surface of the electrode active material layer, wherein  $D_{CC}$  equals the sum of  $2 \times W_E$  and  $|S_{Z1}|$ , (iv) the second vertical end surface of the electrode active material layer wherein  $D_{CC}$  equals the sum of  $2 \times W_E$  and  $|S_{Z2}|$ .~~

8. ~~A secondary battery for cycling between a charged and a discharged state, the secondary battery comprising a battery enclosure, an electrode assembly, and carrier ions within the battery enclosure, and a set of electrode constraints, wherein~~

~~(a) the electrode assembly has mutually perpendicular transverse, longitudinal and vertical axes corresponding to the x, y and z axes, respectively, of an imaginary three dimensional cartesian coordinate system, a first longitudinal end surface and a second longitudinal end surface separated from each other in the longitudinal direction, and a lateral surface surrounding an electrode assembly longitudinal axis  $A_{EA}$  and connecting the first and second longitudinal end surfaces, the lateral surface having opposing first and second regions on opposite sides of the longitudinal axis and separated in a first direction that is orthogonal to the longitudinal axis, the electrode assembly having a maximum width  $W_{EA}$  measured in the longitudinal direction, a maximum length  $L_{EA}$  bounded by the lateral surface and measured in the transverse direction, and a maximum height  $H_{EA}$  bounded by the lateral surface and measured in the vertical direction,~~

~~(b) the electrode assembly further comprises a population of electrode structures, a population of electrode current collectors, a population of separators that are ionically permeable to carrier ions, a population of counter electrode structures, a population of counter electrode collectors, a carrier ion insulating material layer, and a population of unit cells, wherein~~

~~(i) each electrode current collector of the population is electrically isolated from each counter electrode active material layer of the population, and each counter electrode~~

~~current collector of the population is electrically isolated from each electrode active material layer of the population;~~

~~(ii) members of the electrode and counter electrode structure populations are arranged in an alternating sequence in the longitudinal direction;~~

~~(iii) each member of the population of electrode structures comprises a layer of an electrode active material having a length  $L_E$  that corresponds to the Feret diameter of the electrode active material layer as measured in the transverse direction between first and second opposing transverse end surfaces of the electrode active material layer, and a width  $W_E$  that corresponds to the Feret diameter of the electrode active material layer as measured in the longitudinal direction between first and second opposing surfaces of the electrode active material layer, and a height  $H_E$  that corresponds to the Feret diameter of the electrode active material layer as measured in the vertical direction between first and second opposing vertical end surfaces of the electrode active material layer, and each member of the population of counter electrode structures comprises a layer of a counter-electrode active material having a length  $L_C$  that corresponds to the Feret diameter of the counter electrode active material layer as measured in the transverse direction between first and second opposing transverse end surfaces of the counter electrode active material layer, and a width  $W_C$  that corresponds to the Feret diameter of the counter electrode active material layer as measured in the longitudinal direction between first and second opposing longitudinal end surfaces of the counter electrode active material layer, and a height  $H_C$  that corresponds to the Feret diameter of the counter electrode active material layer as measured in the vertical direction between first and second opposing vertical end surfaces of the counter electrode active material layer;~~

~~(iv) each unit cell comprises a unit cell portion of a first member of the electrode current collector population, a member of the separator population that is ionically permeable to the carrier ions, a first electrode active material layer of one member of the electrode population, a unit cell portion of a first member of the counter electrode current collector population and a first counter electrode active material layer of one member of the counter electrode population, wherein (aa) the first electrode active material layer is proximate a first side of the separator and the first counter electrode material layer is~~

proximate an opposing second side of the separator, (bb) the separator electrically isolates the first electrode active material layer from the first counter electrode active material layer and carrier ions are primarily exchanged between the first electrode active material layer and the first counter electrode active material layer via the separator of each such unit cell during cycling of the battery between the charged and discharged state, and (cc) within each unit cell,

a.——the first transverse end surfaces of the electrode and counter electrode active material layers are on the same side of the electrode assembly, a 2D map of the median transverse position of the first opposing transverse end surface of the electrode active material layer in the X-Z plane, along the height  $H_E$  of the electrode active material layer, traces a first transverse end surface plot,  $E_{TP1}$ , a 2D map of the median transverse position of the first opposing transverse end surface of the counter electrode in the X-Z plane, along the height  $H_C$  of the counter electrode active material layer, traces a first transverse end surface plot,  $CE_{TP1}$ , and wherein an absolute value of a separation distance,  $|S_{X1}|$  is the distance as measured in the transverse direction between the plots  $E_{TP1}$  and  $CE_{TP1}$

b.——the second transverse end surfaces of the electrode and counter electrode active material layers are on the same side of the electrode assembly, and oppose the first transverse end surfaces of the electrode and counter electrode active material layers, respectively, a 2D map of the median transverse position of the second opposing transverse end surface of the electrode active material layer in the X-Z plane, along the height  $H_E$  of the electrode active material layer, traces a second transverse end surface plot,  $E_{TP2}$ , a 2D map of the median transverse position of the second opposing transverse end surface of the counter electrode in the X-Z plane, along the height  $H_C$  of the counter electrode active material layer, traces a second transverse end surface plot,  $CE_{TP2}$ , and wherein an absolute value of a separation distance,  $|S_{X2}|$  is the distance as measured in the transverse direction between the plots  $E_{TP2}$  and  $CE_{TP2}$ ,

c.——the first vertical end surfaces of the electrode and the counter electrode active material layers are on the same side of the electrode assembly, a 2D map of the median vertical position of the first opposing vertical end surface of the electrode active

material in the Y-Z plane, along the length  $L_E$  of the electrode active material layer, traces a first vertical end surface plot,  $E_{VP1}$ , a 2D map of the median vertical position of the first opposing vertical end surface of the counter-electrode active material layer in the Y-Z plane, along the length  $L_C$  of the counter-electrode active material layer, traces a first vertical end surface plot,  $CE_{VP1}$ , and wherein an absolute value of a separation distance,  $|S_{Z1}|$  is the distance as measured in the transverse direction between the plots  $E_{VP1}$  and  $CE_{VP1}$ ,

d.—— the second vertical end surfaces of the electrode and counter electrode active material layer are on the same side of the electrode assembly, and oppose the first vertical end surfaces of the electrode and counter-electrode active material layers, respectively, a 2D map of the median vertical position of the second opposing vertical end surface of the electrode active material layer in the Y-Z plane, along the length  $L_E$  of the electrode active material layer, traces a second vertical end surface plot,  $E_{VP2}$ , a 2D map of the median vertical position of the second opposing vertical end surface of the counter-electrode active material layer in the Y-Z plane, along the length  $L_C$  of the counter-electrode active material layer, traces a second vertical end surface plot,  $CE_{VP2}$ , and wherein an absolute value of a separation distance,  $|S_{Z2}|$  is the distance as measured in the transverse direction between the plots  $E_{VP2}$  and  $CE_{VP2}$ ;

e.—— the carrier ion insulating material layer has an ionic conductance of carrier ions that does not exceed 10% of the ionic conductance of the separator of carrier ions during cycling of the battery, and ionically insulates a surface of the electrode current collector layer from the electrolyte that is proximate to and within a distance  $D_{CC}$  of (i) the first transverse end surface of the electrode active material layer, wherein (a) in a case where the first transverse end surface of the electrode active material layer is inwardly disposed with respect to the first transverse end surface of the counter-electrode active material,  $D_{CC}$  equals  $2 \times W_E + |S_{X1}|$ , and (b) in a case where the first transverse end surface of the counter-electrode active material layer is inwardly disposed with respect to the first transverse end surface of the electrode active material,  $D_{CC}$  equals  $2 \times W_E - |S_{X1}|$ , and/or (ii) the second transverse end surface of the electrode active material layer, wherein (a) in a case where the second transverse end surface of the electrode active material layer is inwardly disposed with respect to the second transverse end surface of the counter-

electrode active material,  $D_{CC}$  equals  $2 \times W_E + |S_{X2}|$ , and (b) in a case where the second transverse end surface of the counter electrode active material layer is inwardly disposed with respect to the second transverse end surface of the electrode active material,  $D_{CC}$  equals  $2 \times W_E - |S_{X2}|$ , and/or (iii) the first vertical end surface of the electrode active material layer, wherein (a) in a case where the first vertical end surface of the electrode active material layer is inwardly disposed with respect to the first vertical end surface of the counter electrode active material,  $D_{CC}$  equals  $2 \times W_E + |S_{Z1}|$ , and (b) in a case where the first vertical end surface of the counter electrode active material layer is inwardly disposed with respect to the first vertical end surface of the electrode active material,  $D_{CC}$  equals  $2 \times W_E - |S_{Z1}|$ , and/or (iv) the second vertical end surface of the electrode active material layer, wherein (a) in a case where the second vertical end surface of the electrode active material layer is inwardly disposed with respect to the second vertical end surface of the counter electrode active material,  $D_{CC}$  equals  $2 \times W_E + |S_{Z2}|$ , and (b) in a case where the second vertical end surface of the counter electrode active material layer is inwardly disposed with respect to the second vertical end surface of the electrode active material,  $D_{CC}$  equals  $2 \times W_E - |S_{Z1}|$  wherein  $D_{CC}$  equals the sum of  $2 \times W_E$  and  $|S_{Z2}|$ .

9. The secondary battery according to claim 7 or 8, further comprising a set of electrode constraints, wherein the set of electrode constraints comprises a primary constraint system comprising first and second primary growth constraints and at least one primary connecting member, the first and second primary growth constraints separated from each other in the longitudinal direction, and the at least one primary connecting member connecting the first and second primary growth constraints, wherein the primary constraint system restrains growth of the electrode assembly in the longitudinal direction such that any increase in the Feret diameter of the electrode assembly in the longitudinal direction over 20 consecutive cycles of the secondary battery is less than 20%.

10. The secondary battery according to claim 7, 8 or 9, wherein each unit cell of the unit cell population comprises a carrier ion insulating material, having an ionic conductance that does not exceed 10% of the ionic conductance of the separator of carrier ions during cycling of the battery, and wherein the carrier ion insulating material layer insulates a surface of the electrode current collector layer from the electrolyte.

11. ~~The secondary battery according to any of claims 7-9, comprising:~~

~~(a) an electrode busbar comprises at least one conductive segment configured to electrically connect to the population of electrode current collectors, and extending in the longitudinal direction between the first and second longitudinal end surfaces of the electrode assembly, the conductive segment comprising a first side having an interior surface facing the first transverse end surfaces of the counter electrode active material layers, and an opposing second side having an exterior surface, the conductive segment optionally comprising a plurality of apertures spaced apart on along the longitudinal direction, the conductive segment of the electrode bus bar being arranged with respect to the electrode current collector ends such that the electrode current collector ends extend at least partially past a thickness of the conductive segment, to electrically connect thereto, the thickness of the conductive segment being measured between the interior and exterior surfaces, and~~

~~(b) the counter electrode busbar comprises at least one conductive segment configured to electrically connect to the population of counter electrode current collectors, and extending in the longitudinal direction between the first and second longitudinal end surfaces of the electrode assembly, the conductive segment comprising a first side having an interior surface facing the second transverse end surfaces of the electrode active material layers, and an opposing second side having an exterior surface, the conductive segment optionally comprising a plurality of apertures spaced apart on along the longitudinal direction, the conductive segment of the counter electrode bus bar being arranged with respect to the counter electrode current collector ends such that the counter electrode current collector ends extend at least partially past a thickness of the conductive segment, to electrically connect thereto, the thickness of the conductive segment being measured between the interior and exterior surfaces.~~

12. A method for preparing an electrode assembly comprising a constraint for a secondary battery configured to cycle between a charged and a discharged state, the method comprising:

- ~~—forming a sheet structure;~~
- ~~—cutting the sheet structure into pieces;~~

~~—— stacking the pieces; and~~  
~~—— applying a set of constraints to the stacked pieces,~~  
~~—— wherein the sheet structure comprises at least one of a unit cell and a component of a unit cell,~~  
~~—— wherein the pieces comprise an electrode active material layer, an electrode current collector, a counter electrode active material layer, a counter electrode current collector, and a separator,~~  
~~—— wherein the set of constraints comprise a primary constraint system comprising first and second primary growth constraints and at least one primary connecting member, the first and second primary growth constraints separated from each other in the longitudinal direction, and the at least one primary connecting member connecting the first and second primary growth constraints, wherein the primary constraint system restrains growth of the electrode assembly in the longitudinal direction such that any increase in the Feret diameter of the electrode assembly in the longitudinal direction over 20 consecutive cycles of the secondary battery is less than 20%, and~~  
~~—— wherein one or more of the first and second primary growth constraints are attached to at least one of the electrode active material layer, electrode current collector, counter electrode active material layer, counter electrode current collector, and separator.~~

13. ~~The method according to claim 12, wherein each unit cell of the unit cell population comprises a carrier ion insulating material, having an ionic conductance that does not exceed 10% of the ionic conductance of the separator of carrier ions during cycling of the battery, and wherein the carrier ion insulating material layer insulates a surface of the electrode current collector layer from the electrolyte.~~

14. ~~The method according to any of claims 12-13, comprising providing electrode and counter electrode busbars as a part of the method for preparing the electrode assembly, wherein~~

~~(a) the electrode busbar comprises at least one conductive segment configured to electrically connect to the population of electrode current collectors, and extending in the longitudinal direction of the electrode assembly, the conductive segment comprising a first side having an interior surface facing the first transverse end surfaces of the~~

~~counter-electrode active material layers, and an opposing second side having an exterior surface, the conductive segment optionally comprising a plurality of apertures spaced apart on along the longitudinal direction, the conductive segment of the electrode bus bar being arranged with respect to the electrode current collector ends such that the electrode current collector ends extend at least partially past a thickness of the conductive segment, to electrically connect thereto, the thickness of the conductive segment being measured between the interior and exterior surfaces, and~~

~~—— (b) — the counter-electrode busbar comprises~~

~~(e) (ii) a counter-electrode busbar comprising at least one conductive segment configured to electrically connect to the population of counter-electrode current collectors, and extending in the longitudinal direction of the electrode assembly, the conductive segment comprising a first side having an interior surface facing the second transverse end surfaces of the electrode active material layers, and an opposing second side having an exterior surface, the conductive segment optionally comprising a plurality of apertures spaced apart on along the longitudinal direction, the conductive segment of the counter-electrode bus bar being arranged with respect to the counter-electrode current collector ends such that the counter-electrode current collector ends extend at least partially past a thickness of the conductive segment, to electrically connect thereto, the thickness of the conductive segment being measured between the interior and exterior surfaces.~~

~~15. — The secondary battery and/or method according to any of the preceding claims, wherein at least one of  $|S_{z1}|$ ,  $|S_{z2}|$ ,  $|S_{x1}|$ , and  $|S_{x2}|$ , is any of  $\geq 5\text{ }\mu\text{m}$ ,  $\geq 10\text{ }\mu\text{m}$ ,  $\geq 15\text{ }\mu\text{m}$ ,  $\geq 20\text{ }\mu\text{m}$ ,  $\geq 35\text{ }\mu\text{m}$ ,  $\geq 45\text{ }\mu\text{m}$ ,  $\geq 50\text{ }\mu\text{m}$ ,  $\geq 75\text{ }\mu\text{m}$ ,  $\geq 100\text{ }\mu\text{m}$ ,  $\geq 150\text{ }\mu\text{m}$ , and/or  $\geq 200\text{ }\mu\text{m}$ .~~

~~16.~~

29. The secondary battery according to claim 28, wherein in the case of the electrode busbar (i) the conductive segment comprises a plurality of apertures spaced apart along the longitudinal direction, wherein each of the plurality of apertures are configured to allow one or more electrode current collector ends to extend at least partially therethrough to electrically connect the one or more electrode current collector ends to the electrode busbar, and wherein in the case of the counter-electrode busbar (ii) the conductive segment comprises a plurality of apertures spaced apart along the longitudinal direction, wherein each of the plurality of apertures are configured to allow one or more counter-electrode current collector ends to extend at least partially therethrough

to electrically connect the one or more counter-electrode current collector ends to the counter-electrode busbar.

30. The secondary battery and/or method according to ~~any of the preceding claims~~, wherein at least one of  $|S_{Z1}|$ ,  $|S_{Z2}|$ ,  $|S_{X1}|$ , and  $|S_{X2}|$ , has a value that is any of  $\leq 1000$  microns,  $\leq 500 \mu\text{m}$ , such as  $\leq 475 \mu\text{m}$ ,  $\leq 425 \mu\text{m}$ ,  $\leq 400 \mu\text{m}$ ,  $\leq 375 \mu\text{m}$ ,  $\leq 350 \mu\text{m}$ ,  $\leq 325 \mu\text{m}$ ,  $\leq 300 \mu\text{m}$ , and/or  $\leq 250 \mu\text{m}$ .

~~17.~~ The secondary battery and/or method according to ~~any of the preceding claims~~ claim 25, wherein the set of electrode constraints further comprises a secondary constraint system comprising first and second secondary growth constraints separated in a second direction and connected by at least one secondary connecting member, ~~wherein the secondary constraint system at least partially restrains growth of the electrode assembly in the second direction upon cycling of the secondary battery, the second direction being orthogonal to the longitudinal direction.~~

~~18.~~ The secondary battery and/or method according to any of the preceding claims, wherein the electrode active material has the capacity to accept more than one mole of carrier ion per mole of electrode active material when the secondary battery is charged from a discharged state to a charged state, the charged state is at least 75% of a rated capacity of the secondary battery, and the discharged state is less than 25% of the rated capacity of the secondary battery.

~~19.~~ A method for the preparation of an electrode assembly, the method comprising:

~~removing a population of negative electrode subunits from a negative electrode sheet, the negative electrode sheet comprising a negative electrode sheet edge margin and at least one negative electrode sheet weakened region that is internal to the negative electrode sheet edge margin, the at least one negative electrode sheet weakened region at least partially defining a boundary of the negative electrode subunit population within the negative electrode sheet, the negative electrode subunit of each member of the negative electrode subunit population having a negative electrode subunit centroid,~~

~~removing a population of separator layer subunits from a separator sheet, the separator sheet comprising a separator sheet edge margin and at least one separator sheet weakened region that is internal to the separator sheet edge margin, the at least one separator sheet weakened region at least partially defining a boundary of the separator layer subunit population, each member of the separator layer subunit population having opposing surfaces,~~

~~removing a population of positive electrode subunits from a positive electrode sheet, the positive electrode sheet comprising a positive electrode edge margin and at least one positive electrode sheet weakened region that is internal to the positive electrode sheet edge margin, the at least one positive electrode sheet weakened region at least partially defining a boundary of the positive electrode subunit population within the positive electrode sheet, the positive electrode subunit of each member of the positive electrode subunit population having a positive electrode subunit centroid,~~

~~stacking members of the negative electrode subunit population, the separator layer subunit population and the positive electrode subunit population in a stacking direction to form a stacked population of unit cells, each unit cell in the stacked population comprising at least a unit cell portion of the negative electrode subunit, the separator layer of a stacked member of the separator layer subunit population, and a unit cell portion of the positive electrode subunit, wherein (i) the negative electrode subunit and positive electrode subunit face opposing surfaces of the separator layer comprised by such stacked unit cell population member, and (ii) the separator layer comprised by such stacked unit cell population member is adapted to electrically isolate the portion of the negative electrode subunit and the portion of the positive electrode subunit comprised by such stacked unit cell while permitting an exchange of carrier ions between the negative electrode subunit and the positive electrode subunit comprised by such stacked unit cell.~~

~~20.—The method of claim 19, wherein members of the negative electrode subunit population each comprise a multi-layer negative electrode subunit having a negative electrode active material layer on at least one side of a negative electrode current collector layer.~~

~~21. The method of any of claims 19-20, wherein members of the positive electrode subunit population each comprise a multi-layer positive electrode subunit comprising a positive electrode active material layer on at least one side of a positive-electrode current collector layer.~~

~~22. The method of any of claims 19-21, wherein each member of the stacked population of unit cells has a centroid separation distance wherein the centroid separation distance for an individual member of the population is the distance between the centroid of the unit cell portion of the negative electrode subunit and the centroid of the unit cell portion of the positive electrode subunit comprised by such individual member projected onto an imaginary plane that is orthogonal to the stacking direction, and the centroid distance is within a predetermined limit.~~

~~23. The method of any of claims 19-23, wherein the absolute value of the centroid separation distance for unit cell portions of negative electrode and positive electrode subunits in an individual member of the population  $S_D$  is within a predetermined limit corresponding to either less than 500 microns, or in a case where 2% of the largest dimension of the negative electrode subunit is less than 500 microns, then within a predetermined limit of less than 2% of the largest dimension of the negative electrode subunit.~~

~~24. The method of any of claims 19-23, wherein the average centroid separation distance is within the predetermined limit for at least 10 unit cells, at least 15 unit cells, at least 20 unit cells, and/or at least 25 unit cells in the stacked population.~~

~~25. The method of any of claims 19-24, wherein the average centroid separation distance is within the predetermined limit for at least 75%, at least 80%, at least 90% and/or at least 95% of the unit cell members of the stacked population of unit cells.~~

~~26. The method of any of claims 19-25, wherein the negative electrode sheet comprises a continuous web having the negative electrode subunits formed therein, and/or wherein the positive electrode sheet comprises a continuous web having the positive electrode subunits formed therein, and/or wherein the separator sheet comprises a continuous web having the separator layer subunits formed therein.~~

~~27.—The method of any of claims 19-26, wherein the negative electrode subunits, separator layer subunits, and/or positive electrode subunits are removed from their respective negative electrode sheet, separator sheet, and/or positive electrode sheet, by exerting a force on the subunit that is orthogonal to a plane of the sheet, to~~

~~28.—The method of claim any of claims 19-27, wherein the sheets comprise sheet alignment features, and wherein the method comprises aligning the sheets with respect to one another using the alignment features, to provide alignment of one or more of the subunits in the sheets with respect to one another.~~

~~29.—The method of any of claims 19-28, wherein in the stacked population, (i) the negative electrode subunit has a first set of two opposing end surfaces, and opposing end margins adjacent each of the first set of opposing end surfaces, (ii) the positive electrode subunit has a second set of opposing end surfaces, and opposing end margins adjacent each of the second set of opposing end surfaces, (iii) one or more of the negative electrode subunit and positive electrode subunit have at least one weakened region in at least one of the opposing end margins thereof,~~

~~wherein the method further comprises applying tension to at least one of the opposing end margins of one or more of the negative electrode subunit and positive electrode subunit in the tensioning direction, to remove a portion of one or more of the negative electrode subunit and positive electrode subunit that is adjacent the weakened location in the at least one opposing end margin, such that one or more of the first set of opposing end surfaces of the negative electrode subunit and the second set of opposing end surfaces of the positive electrode subunit comprise at least one end surface exposed by removal of the portion.~~

~~30.—The method of any of claims 19-29, wherein in the stacked population, the opposing end margins of the negative electrode subunit and the positive electrode subunit at least partially overlie one another, and~~

~~—wherein following removal of the portion of one or more of the negative electrode subunit and the positive electrode subunit, at least a portion of one or more of the opposing end surfaces in the first set of opposing end surfaces of the negative electrode subunit are offset relative to at least a portion of one or more of the opposing end surfaces in the second set of opposing end surfaces of the positive electrode subunit, in~~

~~one or more of the tensioning direction and a third direction orthogonal to both the tensioning direction and the stacking direction.~~

~~31. The method according of any of claims 19-30, wherein the alignment is maintained by attaching a plurality of the electrode current collectors and/or positive-electrode current collectors in the stacked population to one or more constraint members on a face of the stacked population that is in a plane of the stacking direction.~~

~~32. The method of any of claims 19-31, wherein the tensioning force is applied to remove the portion of the negative electrode subunit and/or positive electrode subunit adjacent the weakened region in the at least one end margin, by simultaneously pulling alignment pins in alignment features on opposing ends of the negative electrode subunit and/or positive electrode subunit in opposing directions in the tensioning direction.~~

~~33. The method of any of claims 19-32, wherein alignment features are formed in end margins having the at least one subunit weakened region on a same side of both the negative electrode subunit and positive electrode subunit, and wherein applying tension via the alignment pin results in removal of the portions of the end margins comprising the alignment features on the same sides in the negative electrode subunits and positive electrode subunits.~~

~~34. An energy storage device having an electrode assembly comprising, in a stacked arrangement, a negative electrode subunit, a separator layer, and a positive electrode subunit, the electrode assembly comprising:~~

~~an electrode stack comprising a population of negative electrode subunits and a population of positive electrode subunits stacked in a stacking direction, each of the stacked negative electrode subunits having a length L of the negative electrode subunit in a transverse direction that is orthogonal to the stacking direction, and a height H of the negative electrode subunit in a direction orthogonal to both the transverse direction and stacking directions, wherein (i) each member of the population of negative electrode subunits comprises a first set of two opposing end surfaces that are spaced apart along the transverse direction, (ii) each member of the population of positive electrode subunits comprises a second set of two opposing end surfaces that are spaced apart along the transverse direction,~~

~~wherein at least one of the opposing end surfaces of the negative electrode subset and/or positive electrode subunit comprises regions about the opposing end surfaces of one or more of the negative electrode subset and positive electrode subunit that exhibit plastic deformation and fracturing oriented in the transverse direction, due to elongation and narrowing of the cross-section of the negative electrode subunit and/or positive electrode subunit.~~

~~35. The energy storage device according to claim 34, wherein the negative electrode subunit and/or the positive electrode subunit comprise multi-layer units comprising a negative electrode active material layer and a negative electrode current collector for the negative electrode subunit, and a positive electrode active material layer and a positive electrode current collector for the positive electrode current collector.~~

~~36. The energy storage device according to any of claims 34-35, wherein the negative electrode subunits and/or positive electrode subunits have a ratio of a length dimension L, to both the height H and width dimensions W of at least 5:1, such as at least 8:1 and even at least 10:1, and have a ratio of H to W in the range of 0.4:1 to 1000:1, such as in the range of 2:1 to 10:1.~~

~~37. The energy storage device according to any of claims 35-36, further comprising constraints set of electrode constraints comprises a primary constraint system comprising first and second primary growth constraints and at least one primary connecting member, the first and second primary growth constraints separated from each other in the stacking direction, and the at least one primary connecting member connecting the first and second primary growth constraints, wherein the primary constraint array restrains growth of the electrode assembly in the stacking direction such that any increase in the Feret diameter of the electrode assembly in the stacking direction over 20 consecutive cycles of the secondary battery is less than 20%, where the charged state is at least 75% of a rated capacity of the secondary battery, and the discharged state is less than 25% of the rated capacity of the secondary battery.~~

~~38. The method of any of claims 19-34, wherein removal of the subunits is repeated to form the stacking population having a plurality of unit cells.~~

39. A secondary battery comprising an enclosure, an electrode assembly, carrier ions within the battery enclosure, and a set of electrode constraints, wherein

the electrode assembly comprises a series of layers stacked in a stacking direction to form a stacked population, the stacked population comprising a population of negative electrode layers, a population of positive electrode layers, a population of separator material layers, and a population of unit cells, wherein

(i) each unit cell comprises a unit cell portion of a first member of the negative electrode layers, a member of the population of separator material layers that is ionically permeable to the carrier ions, and a unit cell portion of a first member of the positive electrode layers, wherein the negative electrode layer is proximate a first side of the separator material layer, and the positive electrode layer is proximate an opposing second side of the separator material layer, and the separator electrically isolates the negative electrode layer from the positive electrode layer, and carrier ions are primarily exchanged between the first member of the negative electrode layers and the first member of the positive electrode layers via the separator material layer of each such unit cell during cycling of the battery between the charged and discharged state

the set of electrode constraints comprises a primary constraint system and a secondary constraint system wherein

(i) the primary constraint system comprises first and second growth constraints and at least one primary connecting member, the first and second primary growth constraints separated from each other in the stacking direction, and the at least one primary connecting member connecting the first and second primary growth constraints to at least partially restrain growth of the electrode assembly in the stacking direction, and

(ii) the secondary constraint system comprises first and second secondary growth constraints separated in a second direction and connected by secondary connecting members comprising at least a portion of the negative electrode layers, wherein the secondary constraint system at least partially restrains growth of the electrode assembly in the second direction, the second direction being orthogonal to the stacking direction, and

- (iii) ~~the primary constraint system maintains a pressure on the electrode assembly in the stacking direction that exceeds the pressure maintained on the electrode assembly in each of two directions that are mutually perpendicular and perpendicular to the stacking direction,~~
- ~~each unit cell comprises a cell volume in that unit cell that is located bounded by a centerline of the negative electrode layer, the centerline comprising a reference plane that is located in a plane orthogonal to the stacking direction, and by a surface of the separator material layer that faces the negative electrode layer, as well as by the first and second secondary growth constraints that are connected to one another by the negative electrode layer,~~
- ~~wherein the cell volume comprises a first region that is adjacent the separator surface, and a second region that is adjacent the centerline, and wherein the first region comprises at least 10% of the cell volume and has a void fraction greater than 85%, and the second region comprises at least 10% of the cell volume and has a void fraction of less than 60%.~~
- ~~40. The secondary battery according to claim 39, wherein the cell volume comprises a third region between the first and second region, having a void fraction that is between that of the first and second regions.~~
- ~~41. The secondary battery according to any of claims 39-40, wherein the negative electrode layer comprises a negative electrode current collector layer and a negative electrode active material layer disposed on at least one surface of the negative electrode current collector, and wherein the negative electrode current collector layer connects the first and second secondary growth constraints.~~
- ~~42. The secondary battery according to any of claims 39-41, wherein the centerline coincides with the negative electrode current collector layer.~~
- ~~43. The secondary battery according to any of claims 39-42, wherein a void fraction of the cell volume monotonically increases from the second region to the first region.~~
- ~~44. The secondary battery according to any of claims 39-43, wherein the negative electrode layer comprises a layer of negative electrode active material, and wherein a density of the negative electrode active material decreases from the second region to the first region.~~
- ~~45. The secondary battery according to any of claims 39-44, wherein the void fraction in the second region is less than 55%, less than 50%, less than 45%, less than 40%, and/or less than 35%.~~

~~46. The secondary battery according to any of claims 39-45, wherein the void fraction in the first region is greater 90%, greater than 95%, greater than 98%, and/or greater than 99%.~~

~~47. The secondary battery according to according to any of claims 39-46, wherein the negative electrode layer comprises a layer of negative electrode active material having a plurality of protrusions of the electrode active material that extend in the stacking direction towards the separator material layer.~~

~~48. A method for the preparation of an electrode assembly, the method comprising:~~

~~removing a population of negative electrode subunits from a negative electrode sheet, the negative electrode sheet comprising a negative electrode sheet edge margin and at least one negative electrode sheet weakened region that is internal to the negative electrode sheet edge margin, the at least one negative electrode sheet weakened region at least partially defining a boundary of the negative electrode subunit population within the negative electrode sheet, the negative electrode subunit of each member of the negative electrode subunit population having a negative electrode subunit centroid,~~

~~removing a population of separator layer subunits from a separator sheet, the separator sheet comprising a separator sheet edge margin and at least one separator sheet weakened region that is internal to the separator sheet edge margin, the at least one separator sheet weakened region at least partially defining a boundary of the separator layer subunit population, each member of the separator layer subunit population having opposing surfaces,~~

~~removing a population of positive electrode subunits from a positive electrode sheet, the positive electrode sheet comprising a positive electrode edge margin and at least one positive electrode sheet weakened region that is internal to the positive electrode sheet edge margin, the at last one positive electrode sheet weakened region at least partially defining a boundary of the positive electrode subunit population within the positive electrode sheet, the positive electrode subunit of each member of the positive electrode subunit population having a positive electrode subunit centroid, and~~

~~—— stacking members of the negative electrode subunit population, the separator layer subunit population and the positive electrode subunit population in a stacking direction to form a stacked population of unit cells, each unit cell in the stacked population comprising at least a unit cell portion of the negative electrode subunit, the separator layer of a stacked member of the separator layer subunit population, and a unit cell portion of the positive electrode subunit, wherein (i) the negative electrode subunit and positive electrode subunit face opposing surfaces of the separator layer comprised by such stacked unit cell population member, and (ii) the separator layer comprised by such stacked unit cell population member is adapted to electrically isolate the portion of the negative electrode subunit and the portion of the positive electrode subunit comprised by such stacked unit cell while permitting an exchange of carrier ions between the negative electrode subunit and the positive electrode subunit comprised by such stacked unit cell,~~

~~—— affixing a set of electrode constraints to the stacked population of unit cells, the set of electrode constraints comprising a primary constraint system and a secondary constraint system wherein~~

~~—— (i) the primary constraint system comprises first and second growth constraints and at least one primary connecting member, the first and second primary growth constraints separated from each other in the stacking direction, and the at least one primary connecting member connecting the first and second primary growth constraints to at least partially restrain growth of the electrode assembly in the stacking direction, and~~

~~(ii) the secondary constraint system comprises first and second secondary growth constraints separated in a second direction and connected by secondary connecting members comprising at least a portion of the negative electrode subunit, wherein the secondary constraint system at least partially restrains growth of the electrode assembly in the second direction upon cycling of the secondary battery, the second direction being orthogonal to the ~~stacking~~longitudinal direction, and~~

~~(iii) the primary constraint system maintains a pressure on the electrode assembly in the stacking direction that exceeds the pressure maintained on the electrode assembly~~

~~in each of two directions that are mutually perpendicular and perpendicular to the stacking direction;~~

~~— providing, for each member of the population of unit cells, a cell volume in that unit cell that is bounded by a centerline of the negative subunit, the centerline comprising a reference plane that is located in a plane orthogonal to the stacking direction, and by a surface of the separator material subunit that faces the negative electrode subunit, as well as by the first and second secondary growth constraints that are connected to one another by the negative electrode subunit, and~~

~~— wherein the cell volume comprises a first region that is adjacent the surface of the separator subunit, and a second region that is adjacent the centerline, and wherein the first region comprises at least 10% of the cell volume and has a void fraction greater than 85%, and the second region comprises at least 10% of the cell volume and has a void fraction of less than 60%.~~

~~49. The method according to claim 48, the method further comprising:~~

~~— removing a population of negative electrode subunits having protrusions on at least one surface thereof from the negative electrode sheet; and~~

~~— stacking members of the population negative electrode subunits in the stacked population of unit cells such that the protrusions are disposed between the negative electrode subunits and the separator layer subunits.~~

~~50. The method according to any of claims 48-49, the method further comprising:~~

~~— removing a population of negative electrode subunits having protrusions at opposing end margins thereof from the negative electrode sheet,~~

~~— stacking members of the population negative electrode subunits in the stacked population of unit cells such that the protrusions are disposed between the negative electrode subunits and the separator layer subunits.~~

~~51. The method according to any of claims 48-50, the method further comprising:~~

~~— removing a population of separator subunits having protrusions on at least one surface thereof from a separator sheet; and~~

~~— stacking members of the population negative electrode subunits in the stacked population of unit cells such that the protrusions are disposed between the negative electrode subunits and the separator layer subunits.~~

~~— 52. — The method according to any of claims 48-51, the method further comprising:~~

~~— removing a population of spacer subunits from a spacer sheet, and~~

~~— stacking members of the population of spacer subunits in the stacked population of unit cells such that members of the population of spacer subunits are disposed between the negative electrode subunits and the separator layer subunits.~~