growth of Li-metal dendrites gives rise to serious technical barriers for developing such a battery. Recently, modified versions of the Li metal battery, such as the Lithium ion battery, have been introduced with some success. However, the current modified versions possess limitations and inefficiencies that would not arise with a cell that uses Lithium metal as an anode.

Typically, a Lithium metal cell includes an anode and a cathode separated by an electrically insulating barrier or 'separator' and operationally connected by an electrolyte solution. During the charging process, the positively charged lithium ions move from the cathode, through the permeable separator, to the anode and reduce into Li metal. During discharge, the Li metal is oxidized to positively charged lithium ions which move from the anode, through the separator, and onto the cathode, while electrons move through an external load from the anode to the cathode, yielding current and providing power for the load. During repeated charges and discharges, Lithium dendrites begin to grow from on the surface of the anode. Dendritic lithium deposits, sometimes called mossy lithium, eventually tear through the separator and reach the cathode causing an internal short and rendering the cell inoperable. Lithium dendrite formation is inherently unavoidable during the charging and discharging processes of Li-metal cells. Thus, there remains a need for a lithium electrode cell system that does not suffer the effects of dendrite growth while simultaneously maintaining the cycle ability, ionic conductivity, voltage and specific capacity of the cells. ~~The present novel technology addresses these needs.~~

SUMMARY

According to a first aspect of the present invention, there is provided an electrode separator, comprising: an electrically insulating barrier member having an anode-facing side and a cathode-facing side; and a layer of functionalized nanocarbon particles adhered to the anode-facing side of the electrically insulating barrier member; and wherein the functionalized nanocarbon particles are functionalized with ionically associated metal cations for seeding dendrite growth.

According to a second aspect of the present invention, there is provided a lithium metal battery cell, comprising: an electrolyte medium; a cathode positioned in the electrolyte medium; a lithium-containing anode positioned in the electrolyte medium and spaced from the cathode; a separator having an anode-facing side and a cathode-facing side disposed between the lithium-containing anode and the cathode; and a plurality of lithium-functionalized nanocarbon particles operationally connected to the anode-facing side of the separator; wherein the separator is electrically insulating and electrolytically permeable.

According to a third aspect of the present invention, there is provided a device for extending the life of a battery, comprising: an electrode having a metal portion, wherein the metal portion is selected from the group including lithium, calcium, magnesium, sodium, potassium and combinations thereof; an electrolyte permeable membrane; and a metal dendrite seeding material disposed between the electrode and the membrane; wherein the electrode, the membrane and the metal dendrite seeding material are positioned in an electrolyte matrix and; wherein at least one dendrite extending from the electrode toward the electrolyte permeable membrane combines with at least one dendrite extending from the dendrite seeding material.

According to a fourth aspect of the present invention, there is provided a method of extending the life of a battery, comprising: a) positioning a dendrite seeding material in an electrolyte solution disposed between a metal-containing electrode and an electrolyte permeable separator membrane; b) growing metal dendrites from the lithium dendrite seeding material toward the lithium-containing electrode; and c) contacting metal dendrites extending from the metal containing electrode with metal dendrites extending from the metal dendrite seeding material; wherein the electrolyte contains metal ions.

According to a fifth aspect of the present invention, there is provided a method of producing a dendrite seeding separator material, comprising: a) identifying a carbon separator surface; b) functionalizing the carbon separator surface with a chemically bound anion-containing structure; c) introducing a neutral metal salt to the functionalized carbon separator surface; d) reacting the neutral salt to yield a metal cation and an anion; and e) attracting the metal cation to the chemically-bound anion.

According to a sixth aspect of the present invention, there is provided a method for controlling metal dendrite growth in a battery cell comprising: a) determining a desired porosimetry value for an electrolyte membrane; b) providing the electrolyte membrane with the porosimetry value; c) grafting a dendrite seeding material onto the electrolyte membrane; d) introducing a metal cation gradient from a metal electrode through the electrolyte membrane; e) immobilizing a portion of the metal cations on an electrode facing surface of the electrolyte membrane; and f) promoting directional dendrite growth on a membrane facing side of an electrode and on an electrode facing side of a membrane.

According to a seventh aspect of the present invention, there is provided a method for controlling metal dendrite growth in an electrochemical cell comprising: a) coating an electrolytically permeable and electrically insulating membrane with a non-reactive metal coating; b) functionalizing the non-reactive metal coating to yield a functionalized non-reactive metal coating; c) positioning an electrolyte solution between an electrode and the functionalized non-reactive metal coating; d) introducing a metal cation gradient from a metal electrode through the electrolytically permeable and electrically insulating membrane; e) immobilizing a portion of the metal cations on the functionalized non-reactive metal coating; and f) promoting directional dendrite growth through the electrolyte solution from the electrode and from the membrane.

11. The battery cell of claim 6 wherein the battery cell is rechargeable.

12. The battery cell of claim 6 wherein the battery cell is symmetric.

13. A device for extending the life of a battery, comprising:

an electrode having a metal portion, wherein the metal portion is selected from the group including lithium, calcium, magnesium, sodium, potassium and combinations thereof;

an electrolyte permeable membrane; and

a metal dendrite seeding material disposed between the electrode and the membrane;

wherein the electrode, the membrane and the metal dendrite seeding material are positioned in an electrolyte matrix and;

wherein at least one dendrite extendsing from the electrode toward the electrolyte permeable membrane combines with at least one dendrite extending from the dendrite seeding material.

14. The device of claim 13 wherein the metal dendrite seeding material is a plurality of metal functionalized carbon nanoparticles and wherein the metal is selected from the group including lithium, calcium, magnesium, sodium, potassium and combinations thereof.

26. A method for producing an electrolyte polymer membrane comprising:

mixing a particulate carbon source with a plurality of solvents to form a suspension;

identifying a binding element to affect adhesion of suspended carbon particles to a permeable membrane;

applying the binding element to the permeable membrane to define an adhesive membrane;

applying the suspension to the adhesive membrane; and

forming an interface between the suspension.

27. The method of claim 26 wherein the suspension is plurality of functionalized nanocarbon particles.

28. The method of claim 26 wherein the carbon substance is selected from the group including carbon black, graphene, graphite, nanographite, and combinations thereof.

29. The method of claim 26 wherein the binding element and the electrolyte polymer membrane have a substantially similar chemical composition.

30. The method of claim 26 wherein application of the suspension is accomplished by a technique selected from the group including hot pressing, spraying, machine blade coating, brush painting, and combinations thereof.

~~31. The method of claim 26 wherein the suspension is uniformly dispersed.~~

~~32. The method of claim 26 further comprising maintaining adhesion of the suspension by the binding element.~~

2633. A method for controlling metal dendrite growth in an electrochemical cell comprising:

a) coating an electrolytically permeable and electrically insulating membrane with a non-reactive metal coating;

b) functionalizing the non-reactive metal coating to yield a functionalized non-reactive metal coating;

c) positioning an electrolyte solution between and electrode and the functionalized non-reactive metal coating;

d) introducing a metal cation gradient from a metal electrode through the electrolytically permeable and electrically insulating membrane;

e) immobilizing a portion of the metal cations on the functionalized non-reactive metal coating; and

f) promoting directional dendrite growth through the electrolyte solution from the electrode and from the membrane.