

CROSS REFERENCE TO RELATED APPLICATIONS

10 61/665,970, filed June 29, 2012.

The invention relates to methods and apparatus operant to form a device whereon energization elements can be defined upon electrical interconnections. The methods and apparatus to form energization elements may relate to said formation upon electrical
15 interconnection surfaces that occur on substrates that have three-dimensional surfaces. A field of use for the methods and apparatus may include ophthalmic lenses that incorporate energization elements.

Traditionally, an ophthalmic lens, such as a contact lens, an intraocular lens, or a punctal plug, included a biocompatible device with a corrective, cosmetic, or therapeutic quality. A contact lens, for example, may provide one or more of vision correcting functionality, cosmetic enhancement, and therapeutic effects. Each function is provided by a physical characteristic of the lens. A design incorporating a refractive quality into a lens may provide a vision corrective function. A pigment incorporated into the lens may provide a cosmetic enhancement. An active agent incorporated into a Lens may provide a therapeutic functionality. Such physical characteristics are accomplished without the lens entering into an energized state. A punctal plug has traditionally been a passive device.

More recently, it has been theorized that active components may be incorporated
30 into a contact lens. Some components may include semiconductor devices. Some
examples have shown semiconductor devices embedded in a contact lens placed upon

5 animal eyes. It has also been described how the active components may be Energized and activated in numerous manners within the lens structure itself. The topology and size of the space defined by the lens structure creates a novel and challenging environment for the definition of various functionalities. In many embodiments, it is important to provide reliable, compact, and cost effective means to energize components within an ophthalmic
10 lens. These energization elements may include batteries that may also be formed from "alkaline" cell-based chemistry.

Technological embodiments that address such an ophthalmological background may need to generate solutions that not only address ophthalmic requirements but also encompass novel embodiments for the more general technology space of defining
15 energization elements upon interconnections that are within or upon devices that have a three-dimensional surface.

The fabrication of an energization element, which may also be referred to herein as "a printed battery" for inclusion in an ophthalmic Lens presents a number of challenges, particularly in relation to the substrate having a three-dimensional surface.
20 The present disclosure aims to address these challenges.

SUMMARY

Accordingly, an aspect of the present invention includes methods and apparatus to define energization elements upon electrical interconnections that are formed upon three-dimensional surfaces, which may be included as inserts into a finished ophthalmic Lens.
25 Also provided is an insert that may be energized and incorporated into an ophthalmic lens. The insert may be formed in a number of manners that can result in a three-dimensional surface upon which electrical interconnections may be formed. Subsequently, energization elements may be formed in contact with or upon these electrical interconnections. For example, the energization elements may be formed by
30 applying deposits containing battery-cell-related chemicals to the electrical interconnections. The application may be performed, for example, by a printing process in which mixtures of the chemicals can be applied using dispensing needles or other

5 application tools. The novel devices thus formed are an important aspect of the inventive art disclosed herein.

The ophthalmic lens of the present invention may include an active focusing element, such as the active focusing elements described in, for example, WO 2011/143554 A1 "Arcuate Liquid Meniscus Lens" and WO 2012/044589 A1 "Lens with
10 Multi-Segmented Linear Meniscus Wall," the contents of which are herein incorporated by reference. Such an active focusing element may function by utilizing energy that may be stored in an energization element.

The details of the energization element construction may provide important design aspects for the devices. Adhesion of the various deposits may be challenging,
15 especially where wet chemical electrolytes are used. As a result, adhesion may be enhanced by a change in surface roughness of the substrate used, for example, by electrical discharge machining (EDM) texture on plastic, by including patterned current collectors, or both. Patterns may include, for example, different protrusions and gaps in the electrode layers that may enhance adhesion. different deposit compositions may also
20 be relevant to construction for robust performance.

The chemical composition of the various deposit layers provides additional inventive art. The presence and amounts of various binders and fillers may also be relevant. Additionally, the unique microscopic characteristics of chemical constituents of the battery electrodes may also be important. Accordingly, the present invention includes
25 a disclosure of a technological framework for forming and defining energizing elements upon interconnections upon three-dimensional surfaces. Disclosure is made of an ophthalmic lens with an insert upon which energizing components are attached and interconnected by metal, metal-containing, or otherwise conductive lines defined upon the surface of the insert; and an apparatus for forming an ophthalmic lens with energizing
30 elements upon electrical interconnections defined upon three-dimensional surfaces and methods for the same.

In an aspect of the present invention there is provided a method of forming an energized insert on a three-dimensional substrate for an ophthalmic lens, the method comprising the steps of:

5 forming a three-dimensional substrate of suitable size for inclusion in an
ophthalmic lens from a first insulating material;
 defining conductive traces on said substrate;
 forming energization elements on a first portion of the conductive traces,
 wherein said energization elements are comprised of a first Anode Trace and at
10 least a first cathode trace;
 applying electrolyte upon energization elements; and
 encapsulating said energization elements and electrolyte.

 The method may additionally comprise modifying a first portion of a first surface
of said substrate to increase surface area of said first portion. Alternately or in addition,
15 the method may comprise modifying a first portion of a first surface of said substrate to
alter the surface chemistry of said first portion.

 Modification of the first surface of the substrate may include roughening the
surface to form textured patterns.

 The method may additionally comprise the step of coating the substrate with at
20 least a first layer of parylene. The parylene may be parylene-C.

 The three-dimensional substrate forms part of a media insert that may be
incorporated in a hydrogel ophthalmic lens.

 The conductive traces may be formed using printing techniques. The printing
techniques may include moving the substrate in relation to a depositing tip used in the
25 printing technique. The printing techniques may include moving the depositing tip used
in the printing technique in relation to the substrate.

 The method may further comprise forming a first bridge trace between portions of
the anode trace and the cathode trace.

 The conductive traces may be formed using additive lithographic techniques. The
30 lithographic techniques may further include subtractive processing methods.

5 The encapsulation material may be parylene, for example parylene-C.

 The conductive traces may protrude through the encapsulation material.

 The electrolyte may be applied through injection means through the encapsulation material after the encapsulation of the energization elements occurs. The encapsulation of the energization elements may occur prior to the application of the electrolyte, and the
10 electrolyte may be applied onto a filling feature formed into the encapsulation material.

 The method may further comprise the step of sealing the filling feature.

 In a further aspect of the present invention there is provided an ophthalmic lens comprising an Energized insert, wherein the insert comprises:

 a three dimensional substrate comprising a first insulating material;
15 conductive traces on said substrate;
 energization elements on a first portion of the conductive traces, wherein said energization elements are comprised of a first anode trace and at least a first cathode trace;
 an electrolyte upon the energization elements; and
20 an encapsulant encapsulating said energization elements and electrolyte.

 The ophthalmic lens comprising the insert may be a contact lens, preferably a soft contact lens.

 The substrate of the insert may comprise a coating layer of parylene on which the conductive traces are positioned. The parylene may be parylene-C.

25 The insert may further comprise a first bridge trace between portions of the anode trace and the cathode trace.

 The encapsulation material may be parylene. The parylene may be parylene-C.

 The conductive traces may protrude through the encapsulation material.

5 In a further aspect of the present invention, the ophthalmic lens may consist of the insert.

DESCRIPTION OF THE DRAWINGS

10 The foregoing and other features and advantages of the invention will be apparent from the following, more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

Fig. 1 illustrates an exemplary substrate with three-dimensional surfaces upon which interconnections may be defined.

15 Fig. 2 illustrates an exemplary cross-sectional depiction of energization elements on interconnections on a three-dimensional substrate.

Fig. 3 illustrates an example of forming energization elements on a three-dimensional substrate by a printing means.

20 Fig. 4 illustrates a top down depiction of an exemplary battery element construction.

Fig. 5 illustrates of an alternative exemplary design for conductive traces operant for formation of energization elements with enhanced adhesion characteristics.

25 Fig. 6 illustrates exemplary methods steps to form energization elements on Three-dimensional Surfaces.

DETAILED DESCRIPTION

30 Methods and apparatus useful to the formation of energization elements upon electrical interconnects that are upon surfaces having three-dimensional topology are described herein. In the following sections, detailed descriptions of embodiments of the invention will be given. The description of both preferred and alternative embodiments are exemplary embodiments only, and it is understood that to those skilled in the art that variations, modifications, and alterations may be apparent. It is therefore to be

- 5 understood that said exemplary embodiments do not limit the scope of the underlying invention.

GLOSSARY

10 In this description and claims directed to the presented invention, various terms may be used for which the following definitions will apply:

"Anode" as used herein refers to an electrode through which electric current flows into a polarized electrical device. The direction of electric current that is typically opposite to the direction of electron flow. In other words, the electrons flow from the Anode into, for example, an electrical circuit.

15 "Binder" as used herein refers to a polymer that is capable of exhibiting elastic responses to mechanical deformations and that is chemically compatible with other battery components. For example, it may include electroactive materials, electrolyte, and current collectors.

"Cathode" as used herein refers to an electrode through which electric current
20 flows out of a polarized electrical device. The direction of electric current that is typically opposite to the direction of electron flow. Therefore, the electrons flow into the polarized electrical device and out of, for example, the connected electrical circuit.

"Deposit" as used herein refers to any application of material, including, for example, a coating or a film.

25 "Electrode" as used herein can refer to an active mass in the energy source. For example, it may include one or both of the anode and cathode.

"Encapsulate" as used herein refers to creating a barrier surrounding an entity for the purpose of containing specified chemicals within the entity and reducing the amount of specific substances, such as, for example, water, from entering the entity. Preferably,
30 creating a barrier completely surrounding an entity for the purpose of containing specified chemicals within the entity and preventing specific substances, such as, for example, water, from entering the entity.

5 "Encapsulant" as used herein refers to any substance, composite, or mixture that surrounds an entity for the purpose of containing specified chemicals within the entity and reducing the amount of specific substances, such as, for example, water, from entering the entity. Preferably, the encapsulant completely surrounds an entity for the purpose of containing specified chemicals within the entity and preventing specific
10 substances, such as, for example, water, from entering the entity.

"Energized" as used herein refers to the state of being able to supply electrical current to or to have electrical Energy stored within.

"Energy Harvesters" as used herein refers to devices capable of extracting Energy from the environment and converting it to electrical energy.

15 "Energy Source" as used herein refers to any device or layer that is capable of supplying Energy or placing a logical or electrical device in an energized state.

"Energy" as used herein refers to the capacity of a physical system to do work. Many instances of energy used herein may relate to the said capacity of being able to perform electrical actions in doing work.

20 "Filler" as used herein refers to one or more battery separator that does not react with either acid or alkaline electrolytes. Generally, fillers may be substantially water insoluble and operable, including, for example, carbon black, coal dust and graphite, metal oxides and hydroxides such as those of silicon, aluminum, calcium, magnesium, barium, titanium, iron, zinc, and tin; metal carbonates such as those of calcium and
25 magnesium; minerals such as mica, montmorillonite, kaolinite, attapulgite, talc; synthetic and natural zeolites, Portland cement; precipitated metal silicates such as calcium silicate; hollow microspheres, and flakes and fibers; polymer microspheres; glass microspheres.

"Functionalized" as used herein refers to making a layer or device able to perform a function including for example, energization, activation, or control.

30 "Lens" as used herein refers to any device that resides in or on the eye. The device may provide optical correction, may be cosmetic, or provide some functionality unrelated to optic quality. For example, the term lens may refer to a contact lens, intraocular lens, overlay lens, ocular insert, optical insert, or other similar device through which vision is corrected or modified, or through which eye physiology is cosmetically

5 enhanced (e.g. iris color) without impeding vision. Alternately, lens may refer to a device that may be placed on the eye with a function other than vision correction, such as, for example, monitoring of a constituent of tear fluid or means of administering an active agent. Typically, the lens is a contact lens. The preferred lenses of the invention may be soft contact lenses that are made from silicone elastomers or hydrogels, which may
10 include, for example, silicone hydrogels and fluorohydrogels.

"Lens-forming Mixture" or "Reactive Mixture" or "RMM" as used herein refer to a monomeric composition and/or prepolymer material that may be cured and cross-linked or cross-linked to form an ophthalmic lens. Various examples may include lens-forming mixtures with one or more additives such as UV blockers, tints, diluents, photoinitiators
15 or catalysts, and other additives that may be useful in an ophthalmic lenses such as, contact or intraocular lenses.

"Lens-Forming Surface" as used herein refers to a surface that may be used to mold a lens. Any such surface may have an optical quality surface finish, which indicates that it is sufficiently smooth and formed so that a lens surface fashioned by the
20 polymerization of a lens forming material in contact with the molding surface is optically acceptable. Further, the lens-forming surface may have a geometry that may be necessary to impart to the lens surface the desired optical characteristics, including, for example, spherical, aspherical and cylinder power, wave front aberration correction, and corneal topography correction.

25 "Mold" as used herein refers to a rigid or semi-rigid object that may be used to form lenses from uncured formulations. Some preferred molds include two mold parts forming a front curve mold part and a back curve mold part, each mold part having at least one acceptable lens-forming surface.

"Optical Zone" as used herein refers to an area of an ophthalmic lens through
30 which a user of the ophthalmic lens sees.

"Power" as used herein refers to work done or energy transferred per unit of time.

"Rechargeable" or "Re-energizable" as used herein refers to a capability of being restored to a state with higher capacity to do work. Many uses within this invention may

5 relate to the capability of being restored with the ability to flow electrical current at a certain rate for certain, reestablished time periods.

"Reenergize" or "Recharge" as used herein refers to restoring to a state with higher capacity to do work. Many uses within this invention may relate to restoring a device to the capability to flow electrical current at a certain rate for certain, reestablished
10 time periods.

"Released" or "Released from a Mold" as used herein refers to a lens that is either completely separated from the mold or is only loosely attached so that it may be removed with mild agitation or pushed off with a swab.

"Stacked Integrated Component Devices" or "SIC Devices" as used herein refers
15 to the product of packaging technologies that assemble thin layers of substrates, which may contain electrical and electromechanical devices, into operative integrated devices by means of stacking at least a portion of each layer upon each other. The layers may comprise component devices of various types, materials, shapes, and sizes. Furthermore, the layers may be made of various device production technologies to fit and assume
20 various contours.

"Stacked" as used herein refers to the placement at least two component layers in proximity to each other such that at least a portion of one surface of one of the layers contacts a first surface of a second layer. A deposit, whether for adhesion or other functions, may reside between the two layers that are in contact with each other through
25 said deposit.

"Substrate Insert" as used herein refers to a formable or rigid substrate that can be capable of supporting an energy source and may be placed on or within an ophthalmic lens. The substrate insert may also support one or more components.

"Three-dimensional Surface" or "Three-dimensional Substrate" as used herein
30 refers to any surface or substrate that has been three-dimensionally formed where the topography is designed for a specific purpose, in contrast to a planar surface. The three-dimensional substrate comprises a three-dimensional surface. The Three-dimensional Surface is non-planar and may be, for example, curved or conical or may have a complex, irregular topography. Typically, the three-dimensional surface is curved.

5 "Trace" as used herein refers to a battery component capable of electrically connecting the circuit components. For example, circuit traces may include copper or gold when the substrate is a printed circuit board and may be copper, gold, or printed deposit in a flex circuit. Traces may also be comprised of nonmetallic materials, chemicals, or mixtures thereof. A trace may function as a current collector.

10 Devices with three-dimensional surfaces with incorporated energization devices.

The methods and apparatus related to at least portions of the disclosure presented herein relate to forming energization elements within or on three-dimensional substrates with electrical interconnects upon surfaces of a three-dimensional substrate.

Referring to Fig. 1, an exemplary three-dimensional substrate 100 with electrical
15 traces is depicted. The ophthalmic lens may include an active focusing element. Such an active focusing device may function by utilizing energy that may be stored in an energization element. The traces 130, 140, 170, and 180 upon the three-dimensional substrate 100 may additionally provide a substrate to form energization elements upon.

In the exemplary ophthalmic lens, the three-dimensional substrate may include,
20 for example, an optically active region 110. Where the device has a focusing element, the optically active region 110 may represent a front surface of an insert device that comprises the focusing element through which light may pass on its way into a user's eye. In such an arrangement, there may be a peripheral region of the ophthalmic lens that may not be used as an optically relevant path. The peripheral region may comprise the
25 components related to the active focusing function. These components may be electrically connected to each other by metal traces. These metal traces may also provide conductivity and additional useful functions, including for example, supporting the incorporation of energizing elements into the ophthalmic lens.

The energization element may be a battery, including, for example, a solid-state
30 battery or a wet cell battery. Where the energization element is a battery, at least two electrically conductive traces 170 and 140 may allow an electrical potential to form between the anode 150 and the cathode 160 of the battery, providing energization to the active elements in the device. For exemplary purposes, the anode 150 represents the (-)

- 5 potential connection of an energization element to incorporated devices, and the cathode 160 represents the (+) potential connection of an energization element to incorporated devices.

Isolated traces 140 and 170 may be located proximate to neighboring traces 130 and 180. The neighboring traces 130 and 180 may represent an opposite polarity
10 electrode or chemistry type when battery elements are produced upon these traces 130 and 180. For example, a neighboring trace 130 may be connected to a chemical layer allowing the neighboring trace 130 to function as a cathode of a battery cell defined by the components on the isolated trace 140 and the neighboring trace 130.

Two traces 130 and 180 may connect to each other through a trace region 120.
15 The trace region 120 may not be coated with an active chemical layer, allowing the trace region 120 to function as an electrical interconnection.

This example illustrates the electrical traces 130, 140, 170, and 180 where two pairs of electrical cells may be configured as batteries connected in series. The total electrical performance across the connections 150 and 160 may be a combination of two
20 battery cells.

Proceeding to Fig. 2, an example of a cross sectional representation of energization elements upon the exemplary traces of the three-dimensional substrate 200 is depicted. The three-dimensional substrate 200 is a cross sectional representation of Fig. 1 along the dotted line 190. Accordingly, the electrical traces 180 and 130 of Fig. 1
25 are included in cross sectional views of traces 250 and 220 in Fig. 2.

The base material 210 of the three-dimensional substrate may have a thin coating layer 290. The three-dimensional surface with electrical traces 250 and 220 may then be formed into representative battery elements. For example, by applying or coating a deposit layer, an anode layer 260 may be formed and deposited upon an electrical trace
30 250, and a cathode layer 230 may be formed and deposited upon an electrical trace 220. The combination of the anode layer 260 and the cathode layer 230 may comprise important components of a battery.

In some exemplary battery designs, the two elements 260 and 230 may be arranged in a coplanar and separated configuration. Alternatively, a bridge layer (also

5 known herein as "bridge") 240 may connect and at least partially coat the cathode layer 230 and the anode layer 260. The bridge layer 240 may be a porous insulating layer through which ionic diffusion may occur.

In a wet cell type of battery, the electrolyte for the battery cell may be formed by combining solvent, such as an aqueous solution, and other chemicals. The aqueous or
10 wet electrolyte layer 240 may be encapsulated or sealed with a primary encapsulant 270, which may connect and seal to the substrate layers 290 and 210. A secondary encapsulant layer 280, such as parylene-C, may be included, wherein a combination of these layers 270 and 280, when deployed across the surface of the three-dimensional substrate 200 surface, may define a formed energization element.

15 It may be obvious to one skilled in the art that numerous embodiments of energization elements may be practical, and such devices are well within the scope of the inventive art. Therefore, while the cross sectional three-dimensional substrate 200 may represent an exemplary structure for an alkaline-type wet cell battery, other types of energization elements including, for example, solid-state batteries may be appropriate in
20 some other embodiments.

Forming energization elements by printing techniques

Proceeding to Fig. 3, an illustration of forming energization elements by printing techniques is depicted. As used herein, the phrase "printing techniques" is broadly represented by the process of depositing or leaving a deposit of material in defined
25 locations. Although descriptions included herein may focus on "additive" techniques where the material is placed at certain isolated locations upon a three-dimensional surface topology, one skilled in the art may recognize that "subtractive" techniques, where a coating layer may be subsequently patterned to allow for the removal of material in selected locations resulting in a pattern of isolated locations, is also within the scope of
30 the art herein.

In the printing technique 300, a printing means 310 may interact with electrical traces 330 and 340. The printing means 310 may have a printing head 320 that may control the distribution of material into a defined, localized region. In some simple

5 examples, the printing head 320 may include a stainless steel needle that may have an exit orifice size between 150 microns to 300 microns. Some exemplary reference numbers that may enable the printing include, for example, precision stainless steel tips from Nordson EFD for cathode and anode printing, more specifically 25 gauge, 27 gauge, 30 gauge or 32 gauge by 1.4" length tip. Other examples may include SmoothFlow™ tapered tips or EFD Ultimus™ model number 7017041.

The printing means 310 may include and be loaded with a mixture of a variety of active and supportive materials to result in various components of an energization element. These combinations of materials may contain an active battery anode or Cathode materials in microscopic powder form. The various compounds may be processed in sorting manners to result in a mixture that may have a small controlled distribution of sizes of the powder constituents. For example, one anode mixture may contain a zinc powder formulation comprising only powder components small enough to pass through a 25-micron sieve. By restricting the components in size by various techniques, including for example sieving, the size of the orifice of a print head may be made to be very small (e.g. 200 microns or 150 microns).

Table 1 includes examples of mixtures of components for a printable anode formulation. Table 2 provides exemplary mixtures for a printable cathode formulation. Table 3 includes exemplary mixtures for a printable bridge element formulation. In addition to the active components, the mixtures in these tables may also include a variety of solvents, fillers, binders, and other types of additional components. To one ordinarily skilled in the art, it may be obvious that numerous modifications to the makeup, constituents, amounts of materials, nature of the components of the materials, and other changes may be appropriate and is well within the scope of the present disclosure.

30

Table 1a Exemplary Anode Mixture

Material	Function/Description
PEO_Poly(ethylene oxide), Mv = 600k	diluted Binder

5.5% soln' (hot water method)	
Grillo Zn GC 2-0/200Bi/200In (Zinc alloy powder with 200 ppm Bi, 200 ppm In)	<25 μ m Zn powder
Aerosil R972 (hydrophobic fumed silica)	Rheology modifier/stabilizer
Timcal KS6 graphite	conductive particle
PEG600 (poly(ethylene glycol) Mn = 600 g/mol), 10% (w/w) in DI	plasticizer, corrosion inhibitor
Triton X-100 (polyethylene glycol p-(1,1,3,3-tetramethylbutyl)-phenyl ether), 10% (w/w) in DI	Surfactant

5 **Table 1b Exemplary Anode Mixture**

Material	Function/Description
Poly(ethylene oxide), Mv = 600k 5.5 % (w/w) in DI water'	diluted Binder
Zinc alloy powder with 200 ppm Bi, 200 ppm Indium	<25 μ m sieve analysis, active anode
Aerosil R972 (hydrophobic fumed silica)	Rheology modifier/stabilizer
Poly(ethylene glycol) Mn = 600 g/mol, 10% (w/w) in DI water	plasticizer, Zn corrosion inhibitor
Triton X-100 (polyethylene glycol p-(1,1,3,3-tetramethylbutyl)-phenyl ether), 10% (w/w) in DI water	Surfactant

Table 2a Exemplary Cathode Mixture

Material	Function
PEO_Poly(ethylene oxide), Mv = 600k 5.2% soln' (hot water method)	diluted Binder
MnO ₂ , Erachem, unsieved	Cathode active material

Aerosil R972 (hydrophobic fumed silica)	rheology modifier
Silver flake, Ferro SF120	conductive additive
Triton X-100 (polyethylene glycol p-(1,1,3,3-tetramethylbutyl)-phenyl ether), 10% (w/w) in DI	Surfactant

5 **Table 2b Exemplary Cathode Mixture**

Material	Function
Poly(ethylene oxide), Mv = 600k 5.5 % (w/w) in DI water'	diluted Binder
Electrolytic manganese dioxide powder	active cathode
Aerosil R972 (hydrophobic fumed silica)	rheology modifier
Silver flake	conductive additive
Triton X-100 (polyethylene glycol p-(1,1,3,3-tetramethylbutyl)-phenyl ether), 10% (w/w) in DI	Surfactant

Table 3a Exemplary Binder "Bridge" Separator

Material	Function
PEO_ Poly(ethylene oxide), Mv = 600k 5.5% soln' (hot water method)	diluted Binder
Barium Sulfate	Filler, solid
Aerosil R972 (hydrophobic fumed silica)	rheology modifier
PEG600 (poly(ethylene glycol) Mn = 600 g/mol), 10% (w/w) in DI	plasticizer, corrosion inhibitor
Triton X-100 (polyethylene glycol p-(1,1,3,3-tetramethylbutyl)-phenyl ether), 10% (w/w) in DI	Surfactant

Table 3b Exemplary Binder "Bridge" Separator

Material	Function
Poly(ethylene oxide), Mv = 600k 5.5 % (w/w) in DI water'	diluted Binder
Barium Sulfate	Filler, solid
Aerosil R972 (hydrophobic fumed silica)	rheology modifier
Poly(ethylene glycol) Mn = 600 g/mol, 10% (w/w) in DI water	plasticizer, corrosion inhibitor
Triton X-100 (polyethylene glycol p- (1,1,3,3-tetramethylbutyl)-phenyl ether), 10% (w/w) in DI	Surfactant

5

When the printing means 310 is loaded with a material, its printing head 320 may be moved relative to the substrate or the substrate may move relative to the printing head 320, by the control mechanisms of the printing means 310 to locate the printing head in a three-dimensional location above a defined electrical trace 330. For example, the printing means 310 may utilize an nScript device, 3Dn-TABLETOp™. As the substrate is moved relative to the printing head 320 over the correct three-dimensional path, the printing head 320 may be configured to dispense some of the chemical mixture from the printer.

As the printing process occurs, a line or combination of lines or dots may be formed into an appropriate printed feature 350 upon a current collector 330. As the process occurs, different patterns of varied chemical mixtures may be printed upon the three-dimensional substrate. Depending on the purpose of the printed feature 350 and the embodiment, printing may occur above regions with current collectors and above regions without traces.

Proceeding to Fig. 4, an example 400 of a printed energization element upon a three-dimensional surface containing electrical traces is illustrated where the Electrode layers are shown smaller than their respective electrical traces. Alternately, printed layers may completely cover or even to a degree transcend the traces. In some examples, printed features may lie upon traces. For example, an anode feature 410 may be printed

5 upon an electrical trace 440, and a cathode feature 420 may be printed upon an electrical trace 450. There may be included another printed feature 430 in a region that is centered above a portion of the three-dimensional surface where there is no electrical trace. For example, the other printed feature 430 may be a bridge layer between the anode feature 410 and the cathode feature 420.

10 The printing means and energization elements herein described are illustrated for exemplary purposes only, and one ordinarily skilled in the art will recognize that means and elements other than those discussed may also be included within the scope of the disclosure. For example, in some alternatives, it may be possible to deposit an Anode layer across the entire three-dimensional surface. Subtractive processing methods, such as, for example, lithography processes and subtractive etch processing, may be used to
15 remove the deposit except where necessary. The printing means may include a combination of subtractive and additive techniques, such as, for example, where the anode and cathode layers are deposited as layers and subtractively removed while the bridge component may be formed by a printing process as an example.

20 Aspects of the Design of traces for Exemplary Energization Elements

Wet cell alkaline batteries represent a complex example of an energization element that may be useful for the inventive art herein. Among the constituents of this type of batteries, the electrolyte formulations may have basic (as opposed to acidic) characteristics. Adhesion of the various constituents to each other may be an important
25 requirement. In addition, in the presence of basic aqueous solutions, some deposit combinations may have better adhesion than other combinations, and some trace designs may allow for better adhesion than other designs.

For example, the initial surface of the three-dimensional substrate may be coated with a deposit of material that may change its surface properties. For example, the three-
30 dimensional substrate may be a surface that may be hydrophobic in nature. A coating of this three-dimensional substrate with parylene deposit may provide adherence characteristics between the substrate and the parylene deposit and may also thereafter have an altered surface characteristic.

5 Where traces may be formed upon the parylene deposit, which are also hydrophobic in character, the aqueous deposit may be repelled from any interface. An example of a trace formulation with such hydrophobic character may be traces formed from silver impregnated pastes, for example, conductive epoxy. These traces may comprise a significant amount of silver flakes, which may have relatively low resistance and, due to the hydrophobic character of the traces, may form traces that may help provide sufficient adherence to underlying parylene deposits. To those skilled in the art, it will be clear that these traces of silver impregnated paste may also be formed using the printing means discussed in previous sections. The design of the traces may have physical characteristics that may enhance adhesion either by allowing for additional surface area or by creating features that entrap deposited traces that are formed upon them.

 Proceeding to Fig. 5, an exemplary design 500 of metal traces 520, 540 and 550 upon a three-dimensional substrate 510 is depicted. The metal traces 520, 540, and 550 may be formed to include areas without metal, for example, circular spaces 530. These spaces 530 without metal may be accomplished through additive means, where the circular spaces 530 may be screened out during the formation process for the traces 520, 540, and 550. Alternately, by a subtractive process, the spaces 530 may be formed after the application of the traces 520, 540, and 550 where a subtractive removal step, such as removal etch, may create the spaces 530.

25 The edge of the spaces 530 without metal may not be vertical and may be undercut or retrograde, for example. Isotropic etch chemistry, especially where the metal trace is formed from a stack of different metallurgies, may result in a ledge protruding over the edge profile. Where the subsequent trace material is applied by printing means, the subsequent layer material may be flowed under the ledge and may result in a better adherence means. It will be apparent to one skilled in the art that many different designs of protrusions and depressions may be practical to improve adhesion characteristics and are well within the scope of the inventive art herein.

Methods of Forming Energization Elements on Three-dimensional Surfaces

5 Proceeding to Fig. 6, an exemplary flowchart 600 illustrates a process of forming energization elements on a three-dimensional substrate. The order of the steps is provided for exemplary purposes only, and other orders are still within the scope of the disclosure described herein. At 610, the formation of the three-dimensional substrate may occur. The three-dimensional substrate formed at 610 may be the foundation for the energization elements created and added in subsequent steps.

10 At 620, the surface of the three-dimensional substrate may be optionally roughened, for example, to increase the adhesive properties of the surface. Exemplary means to roughen the surface may include, for example, techniques that physically abrade the surface. Other means may include gas or liquid phase etching processing. A roughened surface may have desirable adhesion characteristics due to either or both the altered surface chemistry or the increase in physical surface area. This step may be combined with the formation at 610 where the surface may be roughened during the substrate molding process by providing roughened mold tooling where injection molding or cast molding is used to form the substrates. At 630, a deposit may be optionally deposited upon the surface of the substrate.

20 At 640, conductive traces may be placed upon the three-dimensional surface. Numerous methods may be used to define the conductive traces, including for example, shadow mask deposition of metal conductive traces, photolithography subtractive etch of metal deposits, or direct ablative means for subtractive etch processing. There may be methods of depositing the conductive traces by the printing of conductive pastes formed from adhesives and metal flake mixtures. For example, using an nScript™ printing unit and an engineered fluid dispensing or EFD-type tip, a silver-based paste, such as, for example, Du Pont 5025 silver conductor, may be applied at 640 to define conductive traces.

30 After conductive traces are placed upon the substrate surface, the energization elements may now be formed upon electrical traces. At 650, anode traces may be placed near, upon, or partially upon one of the conductive traces that have been formed. At 650, the same exemplary or similar printing unit as used at 640 may be used to apply a zinc-

5 based formulation to define anode traces. Table 1a and Table 1b provide further examples of formulations that may be appropriate for the formation of the Anode at 650.

At 660, Cathode traces may be placed near, upon, or partially upon one of the conductive traces that have been formed. Table 2a and Table 2b provide examples of formulations that may be appropriate for the formation of the cathode at 660. At 670,
10 bridge traces may be placed near, upon, or partially upon one of the conductive traces or one or both of the anode and cathode traces that have been formed. Table 3a and Table 3b provide examples of formulations that may be appropriate for the formation of the bridge at 670.

The method of forming the anode trace, cathode trace, and the bridge at 650-670
15 may include, for example, additive techniques such as masking or plating techniques, subtractive processing, and printing technology. The printing means and energization elements herein described are illustrated for exemplary purposes only, and one ordinarily skilled in the art will recognize that means and elements other than those discussed may also be included within the scope of the invention. For example, it may be possible to
20 deposit an Anode layer across the entire three-dimensional surface. Alternately, subtractive processing methods, for example, lithography processes and subtractive etch processing, may be used to remove the deposit except where desired. The printing means may include a combination of subtractive and additive techniques, such as, for example, where the anode and cathode layers are deposited as layers and subtractively removed
25 while the bridge component may be formed by a printing process as an example.

The order of the steps to add the anode trace, cathode trace, and the bridge may depend on the particular embodiment. For example, a bridge layer may be first deposited between and/or partially upon the metal traces to provide for better adhesion and to isolate the anode from the cathode, particularly if the printable composition used is prone
30 to spreading. One ordinarily skilled in the art will recognize that formulations and Anode chemistry other than those discussed may also be included within the scope of the disclosure.

At 680, an electrolyte that may typically be in a liquid, gelatinous or in some cases polymeric form may be applied. At 690, the formed energization elements and

5 conductive traces may need to be sealed into an isolated element from other components. Depending on the nature of the electrolyte composition, the order of the steps may be reversed. An encapsulating material may be formed and sealed around the energization element with conductive traces protruding through the encapsulation material. Where the encapsulating process is performed first, the injection of a liquid electrolyte through the
10 encapsulating material or through a defined filling feature formed into the encapsulating material may be used. After the liquid electrolyte is filled, the region in the encapsulating material that the filling occurred through may also be sealed. It may be apparent to those ordinarily skilled in the art that encapsulation processes and electrolyte applications other than those described may be practical and are considered well within the scope of the art
15 herein.

An Ophthalmic Lens with Energization Elements on Three-dimensional Surfaces

In the prior discussion, a number of aspects of the inventive art have been described. It may be illustrative to consider an example of an ophthalmic lens with energization elements on three-dimensional surfaces. For this example, a specific type of
20 ophthalmic lens may be considered where a contact lens is assembled from a cast-molded hydrogel "skin" surrounding an energized media insert and where the insert contains electronics, an energization source, and elements capable of changing the focal characteristics of the contact lens device based on a control signal. The media insert may be formed of a semi-rigid polymer material, which may be formed in two halves. A top
25 half of the insert may contain the front surface where the front is indicated as the portion of the insert that is further from a user's eye surface.

This half of the media insert may have the electronics circuits adhered to its surface. Electrical interconnects that provide low resistance paths to interconnect devices to each other may be deposited between the front portion of the media insert and the
30 adhered electronic circuit. The front half of the media insert may be formed into a varied three-dimensional surface as shown, for example, in Fig. 1.

For optimal adhesion of electrical interconnects to this media insert half, the three-dimensional surface of the media insert may be coated with a thin parylene-c

5 deposit layer. To one ordinarily skilled in the art, other types and variants of parylene may be practical and are considered within the scope of the invention described herein. Subsequently, electrical interconnects may be deposited onto this parylene layer on the inner portion of this variable three-dimensional surface. In this example, the electrical interconnects are first deposited by sputter deposition of a metallic deposit, or stack of
10 deposits, through a shadow mask and onto the parylene layer in specific locations. The shadow mask process may define electrical traces that have regions missing in a generally circular pattern, especially in regions where the battery traces may be made.

Subsequently, a paste containing binders and solvents into which silver flakes may have been added may be printed into features on the electrical interconnects that
15 were deposited on the three-dimensional substrate. The paste with silver flakes may be applied by a printing apparatus to cover the electrical interconnects in regions where batteries may be formed. These adhesive-based silver electrical layers may be printed using a print head configured for traces of around 200-400 microns width. This width may be chosen to ensure that the underlying electrical trace may be sufficiently covered
20 by the adhesive formulation.

A portion of the conductive trace-coated electrical interconnects may be located on a peripheral region of the media insert front surface, and a deposit, or layers of deposits, may be printed to form a portion of an alkaline cell onto this peripheral region. The first deposit to be printed may be the anode trace that overlaps one of the electrical
25 interconnect traces. The anode traces may be printed using a print head configured for traces using the formulations in Table 1. The anode trace may be printed to locate in positions overlapping traces 140 and 180 in Fig. 1.

In a next processing step, the cathode portions of the battery may be formed. This cathode trace may be printed using a print head configured for traces using the
30 formulations in Table 2. The cathode trace may be printed to locate in position overlapping traces 130 and 170 in Fig. 1. In these configurations, the two battery cells may be located in a parallel configuration to generate a nominal initial battery potential load.

5 At 680, the bridge portion of this laterally deployed battery cell may be printed. This is where liquid electrolyte may be imbibed into the porous and optionally gellable structures of cathode, bridge, and anode. The bridge trace may be printed, for example using a print head configured for the formulation in Table 3. The bridge traces may be printed to overlap each of the anode and cathode traces and the region in between the
10 cathode and anode traces in the locations where the anode and cathode traces lie next to each other.

 At 690, regions around the battery traces may be encapsulated by a thin layer of polymeric material that may be both adhesively sealed, or thermo-welded into location. This thin layer functions to contain the battery electrolyte to be located around the anode,
15 cathode, and bridge regions. When the second half of the media insert is sealed to the first half, a media insert may be formed that includes the battery. The second seal may define and additionally provide a second sealing layer for containment of the battery chemistry.

 A liquid or gelled electrolyte formulation may be added to the sealed battery
20 element. To perform this filling step, a set of needles may penetrate the thin polymeric layer. For example, one of the needles may function to fill the electrolyte into the battery region, and the other may allow for an equivalent volume of ambient gas in the battery region to escape during the filling. The battery region may be filled to approximately 95% of its volume with gelled liquid electrolyte. On retraction of the filling needles, the
25 penetration locations may be sealed by application of an adhesive sealant into and on the penetration regions by a set of collocated needles to dispense the adhesive. Further, after the traces and electrolyte are encapsulated, a second encapsulant, such as parylene, for example, may also be used.

 An integrated circuit functional to control all the various functions of the contact
30 Lens with active focal changing elements may be attached to the electrical interconnections 150 and 160 in Fig. 1. The circuit may include a triggering mechanism that may not connect the internal circuitry to the battery until the triggering event occurs so that there is minimal to no draw on the battery until it is needed. The element that may control the active focal adjustment may be added to the half of the media insert and may

5 be connected to the electrical interconnects. The electrical interconnects that it attaches to may typically be connected to output connection points for the integrated circuit.

After these connections are made, the ophthalmic element may be tested by electrically connecting signals to the electrical interconnects that are connected to the active focal adjustment element. Next, the second half of the media insert may be sealed
10 to the first half forming a self-powered fully formed media insert. After the insert is formed inside an ophthalmic lens, a wearable contact lens with energized function to adjust focal characteristics of the contact lens may result.

The three-dimensional surface may be curved. The curvature of the three-dimensional surface may correspond to a curvature of the ophthalmic lens for which the
15 insert is intended to be used. An ophthalmic lens may have numerous design features and the curvature of each design feature may be different. A soft hydrogel contact lens may be described by several parameters, such as an "equivalent base curve radius." Contact lenses may typically have a base curve of about 8.0 mm. A radius of curvature of the three-dimensional substrate may be from about 5 mm to about 5000 mm, from about 6
20 mm to about 1000 mm, from about 7 mm to about 500 mm or from about 8 mm to about 200 mm. The three-dimensional substrate may comprise multiple curvatures, which may each be printed on to form an ophthalmic battery.

The three-dimensional substrate is preferably a wettable substrate. Having a wettable substrate assists in the formation and positioning of the printed battery
25 components, that is, the conductive traces and the energization elements. The substrate may be subjected to surface treatments or the application of one or more coating layers in order to increase substrate surface wettability. The substrate is typically a polymer, for example, a cyclic olefin polymer (such as produced by Topas) or poly(4-methyl-pent-1-ene) polymer (such as TPX® polymethylpentene, produced by Mitsui Chemicals).
30 Preferably the substrate is parylene-C coated Topas cyclic olefin polymer.

The conductive traces or "current collectors" should preferably contribute minimal resistance to the flow of electrons in the circuit. The conductive traces should be electrochemically compatible with the printed battery chemistry as well as having sufficient adhesion to the substrate. The material selected for the conductive traces

5 should be compatible with and adhere to the anode and cathode materials. Preferred
conductive trace material includes conductive epoxies, such as an epoxy containing silver
particles.

The anode may be formed from a printable anode composition. Preferably, the
anode composition comprises zinc as the electroactive component. Zinc alloys
10 comprising high purity zinc and corrosion reducing additives such as bismuth and indium
are known in the battery industry. However the particle sizes of these standard powders
are too large for dispensing through small orifice nozzles, such as in the region of 200
microns, as required for the printing of the anode portion of the energization elements in
the present invention. Furthermore, the aspect ratio of as-produced zinc alloy powders is
15 elongated, and this elongated particle morphology gives rise to higher porosity and better
particle to particle contact. Consequently, the anode composition preferably comprises
powders having lower average particle size than those of standard powders. Traditional
methods for reducing particle size, such as milling, are preferably avoided due to the risk
of contamination of the zinc, which would be problematic in ophthalmic applications.
20 Suitable particle sizes may be obtained by collecting particle size distributions passing
through a sieve having 25 micron mesh openings. However, the particle size should not
be too small because side reactions of the zinc may be potentially increased (e.g.
reduction of water to hydrogen) which may contribute to higher rates of self-discharge
and premature device failure.

25 Preferably, the rheology of the anode composition is such that the metal particles,
such as zinc, do not sediment out of solution during the course of processing (that is, over
a period of several hours). Sedimentation may give rise to non-uniformity in the
dispensed anode and/or clogging of the dispensing orifice. Reduction of the degree of
sedimentation may be achieved by using a polymer solution of a binder polymer in the
30 anode composition. However, a viscous polymer solution alone may not be sufficient to
control sedimentation. The use of graphite in conjunction with a binder polymer
solution may achieve a favourably uniform dispersion that is resistant to sedimentation on
the time scale of processing.

5 The inclusion of a conductive additive, such as graphite, in the anode composition may have a further advantage in improving the conductivity of the anode composition. Without the inclusion of the conductive graphite additive, it has been observed that a lower percentage of utilization of zinc is realized, which may be attributed to zinc particles that are detached from the inter-particle network of zinc.

10 The volatility of aqueous anode compositions can be problematic when ambient humidity is low. Consequently, lower volatility co-solvents such as propylene glycol or dipropylene glycol dimethyl ether are preferably included in the anode composition. Alternatively, or in addition, humidifying the ambient environment during printing of the anode composition may reduce this problem.

15 The cathode may be formed from a printable cathode composition. The electroactive component in the cathode composition is preferably electrolytic manganese dioxide (EMD), which is well-known in the battery industry. As for the anode electroactive particles, the cathode particle size distribution is preferably such that it can be made into a composition capable of being dispensed through a small orifice for
20 printing. EMD may be milled or separated at the time of production to produce fine EMD having a desirable particle size, preferably having an average of approximately 10 microns. A volume fraction of larger particle size (up to about 50 microns) may be included if it does not cause issues with dispensing.

 Where EMD is used as the electroactive species in the cathode composition, the
25 components coming into contact with EMD are preferably selected so as to be relatively unreactive in view of EMD being an oxidant. This may limit the choice of binder polymers, solvents, and additives that may be used in the cathode printable compositions, or other compositions that may be near the cathode, such as the electrolyte and bridge materials. When organic materials react with EMD, volatile by-products can be
30 produced. Furthermore, the utility of EMD may be reduced, and the resulting open circuit voltage of the completed cell may be lower than expected (for example, 1.35 V instead of 1.45 V).

 The bridge may function as a separator. Preferably, the bridge is a physical separator between anode and cathode and, in this way, helps to prevent short circuits.

5 Short circuits may be formed during printing if the anode and/or cathode is printed inaccurately. This can happen, most often, at starts or stops of anode or cathode traces where the material has a tendency to form blobs.

Alternately or in addition, the bridge may function as an electrolyte director. Liquid electrolyte may be applied to a bridge whereupon it is rapidly absorbed and is
10 distributed through the bridge, anode and cathode. Whereas parylene-C surfaces may not be wettable by liquid electrolyte, the porous structure of bridge coating parylene-C surfaces between anode and cathode results in facile wetting and distribution of electrolyte.

A variety of electrolytes, for example, liquid electrolytes and gel electrolytes, may
15 be used in the present invention. An example liquid electrolyte is KOH. Preferably, the liquid electrolyte has low viscosity which allows it to readily penetrate the pores of the anode, cathode and bridge (where present). Preferably, there should be complete permeation of the anode, cathode and bridge in order to realize efficient utilization of active components. Liquid electrolyte may be applied so that it is "just saturated," which
20 means that a minimum amount of bulk liquid is observed on or around the anode, cathode and bridge. Preferably, the liquid electrolyte is 30-40 % KOH, which is preferred due to its conductivity and electrochemical activity. An example gel electrolyte is gelled 30-40 % KOH electrolyte. Gel electrolytes may be used in combination with liquid electrolytes. For example, gelled electrolyte may be printed on top of the anode, bridge,
25 and cathode after a liquid electrolyte is deposited. The gel resists disruption during application of liquid primary encapsulant. A suitable gelling agent is Carbopol 971.

Both liquid and gel electrolytes may be modified with additives such as zinc oxide and surfactants for improved performance. Preferably, the electrolytes may be saturated, or nearly saturated, with zinc oxide to slow the side reaction of zinc with water,
30 which leads to hydrogen evolution. Surfactants aid with wetting and uptake of electrolyte.

The encapsulant is preferably a material that has low reactivity with the anode, cathode and electrolyte components. Preferably, the encapsulant material adheres well to the substrate or substrate coating, where present. Typically the encapsulant is an inert

5 polymer that may flow over the components prior to curing. Preferably, two-part epoxies that have sufficient hydrophobicity and viscosity may be applied directly to activated batteries as an encapsulant. Where a material has low viscosity, the encapsulant material may mix with the electrolyte, which inhibits and/or limits cure. Preferably, an encapsulant having good adhesion to parylene-C is used. An example of a suitable epoxy
10 is Epoxy Technologies 353-ND.

Where parylene comprises or coats the substrate, additional parylene may be coated as a secondary encapsulant on top of a primary encapsulant described above in a manner such that it overlaps the edges onto previously coated parylene. Parylene is conformal, a good moisture barrier, and is biocompatible. A preferred parylene is
15 parylene-C.

Formation of ophthalmic batteries is particularly difficult due to the size and shape of the insert substrate. In particular, the substrate for an ophthalmic lens insert is very thin, typically about 200 microns, and the width available for printing is typically less than about 1 mm. Furthermore, the irregular topography of the substrate, which is
20 typically curved, further complicates printing. Due to the irregular geometry requirements of ophthalmic printed batteries, special hardware is preferably needed to accurately print desirable features. The printing hardware preferably features a servo-driven X-Y stage, a servo driven Z-axis for the dispenser. There may also be a rotary stage for the three-dimensional substrate. The path that the dispenser orifice makes over
25 the three-dimensional substrate may be programmed using G-code or other programming languages. Complex 3D paths may be scripted and executed.

Various dispense tips are suitable for dispensing various printable battery compositions. For low to medium viscosity materials (such as for the traces, encapsulant, and gel electrolyte), straight-walled stainless needle tips such as EFD precision tips may
30 be used. For anode, bridge and cathode composition materials, machined stainless dispense nozzles featuring a conical profile leading to a short straight-walled section just before the orifice are preferred.

A pneumatic pump featuring a servo-driven piston valve may be used for printing components. In some cases, an auger-driven pump may give enhanced resolution and/or

- 5 consistency of features, particularly for high viscosity materials such as anode and/or cathode compositions.

Two or more cells may be printed near each other in a series arrangement to produce a battery. In this case, special care should be taken to isolate the electrolyte between adjacent cells. An inert material, such as epoxy, may be dispensed between
10 adjacent cells as an electrolyte barrier, leading to isolated, interconnected cells.

Specific examples have been described to illustrate aspects of inventive art relating to the formation, methods of formation, and apparatus of formation that may be useful to form energization elements upon electrical interconnects on Three-dimensional
15 Surfaces. These examples are for said illustration and are not intended to limit the scope in any manner. Accordingly, the description is intended to embrace all embodiments that may be apparent to those skilled in the art.

A non-exhaustive list of various aspects and examples of the present invention are set out in
20 the following numbered clauses:

Clause 1. A method of forming an energized insert on a three-dimensional substrate for an ophthalmic lens, the method steps of:

- forming a three-dimensional substrate base of suitable size for inclusion in an ophthalmic lens from a first insulating material;
- 25 defining conductive traces on said substrate base;
- forming energization elements on a first portion of the conductive traces, wherein said energization elements are comprised of a first anode trace and at least a first cathode trace;
- applying electrolyte upon energization elements; and
- 30 encapsulating said energization elements and electrolyte.

Clause 2. The method of Clause 1, additionally comprising:

- modifying a first portion of a first surface of said substrate base to increase surface area of said first portion.

- 5 Clause 3. The method of Clause 1, additionally comprising:
- i. modifying a first portion of a first surface of said substrate base to alter the surface chemistry of said first portion.
- Clause 4. The method of Clause 2, wherein the modification of the first surface of the substrate base includes roughening the surface to form textured patterns.
- 10 Clause 5. The method of Clause 1, additionally comprising the step of:
- i. coating the substrate base with at least a first layer of parylene.
- Clause 6. The method of Clause 5, wherein the parylene is parylene-C.
- Clause 7. The method of Clause 1, wherein the three-dimensional substrate forms part of a media insert that can be incorporated in a hydrogel ophthalmic lens.
- 15 Clause 8. The method of Clause 1, wherein the conductive traces are formed using printing techniques.
- Clause 9. The method of Clause 8, wherein the printing techniques include moving the substrate base in relation to a depositing tip used in the printing technique.
- Clause 10. The method of Clause 8, wherein the printing techniques include moving
- 20 the depositing tip used in the printing technique in relation to the substrate base.
- Clause 11. The method of Clause 1 further comprising:
- a. forming a first bridge trace between portions of the anode trace and the cathode trace.
- Clause 12. The method of Clause 1, wherein the conductive traces are formed using
- 25 additive lithographic techniques.
- Clause 13. The method of Clause 12, wherein the lithographic techniques further includes subtractive processing methods.
- Clause 14. The method of Clause 1, wherein the encapsulation material is parylene.

5 Clause 15. The method of Clause 14, wherein the encapsulation material is parylene-C.

Clause 16. The method of Clause 1, wherein the conductive traces protrude through the encapsulation material.

10 Clause 17. The method of Clause 1, wherein the electrolyte is applied through injection means through the encapsulation material after the encapsulation of the energization elements occurs.

Clause 18. The method of Clause 1, wherein the encapsulation of the energization elements occurs prior to the application of the electrolyte, and wherein the electrolyte is applied onto a filling feature formed into the encapsulation material.

15 Clause 19. The method of Clause 18 further comprising the steps of:
 i. sealing the filling feature.

5

CLAIMS

1. A method of forming an energized insert on a three-dimensional substrate for an ophthalmic lens, the method comprising the steps of:
 - forming a three-dimensional substrate of suitable size for inclusion in an ophthalmic lens from a first insulating material;
 - 10 defining conductive traces on said substrate;
 - forming energization elements on a first portion of the conductive traces, wherein said energization elements are comprised of a first anode trace and at least a first cathode trace;
 - applying electrolyte upon energization elements; and
 - 15 encapsulating said energization elements and electrolyte.
2. The method of Claim 1, additionally comprising:
 - modifying a first portion of a first surface of said substrate to increase surface area of said first portion.
3. The method of Claim 1, additionally comprising:
 - 20 modifying a first portion of a first surface of said substrate to alter the surface chemistry of said first portion.
4. The method of Claim 2, wherein the modification of the first surface of the substrate includes roughening the surface to form textured patterns.
5. The method of Claim 1, additionally comprising the step of:
 - 25 coating the substrate with at least a first layer of parylene.
6. The method of Claim 5, wherein the parylene is parylene-C.
7. The method of Claim 1, wherein the three-dimensional substrate forms part of a media insert that can be incorporated in a hydrogel ophthalmic lens.
8. The method of Claim 1, wherein the conductive traces are formed using printing
30 techniques.

- 5 9. The method of Claim 8, wherein the printing techniques include moving the substrate in relation to a depositing tip used in the printing technique.
10. The method of Claim 8, wherein the printing techniques include moving the depositing tip used in the printing technique in relation to the substrate.
11. The method of Claim 1, further comprising:
- 10 forming a first bridge trace between portions of the anode trace and the cathode trace.
12. The method of any of the preceding Claim 1, wherein the conductive traces are formed using additive lithographic techniques.
13. The method of Claim 12, wherein the lithographic techniques further includes
- 15 subtractive processing methods.
14. The method of Claim 1, wherein the encapsulation material is parylene.
15. The method of Claim 14, wherein the encapsulation material is parylene-C.
16. The method of Claim 1, wherein the conductive traces protrude through the encapsulation material.
- 20 17. The method of Claim 1, wherein the electrolyte is applied through injection means through the encapsulation material after the encapsulation of the energization elements occurs.
18. The method of Claim 1, wherein the encapsulation of the energization elements occurs prior to the application of the electrolyte, and wherein the electrolyte is
- 25 applied onto a filling feature formed into the encapsulation material.
19. The method of Claim 18 further comprising the step of:
- sealing the filling feature.
20. An ophthalmic lens comprising an energized insert, wherein the insert comprises:

- 5 a three dimensional substrate comprising a first insulating material;
 conductive traces on said substrate;
 energization elements on a first portion of the conductive traces, wherein
 said energization elements are comprised of a first anode trace and at least
 a first cathode trace;
- 10 an electrolyte upon the energization elements; and
 an encapsulant encapsulating said energization elements and electrolyte.
21. The ophthalmic lens of Claim 20, wherein the substrate comprises a coating layer
 of parylene on which the conductive traces are positioned.
22. The ophthalmic lens of Claim 21, wherein the parylene is parylene-C.
- 15 23. The ophthalmic lens of Claim 20, wherein the insert further comprises a first
 bridge trace between portions of the anode trace and the cathode trace.
24. The ophthalmic lens of Claim 20, wherein the encapsulation material is parylene.
25. The ophthalmic lens of Claim 24, wherein the parylene is parylene-C.
26. The ophthalmic lens of Claim 1, wherein the conductive traces protrude through
20 the encapsulation material.
27. The ophthalmic lens of Claim 1, wherein the lens is a contact lens.