CLAIMS

1. A secondary battery for cycling between a charged and a discharged state, the secondary battery comprising a battery enclosure, an electrode assembly, carrier ions, and a non-aqueous liquid electrolyte within the battery enclosure, wherein

the electrode assembly comprises a population of anode structures, a population of cathode structures, and an electrically insulating microporous separator material electrically separating members of the anode and cathode structure populations, wherein the anode and cathode structure populations are arranged in an alternating sequence in a longitudinal direction, each member of the anode structure population has a first cross-sectional area, A_1 when the secondary battery is in the charged state and a second cross-sectional area, A_2, when the secondary battery is in the discharged state, each member of the cathode structure population has a first cross-sectional area, C_1 when the secondary battery is in the charged state and a second cross-sectional area, C_2, when the secondary battery is in the discharged state, and the cross-sectional areas of the members of the anode and cathode structure populations are measured in a first longitudinal plane that is parallel to the longitudinal direction;

the electrode assembly further comprises a set of electrode constraints that at least partially restrains growth of the electrode assembly in the longitudinal direction upon cycling of the secondary battery between the charged and discharged states wherein the set of electrode constraints comprises: a primary growth constraint system and a secondary growth constraint system, wherein (i) the primary growth 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, and (ii) the secondary growth constraint system comprises first and second secondary growth constraints separated in a second direction and connected by at least one secondary connecting member, wherein the secondary growth constraint system at least partially restrains growth of the electrode

assembly in a second direction upon cycling of the secondary battery, the second direction being orthogonal to the longitudinal direction;

each member of the population of cathode structures comprises a layer of a cathode active material comprising filler particles that are compressible and elastic, and each member of the population of anode structures comprises a layer of an anode active material having a capacity to accept more than one mole of carrier ion per mole of anode active material when the secondary battery is charged from a discharged state to a charged state,

A_1 is greater than A_2 for each of the members of a subset of the anode structure population and C_1 is less than C_2 for each of the members of a subset of the cathode structure population, and wherein a difference C_2-C_1 does not exceed a difference A_1-A_2 during cycling of the secondary battery;

wherein a ratio of C_2 to C_1 for each of the members of the subset of the cathode structure population is at least 1.1:1; and

the charged state is at least 75% of the rated capacity of the secondary battery, and the discharged state is less than 25% of the rated capacity of the secondary battery.

2. The secondary battery of any preceding claim, wherein the anode structure population subset has a first median cross-sectional area MA_{A1} when the secondary battery is in the charged state and a second median cross-sectional area MA_{A2} when the secondary battery is in a discharged state, and the cathode structure population subset has a first median cross-sectional area MA_{c1} when the secondary battery is in the charged state and a second median cross-sectional area MAC_2 when the secondary battery is in a discharged state, wherein MA_{A1} is greater than MA_{A2} and MA_{C1} is less than MA_{C2}.

3. The secondary battery of any preceding claim, wherein the anode structure population subset comprises at least five members, and the cathode structure population subset comprises at least five members.

4. The secondary battery of any preceding claim, wherein the anode structure population subset comprises at least 75% of the total population of anode structures, and the cathode structure population subset comprises at least 75% of the total population of cathode structures.

5. The secondary battery of any preceding claim, wherein members of the population of anode structures comprise a length L_A and members of the population of cathode structures comprise a length L_C, extending from a bottom of the member to a top of the member, the bottom being proximate to a plane from which the member extends, and the top being distal to the plane, and wherein the first longitudinal plane is perpendicular to the direction of the lengths L_A and L_C.

6. The secondary battery as in any preceding claim, wherein each member of the cathode population comprises orthogonal height H_C, width W_C, and length L_C directions, and wherein a ratio of the length L_C to each of the height H_C and the width W_C is at least 5:1.

7. The secondary battery as in any preceding claim , wherein the longitudinal plane is in a Z-Y plane, where Y corresponds to an axis that is parallel to the longitudinal direction, and Z corresponds to an axis that is orthogonal to the longitudinal axis, and that is also orthogonal to the lengths L_A and L_C of the members of the population of anode structures and cathode structures, respectively.

8. The secondary battery as in any preceding claim, wherein the longitudinal plane is in a plane that is less than 15 degrees away from a Z-Y plane as rotated along a Y-axis, where the Y-axis corresponds to an axis that is parallel to the longitudinal direction, and Z corresponds to an axis that is orthogonal to the longitudinal axis, and that is also orthogonal to the lengths L_A and L_C of the members of the population of anode structures and cathode structures, respectively.

9. The secondary battery as in any preceding claim, wherein the longitudinal plane is in a plane that is greater than 45 degrees but less than 90 degrees from a Z-Y plane as rotated along a Y-axis, where the Y-axis corresponds to an axis that is parallel to the longitudinal direction, and Z corresponds to an axis that is orthogonal to the longitudinal

axis, and that is also orthogonal to the lengths L_A and L_C of the members of the population of anode structures and cathode structures, respectively.

10. The secondary battery as in any preceding claim, wherein the longitudinal plane is in an XY plane, where the Y-axis corresponds to an axis that is parallel to the longitudinal direction, and the X-axis corresponds to an axis that is orthogonal to the longitudinal axis, and that is also parallel to the lengths L_A and Lc of the members of the population of anode structures and cathode structures, respectively.

11. The secondary battery of any preceding claim, wherein at least one member of the anode structure population subset has a first median cross-sectional area, ML_{A1} when the secondary battery is in the charged state, and a second median cross-sectional area, ML_{A2} when the secondary battery is in the discharged state, and at least one member of the cathode structure population subset has a first median cross-sectional area, ML_{C1} when the secondary battery is in the charged state, and a second median cross-sectional area ML_{C2} when the secondary battery is in the discharged state, where the median cross-sectional areas ML_{A1}, ML_{A2}, ML_{C1} and ML_{C2} are measured in a plurality of longitudinal planes parallel to the longitudinal direction for each member, and wherein ML_{A1} is greater than ML_{A2} for each of the members of the subset of the anode structure population and ML_{C1} is less than ML_{C2} for each of the members of the subset of the cathode structure population.

12. The secondary battery of any preceding claim, wherein the median cross-sectional areas ML_{A1}, ML_{A2}, ML_{C1} and ML_{C2} are the median cross sectional areas as measured in at least three longitudinal planes for the anode and cathode structure population subsets.

13. The secondary battery of any of claims 2-12, wherein the first median cross-sectional area MA_{A1} of the subset of the population of anode structures is in the range of from $4.7X10^3$ μm^2 to $6.8X10^6$ μm^2, and the second median cross sectional area MA_{A2} of the subset of the population of anode structures is in the range of from $1.6X10^3$ μm^2 to $7.1X10^6$ μm^2.

14. The secondary battery of any of claims 2-13, wherein the second median cross-sectional area MA_{C2} of the subset of the population of cathode structures is in the range of from $1.05X10^3$ $\mu m^2$to $9.5X10^6$ μm^2, and the first median cross-sectional MA_{C1} of the subset of the population of cathode structures is in the range of from $2.6X10^2$ μm^2 to $9.03X10^6$ μm^2.

15. The secondary battery of any of claims 11-14, wherein a subset of member of the anode structure population have a first median cross-sectional area MO_{A1} that is the median of the cross-sectional areas as measured in a plurality of longitudinal planes parallel to the longitudinal direction for each member of the subset, for a subset having at least two members, when the secondary battery is in the charged state, and a second median cross-sectional area MO_{A2} that is the median of the cross-sectional areas as measured in a plurality of longitudinal planes parallel to the longitudinal direction for each member of the subset, for a subset having at least two members, when the secondary battery is in the discharged state, and wherein a subset of member of the cathode structure population have a first median cross-sectional area MO_{C1} that is the median of the cross-sectional areas as measured in a plurality of longitudinal planes parallel to the longitudinal direction for each member of the subset, for a subset having at least two members, when the secondary battery is in the charged state, and a second median cross-sectional area MO_{C2} that is the median of the cross-sectional areas as measured in a plurality of longitudinal planes parallel to the longitudinal direction for each member of the subset, for a subset having at least two members, when the secondary battery is in the discharged state, and wherein MO_{A1} is greater than MO_{A2}, and MO_{C1} is less than MO_{C2}.

16. The secondary battery of claim 15, wherein the first median cross-sectional area MO_{A1} of the subset of the population of anode structures is in the range of from 100 μm^2 to $1.5X10^7$ μm^2, and the second median cross sectional area MO_{A2} of the subset of the population of anode structures is in the range of from 500 μm^2 to $3X10^7$ μm^2.

17. The secondary battery of any preceding claim, wherein members of the population of anode structures have a first width W_{A1} when the secondary battery is in the charged

state, and a second width W_{A2} when the secondary battery is in the discharged state, and wherein members of the population of cathode structures have a first width W_{C1} when the secondary battery in in the charged state, and a second width W_{C2} when the secondary battery is in the discharged state, and wherein W_{A1} is greater than W_{A2} for a subset of the anode structure population, and W_{C1} is less than W_{C2} for a subset of the cathode structure population, the widths W_{A1}, W_{A2}, W_{C1} and W_{C2} being measured in the longitudinal direction.

18. The secondary battery of claim 17, wherein the widths are measured at a line formed by bisection of the longitudinal plane with an orthogonal X-Y plane, where the Y- axis is parallel to the longitudinal direction, and the X- axis is parallel to a direction of the length L_A and L_C of the members of the anode and cathode structure populations.

19. The secondary battery of any of claims 17 – 18, wherein the XY-plane is located at a midpoint of the height H of the cathode structures, the height being measured in a direction orthogonal to both the longitudinal direction and the direction of the lengths L_A and L_C of the members of the anode and cathode structure populations.

20. The secondary battery of claim 17, wherein the XY plane is located at a position along the height of the cathode structures that is anywhere from 25% to 75% of the total height H of the cathode structures, the height being measured in a direction orthogonal to both the longitudinal direction and the direction of the lengths L_A and L_C of the members of the anode and cathode structure populations.

21.The secondary battery of any of claims 17 – 20, wherein the first width W_{A1} is in the range of from 50 μm to 2000 μm, and the second width W_{A2} is in the range of from 15 μm to 2500 μm.

22. The secondary battery of any of claims 17 – 21, wherein the first width W_{C1} is in the range of from 2 μm to 5000 μm, and the second width W_{C2} is in the range of from 5 μm to 5000 μm.

23. The secondary battery of any of claims 17 – 22, wherein a ratio of W_{A1} to W_{A2} is at least 1.01:1.

24. The secondary battery according to any preceding claim, wherein members of the population of cathode structures comprise a layer of cathode active material that is porous, and wherein the layer of cathode active material has a first porosity P_1 when the secondary battery is in a charged state, and a second porosity P_2 when the secondary battery is in a discharged state, the first porosity P_1 being less than the second porosity P_2.

25. The secondary battery according to claim 24, wherein the first porosity P_1 is no more than 30%, and the second porosity P_2 is at least about 50%.

26. The secondary battery according to any of claims 24 - 25, wherein a ratio of the second porosity P_2 to the first porosity P_1 is at least 1.1:1.

27. The secondary battery according to any preceding claim, wherein the secondary battery has an areal capacity of at least 5 $mA \cdot h/cm^2$ at 0.1C.

28. The secondary battery of claim 27, wherein the secondary battery has a rate capability of 1C:C/10 of at least 75%.

29. The secondary battery of any preceding claim, wherein members of the population of cathode structure comprise a layer of cathode active material having particles dispersed in a matrix.

30. The secondary battery of claim 28, wherein the cathode active material layer comprises particles of cathode active material selected from the group consisting of one of transition metal oxides, transition metal sulfides, transition metal nitrides, lithium-transition metal oxides, lithium-transition metal sulfides, and lithium-transition metal nitrides, dispersed in a matrix comprising a polymeric material.

31. The secondary battery of any of claims 29 – 30, wherein the filler particles comprise polymer-containing beads.

32. The secondary battery of any preceding claim, wherein the microporous separator material comprises a flexible membrane having insulating particles interspersed in a polymeric matrix.

33. The secondary battery of any preceding claim, wherein members of the population of cathode structures exhibit at least a 5% decrease in cross-sectional area C at a psi of 100.

34. The secondary battery in any preceding claim, wherein the primary growth 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%.

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

36. The secondary battery according to claim 1, wherein members of the population of cathode structures comprise a porous cathode active material, wherein a volume V_2 of the porous cathode active material occupied by the non-aqueous liquid electrolyte in the discharged state is greater than a volume V_1 of the porous cathode active material occupied by the non-aqueous electrolyte in the charged state.

37. The secondary battery according to claim 36, wherein a ratio of the volume V_2 to V_1 of the porous cathode active material occupied by the non-aqueous liquid electrolyte is at least 1.1:1.

38. The secondary battery according to claim 1, wherein members of the population of anode structures comprise an anode active material, and members of the population of cathode structures comprise a cathode active material, members of the population of cathode structures having an areal capacity of at least 5 $mA \cdot h/cm^2$ at 0.1C, and a rate capability of 1C:C/10 of at least 80% for discharge from a charged state to a discharged state.

39. The secondary battery according to claim 38, wherein the areal capacity is at least 8 $mA \cdot h/cm^2$ at 0.1C.

40. The secondary battery according to any of claims 38 – 39, wherein the secondary battery has a rate capability of 1C:C/10 of at least 90% for discharge from a charged state to a discharged state.

41. The secondary battery according to claim 1, wherein the ratio of the second cross-sectional area C_2 to the first cross-sectional area C_1 is in the range of from 1.1:1 to 6:1.