electrolyte or hydrogel separator, for example, may compress on assembly and not simply run out of the battery as a liquid electrolyte would. Once the battery is sealed, the electrolyte and/or separator may then push back against the cathode. An embossing step may be performed after assembly of the laminar stack, introducing compression into the stack.

Exemplary Illustrated Processing of Biocompatible Energization Elements – Placed Separator

An example of the steps that may be involved in processing biocompatible energization elements may be found referring to Figs. 4A – 4N. The processing at some of the exemplary steps may be found in the individual figures. In Fig. 4A, a combination of a PET Cathode Spacer 401 and a PET Gap Spacer 404 may be illustrated. The PET Cathode Spacer 401 may be formed by applying films of PET 403 which, for example, may be roughly 3 mils thick. On either side of the PET layer may be found PSA layers or these may be capped with a polyvinylidene fluoride (PVDF) release layer 402 which may be roughly 1 mil in thickness. The PET Gap spacer 404 may be formed of a PVDF layer 409 which may be roughly 3 mils in thickness. There may be a capping PET layer 405 which may be roughly 0.5 mils in thickness. Between the PVDF layer 409 and the capping PET layer 405, in some examples, may be a layer of PSA.

Proceeding to Fig. 4B, a hole 406 in the Gap spacer layer may be cut by laser cutting treatment. Next at Fig. 4C, the cut PET Gap spacer layer may be laminated 408 to the PET Cathode Spacer layer. Proceeding to Fig. 4D, a cathode spacer hole 410 may be cut by laser cutting treatment. The alignment of this cutting step may be registered to the previously cut features in the PET Gap spacer Layer. At Fig. 4E, a layer of Celgard 412, for an ultimate separator layer, may be bonded to a carrier 411. Proceeding to Fig. 4F, the Celgard material may be cut to figures that are between the size of the previous two laser cut holes, and approximately the size of the PET gap spacer hole, forming a precut separator 420. Proceeding to Fig. 4G, a pick and place tool 421 may be used to pick and place discrete pieces of Celgard into their desired locations on the growing device. At Fig. 4H, the placed Celgard pieces 422 are fastened into place and then the PVDF release layer 423 may be removed. Proceeding to Fig. 4I, the growing device structure may be bonded to a film of the anode 425. The anode may be comprised of an anode collector film upon which a zinc anode

film has been electrodeposited.

Proceeding to Fig. 4J, a cathode slurry 430 may be placed into the formed gap. A squeegee 431 may be used in some examples to spread the cathode mix across a work piece and in the process fill the gaps of the battery devices being formed. After filling, the remaining PVDF release layer 432 may be removed which may result in the structure illustrated in Fig. 4K. At Fig. 4L the entire structure may be subjected to a drying process which may shrink the cathode slurry 440 to also be at the height of the PET layer top. Proceeding to Fig. 4M, a cathode film layer 450, which may already have the cathode collector film upon it, may be bonded to the growing structure. In a final illustration at Fig. 4N a laser cutting process may be performed to remove side regions 460 and yield a battery element 470. There may be numerous alterations, deletions, changes to materials and thickness targets that may be useful within the intent of the present disclosure.

The result of the exemplary processing may be depicted in some detail at Fig. 5. In an example, the following reference features may be defined. The Cathode chemistry 510 may be located in contact with the cathode and cathode collector 520. A pressure sensitive adhesive layer 530 may hold and seal the cathode collector 520 to a PET Spacer layer 540. On the other side of the PET Spacer layer 540, may be another PSA layer 550, which seals and adheres the PET Spacer layer 540 to the PET Gap layer 560. Another PSA layer 565 may seal and adhere the PET Gap layer 560 to the Anode and Anode Current Collector layers. A Zinc Plated layer 570 may be plated onto the Anode Current Collector 580. The separator layer 590 may be located within the structure to perform the associated functions as have been defined in the present disclosure. In some examples, an electrolyte may be added during the processing of the device, in other examples, the separator may already comprise electrolyte.

Exemplary Processing Illustration of Biocompatible Energization Elements – Deposited Separator

An example of the steps that may be involved in processing biocompatible energization elements may be found in Figs. 6A – 6H. The processing at some of the exemplary steps may be found in the individual figures. There may be numerous alterations, deletions, changes to materials and thickness targets that may be useful within the intent of

WHAT IS CLAIMED IS:

1. A method of forming a biocompatible energization element, the method comprising:

receiving a first substrate film of a first insulating material;

cutting a cavity in the first substrate film to form a cathode spacer layer, wherein an edge of the cavity defines a sidewall of the cavity;

receiving an anode film comprising anode chemicals;

adhering a first surface of the cathode spacer layer to a first surface of the anode film;

depositing a separator into the biocompatible energization element through the cavity in the cathode spacer layer, wherein the separator comprises a mixture of polymerizable material intermixed with droplets of non-polymerizable material;

polymerizing the polymerizable material.

immersing the substrate film with deposited separator in a solvent, wherein the solvent dissolves the droplets of non-polymerizable material and does not dissolve the polymer, wherein the dissolving of droplets of non-polymerizable material creates voids in the separator;

receiving a cathode slurry comprising cathode chemicals; and

placing the cathode slurry into the cavity in the cathode spacer layer, wherein the sidewall of the cavity in the cathode spacer layer and a surface of the deposited separator contain the cathode slurry.

2. The method of claim 1 further comprising adding an electrolyte to the cathode slurry in the cavity.

3. The method of claim 2 wherein the electrolyte comprises lithium hexafluorophosphate.

4. The method of claim 1 wherein the cathode chemicals comprise a salt of lithium.

5. The method of claim 4 wherein the salt of lithium comprises lithium iron phosphate.

6. The method of claim 1 wherein the cathode chemicals comprise one or more of lead, nickel, lithium, cobalt, zinc, sodium, vanadium, silver, or silicon.

7. The method of claim 1 wherein the cathode chemicals comprise sodium carboxymethyl cellulose.

8. The method of claim 1 wherein the cathode chemicals comprise one or more of synthetic graphite, styrene butadiene rubber and carbon black.

9. The method of claim 1 wherein the anode chemicals comprise intercalated metal atoms.

10. The method of claim 9 wherein the intercalated metal atoms comprise intercalated lithium atoms.

11. The method of claim 1 additionally comprising:

receiving a second packaging film comprising a film stack wherein a film layer of the film stack is a metallic moisture barrier; and

adhering the second packaging film to at least a portion of the anode film.

12. The method of claim 1 wherein the polymerizable material comprises:

hydroxyethylmethacrylate (HEMA);

ethylene glycol dimethylacrylate (EGDMA); and

polyvinylpyrrolidone (PVP).

13. The method of claim 1 further comprising connecting the biocompatible energization element to an electroactive element within a biomedical device.

14. The method of claim 13 further comprising connecting the biocompatible energization element to the electroactive element within the biomedical device.

15. The method of claim 14 wherein the biomedical device is an ophthalmic device.

16. The method of claim 15 wherein the biomedical device is a contact lens.

17. A method of forming a biocompatible energization element, the method comprising:

receiving a first substrate film of a first insulating material;

receiving a second substrate film of a second insulating material;

cutting a first cavity in the second substrate film to form a gap spacer layer;

cutting a second cavity in the first substrate film to form a cathode spacer layer, wherein an edge of the second cavity defines a sidewall of the cavity;

laminating a first surface of the gap spacer layer to a first surface of the cathode spacer layer;

placing a separator into the biocompatible energization element through the first cavity;

receiving an anode film comprising anode chemicals, wherein the anode chemicals comprise intercalated metal atoms;

adhering a second surface of the gap spacer layer to a first surface of the anode film;

receiving a cathode slurry comprising cathode chemicals; and

placing the cathode slurry into the second cavity, wherein the sidewall of the second cavity and a surface of the separator form a third cavity to contain the cathode slurry.

18. The method of claim 17 additionally comprising:

receiving a cathode contact film; and

adhering a second surface of the cathode spacer layer to at least a portion of a first surface of the cathode contact film.

19. The method of claim 18 additionally comprising:

receiving a first packaging film comprising a film stack wherein one layer is a metallic moisture barrier; and

adhering the first packaging film to at least a portion of the cathode contact film.

20. The method of claim 19 additionally comprising:

adhering the biocompatible energization element to a portion of a biomedical device.

21. The method of claim 17 wherein the biocompatible energization element is added to an insert of a biomedical device, wherein the biocompatible energization element is sealed within the insert.

22. The method of claim 21 wherein the biomedical device is a contact lens.

23. The method of claim 17 wherein the cathode chemicals comprise a salt of lithium.

24. The method of claim 23 wherein the cathode chemicals comprise lithium iron phosphate.

25. The method of claim 17 wherein the anode chemicals comprise intercalated lithium atoms.

26. The method of claim 17 wherein the anode chemicals comprise intercalated sodium atoms.

27. The method of claim 26 wherein the cathode chemicals comprise one or more of lead, nickel, lithium, cobalt, zinc, sodium, vanadium, silver, or silicon.

28. The method of claim 27 wherein the cathode chemicals comprise lithium iron phosphate.

29. The method of claim 28 wherein the cathode chemicals comprise sodium carboxymethyl cellulose.

30. The method of claim 29 wherein the cathode chemicals comprise one or more of synthetic graphite and carbon black.

31. The method of claim 30 wherein the cathode chemicals comprise one or more of styrene butadiene rubber.

32. The method of claim 17 further comprising adding an electrolyte to the cathode slurry, wherein the electrolyte comprises lithium hexafluorophosphate.

33. The method of claim 32 further comprising connecting the biocompatible energization element to an electroactive element within a biomedical device.

34. The method of claim 33 further comprising connecting the biocompatible energization element to the electroactive element within the biomedical device.

35. The method of claim 34 wherein the biomedical device is an ophthalmic device.

36. The method of claim 35 wherein the biomedical device is a contact lens.

electrolyte or hydrogel separator, for example, may compress on assembly and not simply run out of the battery as a liquid electrolyte would. Once the battery is sealed, the electrolyte and/or separator may then push back against the cathode. An embossing step may be performed after assembly of the laminar stack, introducing compression into the stack.

Exemplary Illustrated Processing of Biocompatible Energization Elements – Placed Separator

An example of the steps that may be involved in processing biocompatible energization elements may be found referring to Figs. 4A – 4N. The processing at some of the exemplary steps may be found in the individual figures. In Fig. 4A, a combination of a PET Cathode Spacer 401 and a PET Gap Spacer 404 may be illustrated. The PET Cathode Spacer 401 may be formed by applying films of PET 403 which, for example, may be roughly 3 mils thick. On either side of the PET layer may be found PSA layers or these may be capped with a polyvinylidene fluoride (PVDF) release layer 402 which may be roughly 1 mil in thickness. The PET Gap spacer 404 may be formed of a PVDF layer 409 which may be roughly 3 mils in thickness. There may be a capping PET layer 405 which may be roughly 0.5 mils in thickness. Between the PVDF layer 409 and the capping PET layer 405, in some examples, may be a layer of PSA.

Proceeding to Fig. 4B, a hole 406 in the Gap spacer layer may be cut by laser cutting treatment. Next at Fig. 4C, the cut PET Gap spacer layer 404 may be laminated 408 to the PET Cathode Spacer layer. Proceeding to Fig. 4D, a cathode spacer hole 410 may be cut by laser cutting treatment. The alignment of this cutting step may be registered to the previously cut features in the PET Gap spacer Layer. At Fig. 4E, a layer of Celgard 412, for an ultimate separator layer, may be bonded to a carrier 411. Proceeding to Fig. 4F, the Celgard material may be cut to figures that are between the size of the previous two laser cut holes, and approximately the size of the PET gap spacer hole, forming a precut separator 420. Proceeding to Fig. 4G, a pick and place tool 421 may be used to pick and place discrete pieces of Celgard into their desired locations on the growing device. At Fig. 4H, the placed Celgard pieces 422 are fastened into place and then the PVDF release layer 423 may be removed. Proceeding to Fig. 4I, the growing device structure may be bonded to a film of the anode 425. The anode may be comprised of an anode collector film upon which a zinc anode

film has been electrodeposited.

Proceeding to Fig. 4J, a cathode slurry 430 may be placed into the formed gap. A squeegee 431 may be used in some examples to spread the cathode mix across a work piece and in the process fill the gaps of the battery devices being formed. After filling, the remaining PVDF release layer 432 may be removed which may result in the structure illustrated in Fig. 4K. At Fig. 4L the entire structure may be subjected to a drying process which may shrink the cathode slurry 440 to also be at the height of the PET layer top. Proceeding to Fig. 4M, a cathode film layer 450, which may already have the cathode collector film upon it, may be bonded to the growing structure. In a final illustration at Fig. 4N a laser cutting process may be performed to remove side regions 460 and yield a battery element 470. There may be numerous alterations, deletions, changes to materials and thickness targets that may be useful within the intent of the present disclosure.

The result of the exemplary processing may be depicted in some detail at Fig. 5. In an example, the following reference features may be defined. The Cathode chemistry 510 may be located in contact with the cathode and cathode collector 520. A pressure sensitive adhesive layer 530 may hold and seal the cathode collector 520 to a PET Spacer layer 540. On the other side of the PET Spacer layer 540, may be another PSA layer 550, which seals and adheres the main portion of the PET Spacer layer 540 to the remainder of the PET spacer layer 560. Another PSA layer 565 may seal and adhere the PET Gap layer 560 to the Anode and Anode Current Collector layers. A Zinc Plated layer 570 may be plated onto the Anode Current Collector 580. The separator layer 590 may be located within the structure to perform the associated functions as have been defined in the present disclosure. In some examples, an electrolyte may be added during the processing of the device, in other examples, the separator may already comprise electrolyte.

Exemplary Processing Illustration of Biocompatible Energization Elements – Deposited Separator

An example of the steps that may be involved in processing biocompatible energization elements may be found in Figs. 6A – 6H. The processing at some of the exemplary steps may be found in the individual figures. There may be numerous alterations, deletions, changes to materials and thickness targets that may be useful within the intent of

CLAIM S

1. A method of forming a biocompatible energization element (110), the method comprising:

receiving a first substrate film (403) of a first insulating material;

cutting a cavity (410) in the first substrate film to form a cathode spacer layer (401), wherein an edge of the cavity defines a sidewall of the cavity;

receiving an anode film (425) comprising anode chemicals;

adhering a first surface of the cathode spacer layer (401) to a first surface of the anode film (425);

depositing a separator (422) into the biocompatible energization element (110) through the cavity (410) in the cathode spacer layer (401), wherein the separator (422) comprises a mixture of polymerizable material intermixed with droplets of non-polymerizable material;

polymerizing the polymerizable material;

immersing the substrate film with deposited separator (422) in a solvent, wherein the solvent dissolves the droplets of non-polymerizable material and does not dissolve the polymer, wherein the dissolving of droplets of non-polymerizable material creates voids in the separator (422);

receiving a cathode slurry (430) comprising cathode chemicals; and

placing the cathode slurry (430) into the cavity in the cathode spacer layer, wherein the sidewall of the cavity in the cathode spacer layer and a surface of the deposited separator (422) contain the cathode slurry (430).

2. The method of claim 1 further comprising:

adding an electrolyte to the cathode slurry (430) in the cavity.

3. The method of claim 2 wherein the electrolyte comprises lithium hexafluorophosphate.

4. The method of claim 1 wherein the cathode chemicals comprise a salt of lithium.

5. The method of claim 4 wherein the salt of lithium comprises lithium iron phosphate.

6. The method of claim 1 wherein the cathode chemicals comprise one or more of lead, nickel, lithium, cobalt, zinc, sodium, vanadium, silver, or silicon.

7. The method of claim 1 wherein the cathode chemicals comprise sodium carboxymethyl cellulose.

8. The method of claim 1 wherein the cathode chemicals comprise one or more of synthetic graphite, styrene butadiene rubber and carbon black.

9. The method of claim 1 wherein the anode chemicals comprise intercalated metal atoms.

10. The method of claim 9 wherein the intercalated metal atoms comprise intercalated lithium atoms.

11. The method of claim 1 additionally comprising:

receiving a second packaging film comprising a film stack wherein a film layer of the film stack is a metallic moisture barrier; and

adhering the second packaging film to at least a portion of the anode film.

12. The method of claim 1 wherein the polymerizable material comprises:

hydroxyethylmethacrylate (HEMA);

ethylene glycol dimethylacrylate (EGDMA); and

polyvinylpyrrolidone (PVP).

13. The method of claim 1 further comprising:

connecting the biocompatible energization element (110) to an electroactive element within a biomedical device.

14. The method of claim 13 further comprising:

connecting the biocompatible energization element (110) to the electroactive element within the biomedical device.

15. The method of claim 14 wherein the biomedical device is an ophthalmic device.

16. The method of claim 15 wherein the biomedical device is a contact lens.

17. A method of forming a biocompatible energization element, (110) the method comprising:

receiving a first substrate film (403) of a first insulating material;

receiving a second substrate film (409) of a second insulating material;

cutting a first cavity (406) in the second substrate film to form a gap spacer layer (404);

cutting a second cavity (410) in the first substrate film to form a cathode spacer layer (401), wherein an edge of the second cavity (410) defines a sidewall of the cavity;

laminating (408) a first surface of the gap spacer layer (404) to a first surface of the cathode spacer layer (401);

placing a separator (820/822) into the biocompatible energization element (110) through the first cavity (406);

receiving an anode film (425) comprising anode chemicals, wherein the anode chemicals comprise intercalated metal atoms;

adhering a second surface of the gap spacer layer (404) to a first surface of the anode film;

receiving a cathode slurry (430) comprising cathode chemicals; and

placing the cathode slurry (430) into the second cavity (410), wherein the sidewall of the second cavity (410) and a surface of the separator (820/822) form a third cavity (822) to contain the cathode slurry (430).

18. The method of claim 17 additionally comprising:

receiving a cathode contact film (450); and

adhering a second surface of the cathode spacer layer (401) to at least a portion of a first surface of the cathode contact film (450).

19. The method of claim 18 additionally comprising:

receiving a first packaging film comprising a film stack wherein one layer is a metallic moisture barrier; and

adhering the first packaging film to at least a portion of the cathode contact film (450).

20. The method of claim 19 additionally comprising:

adhering the biocompatible energization element (110) to a portion of a biomedical device (100).

21. The method of claim 17 wherein the biocompatible energization element (110) is added to an insert of a biomedical device (100), wherein the biocompatible energization element (110) is sealed within the insert.

22. The method of claim 21 wherein the biomedical device (100) is a contact lens.

23. The method of claim 17 wherein the cathode chemicals comprise a salt of lithium.

24. The method of claim 23 wherein the cathode chemicals comprise lithium iron phosphate.

25. The method of claim 17 wherein the anode chemicals comprise intercalated lithium atoms.

26. The method of claim 17 wherein the anode chemicals comprise intercalated sodium atoms.

27. The method of claim 26 wherein the cathode chemicals comprise one or more of lead, nickel, lithium, cobalt, zinc, sodium, vanadium, silver, or silicon.

28. The method of claim 27 wherein the cathode chemicals comprise lithium iron phosphate.

29. The method of claim 28 wherein the cathode chemicals comprise sodium carboxymethyl cellulose.

30. The method of claim 29 wherein the cathode chemicals comprise one or more of synthetic graphite and carbon black.

31. The method of claim 30 wherein the cathode chemicals comprise one or more of styrene butadiene rubber.

32. The method of claim 17 further comprising:

adding an electrolyte to the cathode slurry, wherein the electrolyte comprises lithium hexafluorophosphate.

33. The method of claim 32 further comprising:

connecting the biocompatible energization element (110) to an electroactive element within a biomedical device (100).

34. The method of claim 33 further comprising:

connecting the biocompatible energization element (110) to the electroactive element within the biomedical device (100).

35. The method of claim 34 wherein the biomedical device (100) is an ophthalmic device.

36. The method of claim 35 wherein the biomedical device (100) is a contact lens.