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(54) Titre : DISPOSITIF DE STOCKAGE D'ENERGIE ELECTRIQUE A ELECTROLYTE NON AQUEUX
(54) Title: ELECTRICAL ENERGY STORAGE DEVICE WITH NON-AQUEOUS ELECTROLYTE

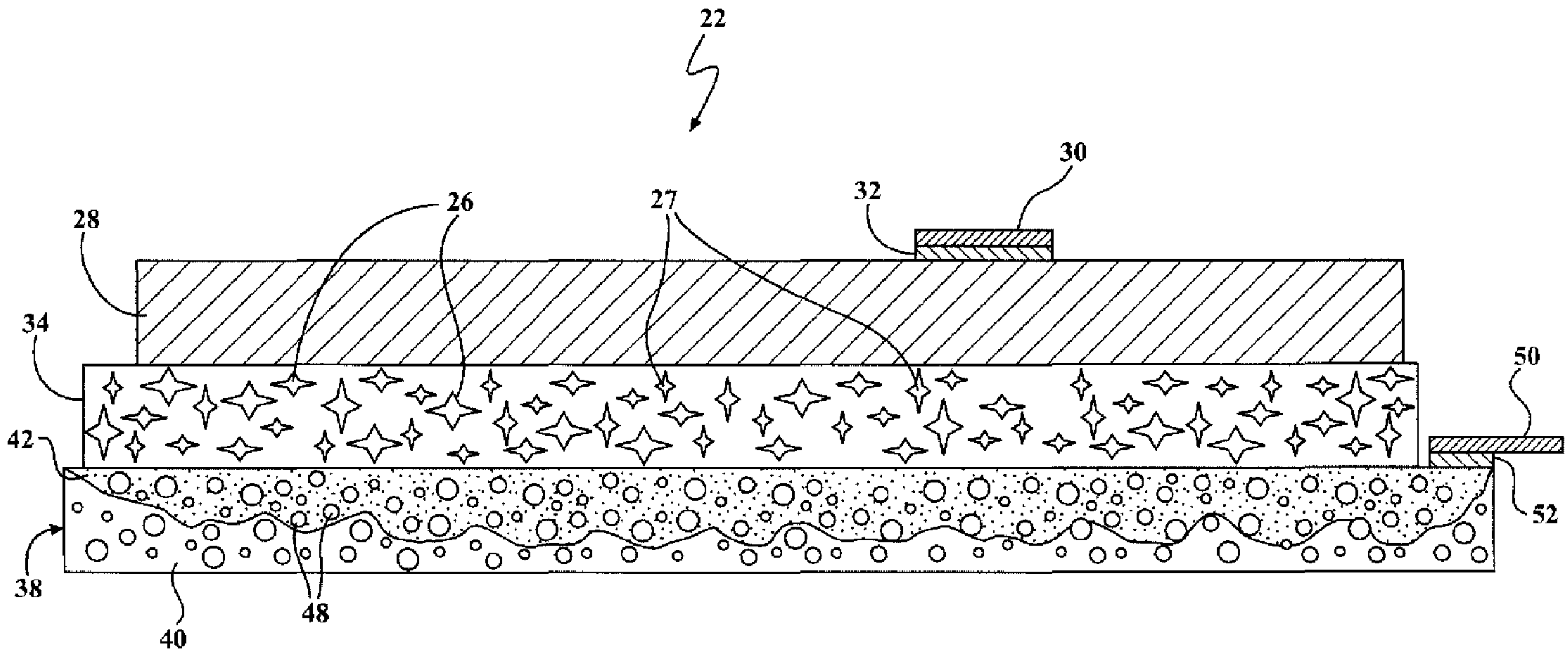

FIG. 1

(57) Abrégé/Abstract:
An electrical energy storage device (20) is disclosed as a secondary battery device (22) having an anode (28) containing Aluminum and Indium and a cathode (38) that includes an electroactive layer (42) with a host lattice (44) having a conjugated system with

(57) **Abrégé(suite)/Abstract(continued):**
delocalized p electrons. A dopant (48) containing Aluminum is bonded with and intercalated in the host lattice (44). A membrane (34) of cellulose is wetted with a non-aqueous electrolyte (24) containing glycerol and first ions (26) containing Aluminum and having a positive charge and second ions (27) containing Aluminum and having a negative charge, and is sandwiched between the anode (28) and the cathode (38). A method for constructing a secondary battery device (22) is disclosed as well, including steps for producing the electrolyte (24), the anode (28), and the cathode (38) including the dopant (48).

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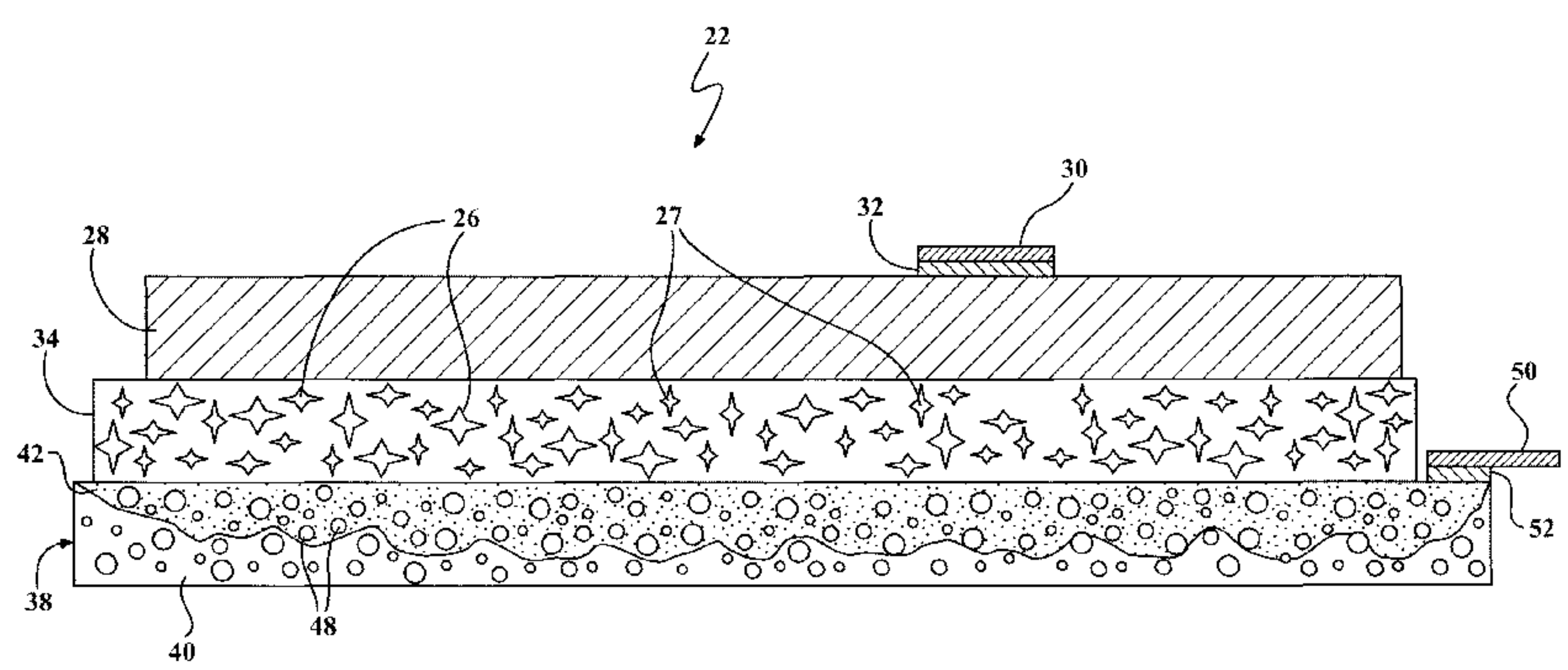

FIG. 1

(57) Abstract: An electrical energy storage device (20) is disclosed as a secondary battery device (22) having an anode (28) containing Aluminum and Indium and a cathode (38) that includes an electroactive layer (42) with a host lattice (44) having a conjugated system with delocalized π electrons. A dopant (48) containing Aluminum is bonded with and intercalated in the host lattice (44). A membrane (34) of cellulose is wetted with a non-aqueous electrolyte (24) containing glycerol and first ions (26) containing Aluminum and having a positive charge and second ions (27) containing Aluminum and having a negative charge, and is sandwiched between the anode (28) and the cathode (38). A method for constructing a secondary battery device (22) is disclosed as well, including steps for producing the electrolyte (24), the anode (28), and the cathode (38) including the dopant (48).

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ELECTRICAL ENERGY STORAGE DEVICE WITH NON-AQUEOUS ELECTROLYTE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims benefit of U.S. Utility Application Serial Number 14/607,429, filed January 28, 2015, which is a continuation-in-part of U.S. Utility Patent Application Serial Number 14/539,448, filed November 12, 2014, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] This invention relates to electrical energy storage devices having an anode of Aluminum and an electrolyte containing ions of Aluminum.

[0003] This invention also relates to a method for constructing an electrical energy storage device having an anode of Aluminum and an electrolyte including ions containing Aluminum.

2. Description of the Prior Art

[0004] It is generally known to construct batteries with an anode comprising a layer of Aluminum. These Aluminum batteries typically take the form of primary, or non-rechargeable Aluminum-Air batteries, such as the type disclosed in US Patent No. 4,925,744. The use of Aluminum alloy with .1 to .5 % by weight of Indium to make a thin film battery electrode is disclosed in US Patent Application Pub. No. 2002/0,148,539. US Patent Application 2012/0,082,904 discloses a battery that includes an anode comprising aluminum metal and an electrolyte including ions containing Aluminum.

[0005] It is also well known to construct batteries as a sandwich of layers, with a cathode sandwiched with the membrane and disposed in spaced and parallel relationship with the anode and an electrolyte impregnating the membrane to carry an ion current through the membrane. One such example is shown in US Patent Application 2009/0142668.

[0006] It is known to use a dopant to alter the electrochemical properties of a battery cathode. Such a doped cathode is disclosed in US Patent No. 6,949,233.

[0007] Existing energy storage devices with anodes of Aluminum have been constrained by corrosion and by the formation of oxides on the surface of the anode which blocks ions in the electrolyte from being able to react with the anode and inhibits such batteries from being discharged and recharged again.

SUMMARY OF THE INVENTION

[0008] The invention provides for an electrical energy storage device with an Anode containing Aluminum and a cathode including a host lattice having a conjugated system with delocalized π electrons bonded with a dopant that contains Aluminum and an electrolyte with positive and negative ions of Aluminum dispersed in Glycerol. The invention also provides for a method of constructing such an electrical energy storage device including the step of making the electrolyte by dissolving Aluminum Perchlorate powder in Glycerol.

ADVANTAGES OF THE INVENTION

[0009] The invention in its broadest aspect provides for an electrical energy storage device that includes an anode of Aluminum and a novel electrolyte including ions containing Aluminum dispersed in Glycerol.

[0010] Because of its unique electrochemical properties, Aluminum offers the potential for much greater energy density compared with other materials commonly used in electrical energy storage devices, such as in Lithium-Ion batteries. Aluminum offers further advantages in that it is abundant, inexpensive, and much less flammable than Lithium.

[0011] Glycerol, which is also called glycerine, glycerin, or propane-1,2,3-triol, is a simple polyol (sugar alcohol) having a molecular formula $C_3H_8O_3$. Glycerol is an abundant, stable, hygroscopic, and nontoxic solvent, ideal for use in a non-aqueous electrolyte. This electrolyte enables an Aluminum Secondary battery to be constructed with an anode of Aluminum which is capable of multiple charge and discharge cycles because it does not suffer from destructive corrosion or formation of oxides on the Aluminum in the anode.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Other advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0013] Figure 1 is a schematic cut-away view of an Aluminum secondary battery.

[0014] Figure 2 is a top view of a secondary battery with an anode disposed above a cathode layer.

DESCRIPTION OF THE ENABLING EMBODIMENT

[0015] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, an electrical energy storage device **20** is disclosed as a secondary battery device **22** using a non-aqueous electrolyte **24** including ions **26, 27** containing Aluminum. The term "secondary battery" refers to an electrochemical energy storage device that is capable of being recharged. The term "non-aqueous" refers to a substance that contains no substantial quantity of water. Other types of electrical energy storage devices **20** may be constructed according to the present invention. Such electrical energy storage devices **20** include, for example, primary, or non-rechargeable batteries, and electrolytic capacitors.

[0016] As shown in the figures, the secondary battery device **22** is constructed as a stack of thin layers. It should be appreciated that the secondary battery device **22** could be made in numerous different physical arrangements. Examples of those arrangements are coin cells, cylindrical batteries, and multi-cell packages such as those that as are commonly used in laptop computers, personal electronics, and electric or hybrid-electric vehicles.

[0017] The secondary battery device **22** includes an anode **28** of Aluminum of 99.95 % purity and 0.1 to 0.6 wt% of Indium. The Anode **28** has a rectangular shape with a first length of 1.2 cm and a first width of 1.7 cm and a first thickness of 0.1 mm.

[0018] A negative lead **30** of an electrically conductive material is attached in electrical contact with the anode **28** using an electrically conductive cement **32** that includes particles of metal. Examples of such electrically conductive cement **32** are *Two Part Conductive Silver Paint* (Part No. 12642-14), sold by Electron Microscopy Sciences and *Solder-It Aluminum Solder Paste*, sold by SOLDER-IT, INC. of Pleasantville, New York. The negative lead **30** serves as a point of connection to conduct electrical current between the anode **28** and an external circuit for charging or discharging the battery device. The negative lead **30** could also serve as a point of connection to another battery cell as part of a multi-cell battery device. The negative lead **30** could be a wire, pad, terminal, or any other suitable means of making an electrical connection.

[0019] A membrane **34** of cellulose having a thickness of 0.08 mm and defining a plurality of pores **36** is sandwiched parallel to and contacting the anode **28**. The membrane **34** is an electrical insulator, but is permeable to dissolved ions **26, 27**.

[0020] The secondary battery device **22** also includes a cathode **38** having a rectangular shape with a second length of 1.4 cm and a second width of 1.9 cm and a second thickness of 0.1 mm. The cathode **38** is disposed adjacent and parallel to the membrane **34**, with the membrane **34** sandwiched between the cathode **38** and the anode **28**.

[0021] The cathode **38** includes a carrier sheet **40** of cellulose and an electroactive layer **42** disposed upon and integrated within the carrier sheet **40** on the side facing the anode **28**. In other words, the electroactive layer **42** coats the surface and extends into the structure of the carrier sheet **40**. The electroactive layer **42** contains a host lattice **44** that defines a plurality of voids and includes a conjugated system with delocalized π electrons. A conjugated system is defined as a system of connected p-orbitals containing delocalized electrons in chemical compounds. More specifically, the conjugation is the overlapping of one p-orbital with another across adjacent single (sigma) bonds. One such compound that has such a conjugated system is graphite. Other compounds such as, but not limited to, polyaniline and polyconjugated linear hydrocarbon polymers also include the conjugated systems with overlapping p-orbitals. A dopant **48** that includes Aluminum Alcoholate and Aluminum Glycerate is bonded to the conjugated system of the host lattice **44** to alter the electrochemical properties of the electroactive layer **42** of the cathode **38** to increase the rate of the reactions with the first ions **26** and the second ions **27** for charging and discharging the secondary battery device **22**. The dopant **48** is also intercalated in the host lattice **44** so that particles of the dopant **48** are embedded in the voids of the host lattice **44**.

[0022] A positive lead **50** containing graphite is electrically connected to the electroactive layer **42** of the cathode **38** for conducting electrical current between the cathode **38** and an external circuit for charging or discharging the battery. The positive lead **50** is electrically and mechanically attached to the electroactive layer **42** of the cathode **38** with a conductive adhesive **52** containing graphite. One such conductive adhesive **52** is *Graphite Conductive Adhesive 52 112* (Part No. 12693-30), sold by Electron Microscopy Sciences. The positive lead **50** is preferably made of a thin film strip of thermally expanded graphite. The positive lead **50** may also be a rod of graphite with a diameter of 0.1 mm. The positive lead **50** could also serve as a point of connection to another battery cell as part of a multi-cell battery device. The positive lead **50** could be constructed as a wire, pad, terminal, or any other suitable means of making an electrical connection. Conductors of metal should not be placed in direct contact with the electroactive layer **42** of the cathode **38** because some metals have been shown to migrate into the electroactive layer **42** and interfere with the functionality of the cathode **38** in charging and discharging the secondary battery device **22**.

[0023] An electrolyte **24**, consisting essentially of glycerol and first ions **26** containing Aluminum and having a positive charge, including $[Al(ClO_4)_2 \bullet \{C_3H_5(OH)_3\}_2]^+$ and second ions **27** containing Aluminum and having a negative charge, including $[Al(ClO_4)_4]^-$, impregnates or soaks the pores **36** of the membrane **34** for conveying the ions **26, 27** through the membrane **34**. The ions **26, 27** of Aluminum thereby comprise an ion current as they migrate between and react with the anode **28** and the cathode **38** to charge and discharge the battery.

[0024] In one embodiment, the host lattice **44** of the electroactive layer **42** comprises flakes **54** of graphite having particle size of 200 to 300 μm and a binder material that is wettable by glycerol. Alkyl glue and acrylic glue are each suitable binder materials, and either may be used.

[0025] In an alternative embodiment, the host lattice **44** of the electroactive layer **42** comprises particles of amorphous thermally expandable graphite and manganese dioxide and activated manganese dioxide and acetylene black and an electrically conductive paint including graphite and a binder material that is wettable by glycerol. Alkyl glue, acrylic glue, and conductive paint that includes graphite have each been found to be suitable binders.

[0026] In another alternative embodiment, the host lattice **44** of the electroactive layer **42** includes a polyconjugated linear hydrocarbon polymer.

[0027] In another alternative embodiment, the host lattice **44** of the electroactive layer **42** includes a cyclic polyconjugated chain polymer such as polyaniline.

[0028] The present invention also provides a method for constructing a secondary battery device **22**.

[0029] The method includes the steps of making a foil **56** by heating a plate of Aluminum of 99.95 % purity and 0.1 to 0.6 wt% of Indium to a temperature of 450°C, rolling the plate to reduce the thickness of the plate while cooling at a rate of more than 10°C per minute to a reduced thickness, reheating the reduced thickness of the plate and rerolling the reduced thickness of the plate into a foil **56** coated with Aluminum Oxide and surface contaminants and having a thickness between 0.05 and 0.1 mm.

[0030] The method proceeds with steps for processing and storing the foil **56**, which include: rinsing the foil **56** with ethanol to remove surface contaminants therefrom, submerging the foil **56** in a 4mol solution of water and Hydroxide for one minute to remove any Aluminum Oxide from the surface of the foil **56**, rinsing the foil **56** with water to remove all Hydroxide therefrom, subjecting the foil **56** to 70°C for 30 minutes to evaporate any moisture from it, and storing the foil **56** in an anhydrous environment to prevent oxidation.

[0031] The method continues with steps for making an anode **28** from the foil **56** by dividing the foil **56** into a rectangular shape to define the anode **28** having a first length of 1.2 cm and a first width of 1.7 cm, and attaching a negative lead **30** to the anode **28** with a cement **32** of silver paint or aluminum solder paste.

[0032] The method includes steps for constructing the battery device by wetting the membrane **34** with an electrolyte **24**, and stacking the membrane **34** upon and parallel to the anode **28**.

[0033] The method includes the steps of making a cathode **38** by applying the cathodic mixture **60** in a thin film layer to one side of a carrier sheet **40** of cellulose to soak into the carrier sheet **40**, subjecting the cathodic mixture **60** to a temperature of 50 to 60°C to solidify the cathodic mixture **60** into a host lattice **44** that is disposed upon and within the carrier sheet **40**, wetting the host lattice **44** with a doping fluid **62** containing a dopant **48** to allow the dopant **48** to bond with and intercalate into the host lattice **44** to produce an electroactive layer **42**, and attaching a positive lead **50** in electrical contact with the electroactive layer **42** of the cathode **38** with an adhesive **52** containing graphite.

[0034] The method includes further steps for constructing the battery device by stacking the cathode **38** upon and parallel to the membrane **34** with the membrane **34** disposed between the anode **28** and the cathode **38**.

[0035] The method includes steps for producing an electrolyte **24** by dissolving Aluminum Perchlorate powder in glycerol to saturation to produce the electrolyte **24**.

[0036] The method also includes steps for producing the doping fluid **62** by dissolving $AlCl_3$ powder in ethanol to saturation to produce a background solution **66,** combining 40 wt% of the background solution **66** with 60 wt% of glycerol to produce a binary solvent **68**, grating 1 cm^3 of 99.4 to 99.9 wt% of Aluminum of 99.95 % purity and 0.1 to 0.6 wt% of Indium to make filings **70** with an equivalent surface area of 20 to 30 cm^2, immersing the filings **70** in 150 to 200 ml of the binary solvent **68** until the filings **70** have dissolved to produce the doping fluid **62.**

[0037] The present invention also provides a first method for making the cathodic mixture **60** by mixing 5 wt% of alkyl glue with 60 wt% of ethanol with 35 wt% of flakes **54** of graphite.

[0038] The present invention provides a second, alternative, method for making the cathodic mixture **60** by mixing amorphous thermally expandable graphite powder with 1-5 wt% MnO_2 with 1-5 wt% activated MnO_2 with 1-5 wt% acetylene black to make an intermediate mixture, and adding a binder of alkyl glue and ethanol or acrylic glue or graphite paint to the intermediate mixture to make the cathodic mixture **60** having a consistency of thick spreadable paste.

[0039] Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the appended claims. That which is prior art in the claims precedes the novelty set forth in the "characterized by" clause. The novelty is meant to be particularly and distinctly recited in the "characterized by" clause whereas the antecedent recitations merely set forth the old and well-known combination in which the invention resides. These antecedent recitations should be interpreted to cover any combination in which the inventive novelty exercises its utility. The use of the word "said" in the apparatus claims refers to an antecedent that is a positive recitation meant to be included in the coverage of the claims whereas the word "the" precedes a word not meant to be included in the coverage of the claims. In addition, the reference numerals in the claims are merely for convenience and are not to be read in any way as limiting.

CLAIMS

What is claimed is:

1. An electrical energy storage device **(20)** comprising;

an anode **(28)** comprising a layer of Aluminum,

a membrane **(34)** sandwiched with said anode **(28)**,

an electrolyte **(24)** including first ions **(26)** containing Aluminum and having a positive charge and including second ions **(27)** containing Aluminum and having a negative charge and said electrolyte **(24)** impregnating said membrane **(34)** to carry an ion current through said membrane **(34)**,

a cathode **(38)** sandwiched with said membrane **(34)** and disposed in spaced and parallel relationship with said anode **(28)**,

and characterized by,

said electrolyte **(24)** consisting essentially of glycerol and said first ions **(26)** containing Aluminum and said second ions **(27)** containing Aluminum dispersed in said glycerol for migrating between and reacting with said anode **(28)** of Aluminum and said cathode **(38)** to charge and discharge the electrical energy storage device **(20)**.

2. An electrical energy storage device **(20)** as set forth in claim 1 wherein said first ions **(26)** containing Aluminum include $[Al(ClO_4)_2 \bullet \{C_3H_5(OH)_3\}_2]^+$ and said second ions **(27)** containing Aluminum include $[Al(ClO_4)_4]^-$.

3. An electrical energy storage device **(20)** comprising;

an anode **(28)** comprising a layer of Aluminum,

a membrane **(34)** sandwiched with said anode **(28)**, a cathode **(38)** sandwiched with said membrane **(34)** and disposed in spaced and parallel relationship with said anode **(28)**,

and characterized by,

said cathode **(38)** containing a host lattice **(44)** having a conjugated system with delocalized π electrons and a dopant **(48)** containing Aluminum Glycerate bonded with said host lattice **(44)** to alter the electrochemical properties of said host lattice **(44)** of said cathode **(38)**.

4. An electrical energy storage device **(20)** as set forth in claim 3 wherein said dopant **(48)** contains Aluminum Alcoholate.

5. A secondary battery device **(22)** comprising;

an anode **(28)** consisting of a layer of 99.4 to 99.9 wt% of solid Aluminum of 99.95 % purity and 0.1 to 0.6 wt% of Indium and having a rectangular shape with a first length of 1.2 cm and a first width of 1.7 cm and a first thickness of 0.1 mm,

a negative lead **(30)** of an electrically conductive material in electrical contact with said anode **(28)** for conducting electrical current with external circuitry,

a cement **(32)** including particles of metal disposed between and bonding said anode **(28)** and said negative lead **(30)** for conducting electrical current therebetween,

a membrane **(34)** of cellulose having a third thickness of 0.08 mm and defining a plurality of pores **(36)** and sandwiched with said anode **(28)** for providing electrical insulation therebetween,

an electrolyte **(24)** including first ions **(26)** containing Aluminum and having a positive charge and including second ions **(27)** containing Aluminum and having a negative charge and said electrolyte **(24)** impregnating said pores **(36)** of said membrane **(34)** to carry an ion current through said membrane **(34)**,

a cathode **(38)** having a rectangular shape with a second length of 1.4 cm and a second width of 1.9 cm and a second thickness of 0.1 mm disposed adjacent and parallel to said membrane **(34)** with said membrane **(34)** being sandwiched between said cathode **(38)** and said anode **(28)**,

said cathode **(38)** including a carrier sheet **(40)** of cellulose and an electroactive layer **(42)** integrated with and upon said carrier sheet **(40)** facing said anode **(28)**,

a positive lead **(50)** containing graphite in electrical contact with said electroactive layer **(42)** of said cathode **(38)** for conducting electrical current with external circuitry,

an adhesive **(52)** containing graphite disposed between and bonding said electroactive layer **(42)** and said positive lead **(50)** for conducting electrical current therebetween,

and characterized by,

said electrolyte **(24)** consisting essentially of glycerol and said first ions **(26)** including $[Al(ClO_4)_2 \cdot \{C_3H_5(OH)_3\}_2]^+$ and said second ions **(27)** including $[Al(ClO_4)_4]^-$ for migrating between and reacting with said anode **(28)** and said cathode **(38)** to charge and discharge said secondary battery device **(22)**,

said electroactive layer **(42)** of said cathode **(38)** containing a host lattice **(44)** having a conjugated system with delocalized π electrons and defining voids and a dopant **(48)** containing Aluminum Alcoholate and Aluminum Glycerate bonded with said conjugated system of said host lattice **(44)** and intercalated in said voids to alter the electrochemical properties of said electroactive layer **(42)** of said cathode **(38)** to increase the rate of the reactions with said first ions **(26)** and said second ions **(27)** for charging and discharging said secondary battery device **(22)**.

6. The secondary battery device **(22)** as set forth in claim 5 wherein said host lattice **(44)** of said electroactive layer **(42)** comprises flakes **(54)** of graphite having particle size of 200 to 300 μm and a binder material wettable by glycerol.

7. The secondary battery device **(22)** as set forth in claim 6 wherein said binder material comprises alkyl glue.

8. The secondary battery device **(22)** as set forth in claim 6 wherein said binder material comprises acrylic glue.

9. The secondary battery device **(22)** as set forth in claim 5 wherein said host lattice **(44)** of said electroactive layer **(42)** comprises particles of amorphous thermally expandable graphite and manganese dioxide and activated manganese dioxide and acetylene black and a binder material being wettable by glycerol and an electrically conductive paint including graphite.

10. The secondary battery device **(22)** as set forth in claim 9 wherein said binder material is alkyl glue.

11. The secondary battery device **(22)** as set forth in claim 9 wherein said binder material is acrylic glue.

12. The secondary battery device **(22)** as set forth in claim 9 wherein said binder material is an electrically conductive paint including graphite.

13. The secondary battery device **(22)** as set forth in claim 5 wherein said host lattice **(44)** of said electroactive layer **(42)** includes a polyconjugated linear hydrocarbon polymer.

14. The secondary battery device **(22)** as set forth in claim 5 wherein said host lattice **(44)** of said electroactive layer **(42)** includes a cyclic polyconjugated chain polymer of polyaniline.

15. A method for constructing an electrical energy storage device **(20)** having an anode **(28)** and a membrane **(34)** and an electrolyte **(24)** and a cathode **(38)**, said method comprising;

wetting the membrane **(34)** with an electrolyte **(24)**,

stacking the membrane **(34)** upon and parallel to the anode **(28)**,

stacking the cathode **(38)** upon and parallel to the membrane **(34)** with the membrane **(34)** disposed between the anode **(28)** and the cathode **(38)**,

and characterized by,

dissolving Aluminum Perchlorate powder in glycerol to saturation to make the electrolyte **(24)**.

16. The method as set forth in claim 15 further comprising steps for making a doping fluid **(62)** for carrying a dopant **(48)** containing Aluminum into an electrode **(28, 38)**

of an electrical energy storage device **(20)** using filings **(70)** containing Aluminum, said method comprising;

dissolving $AlCl_3$ powder in ethanol to create a background solution **(66)**,

and characterized by,

combining the background solution **(66)** with glycerol to produce a binary solvent **(68),**

immersing the filings **(70)** containing Aluminum in the binary solvent **(68)** until the filings **(70)** containing Aluminum have dissolved to produce the doping fluid **(62)**.

17. A method for constructing a secondary battery device **(22)** having an anode **(28)** and a negative lead **(30)** and a membrane **(34)** and an electrolyte **(24)** and a cathode **(38)** having a carrier sheet **(40)** of cellulose using a cathodic mixture **(60)**, said method comprising;

heating a plate of Aluminum of 99.95 % purity and 0.1 to 0.6 wt% of Indium to a temperature of 450°C,

rolling the plate to reduce the thickness of the plate while cooling at a rate of more than 10°C per minute to a reduced thickness,

reheating the reduced thickness of the plate and rerolling the reduced thickness of the plate into a foil **(56)** coated with Aluminum Oxide and surface contaminants and having a thickness between 0.05 and 0.1 mm,

rinsing the foil **(56)** with ethanol to remove surface contaminants therefrom,

submerging the foil **(56)** in a solution of water and Hydroxide having a concentration of 4mol for one minute for removing the Aluminum Oxide from the surface of the foil **(56)**,

rinsing the foil **(56)** with water for removing the Hydroxide therefrom, subjecting the foil **(56)** to 70°C for 30 minutes for evaporating moisture therefrom,

surrounding the foil **(56)** with an anhydrous environment,

dividing the foil **(56)** into a rectangular shape to define the anode **(28)** having a first length of 1.2 cm and a first width of 1.7 cm,

attaching a negative lead **(30)** to the anode **(28)** with a cement **(32)** including particles of silver,

wetting the membrane **(34)** with the electrolyte **(24)**,

stacking the membrane **(34)** upon and parallel to the anode **(28)**,

applying the cathodic mixture **(60)** in a thin film layer to one side of the carrier sheet **(40)** of cellulose to soak into the carrier sheet **(40)**,

subjecting the cathodic mixture **(60)** to a temperature of 50 to 60°C to solidify the cathodic mixture **(60)** into a host lattice **(44)** being disposed upon and within the carrier sheet **(40)**,

wetting the host lattice **(44)** with a doping fluid **(62)** containing a dopant **(48)** to allow the dopant **(48)** to bond with and intercalate into the host lattice **(44)** to produce an electroactive layer **(42)**,

attaching a positive lead **(50)** in electrical contact with the electroactive layer **(42)** of the cathode **(38)** with an adhesive **(52)** containing graphite,

stacking the cathode **(38)** upon and parallel to the membrane **(34)** with the membrane **(34)** disposed between the anode **(28)** and the cathode **(38)**,

and characterized by,

dissolving Aluminum Perchlorate powder in glycerol to saturation to produce the electrolyte **(24)**,

dissolving $AlCl_3$ powder in ethanol to produce a background solution **(66)**, combining 40 wt% of the background solution **(66)** with 60 wt% of glycerol to produce a binary solvent **(68),**

grating 1 cm^3 of 99.4 to 99.9 wt% of Aluminum of 99.95 % purity and 0.1 to 0.6 wt% of Indium to make filings **(70)** with an equivalent surface area of 20 to 30 cm^2,

immersing the filings **(70)** in 150 to 200 ml of the binary solvent **(68)** until the filings **(70)** have dissolved to produce the doping fluid **(62)**.

18. The method as set forth in claim 17 further comprising a step for making the cathodic mixture **(60)** characterized by;

mixing 5 wt% of alkyl glue with 60 wt% of ethanol with 35 wt% of flakes **(54)** of graphite to make the cathodic mixture **(60)**.

19. The method as set forth in claim 17 further comprising a step for making the cathodic mixture **(60)** characterized by;

mixing amorphous thermally expandable graphite powder with 1-5 wt% MnO_2 with 1-5 wt% activated MnO_2 with 1-5 wt% acetylene black to make an intermediate mixture.

20. The method as set forth in claim 19, further comprising the step of adding a binder of alkyl glue and ethanol to the intermediate mixture to make the cathodic mixture **(60)** having a consistency of thick spreadable paste.

21. The method as set forth in claim 19, further comprising the step of adding a binder of acrylic glue to the intermediate mixture to make the cathodic mixture **(60)** having a consistency of thick spreadable paste.

22. The method as set forth in claim 19, further comprising the step of adding a binder of graphite paint to the intermediate mixture to make the cathodic mixture **(60)** having a consistency of thick spreadable paste.

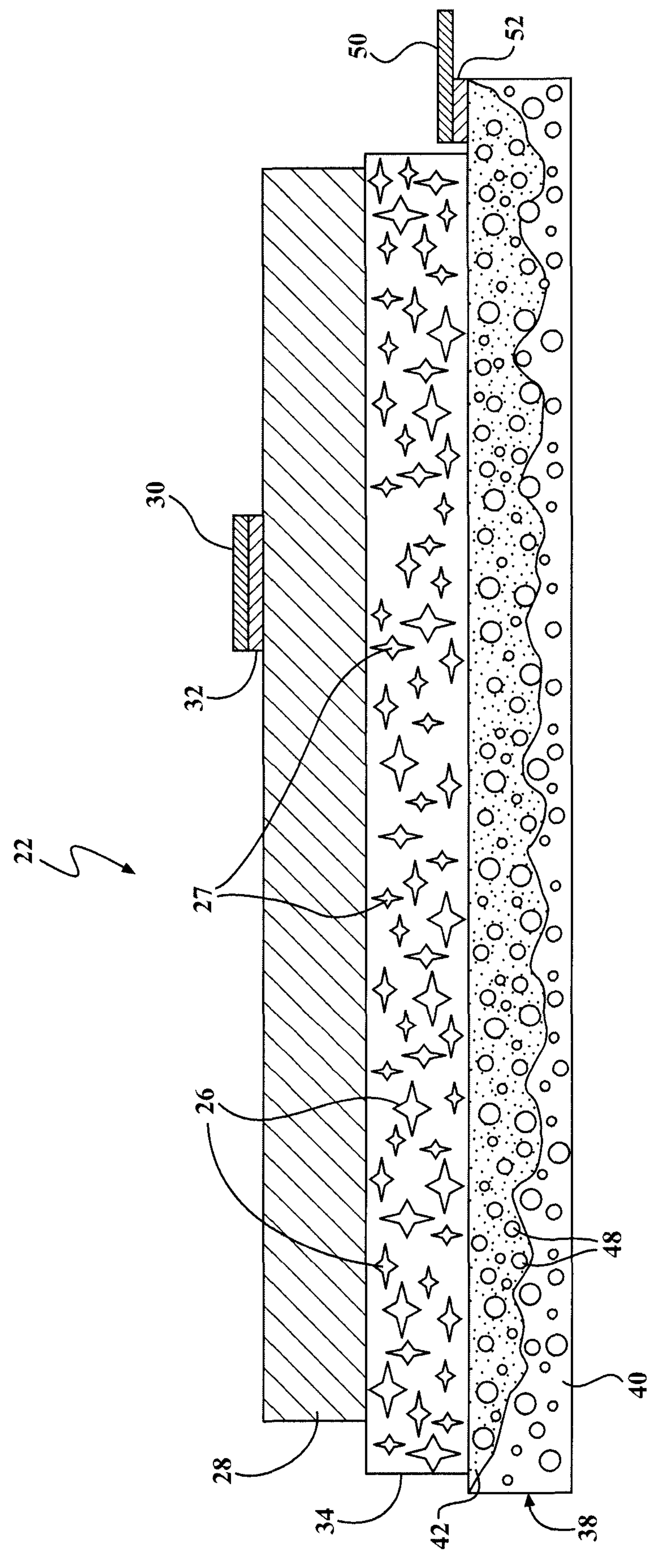

FIG. 1

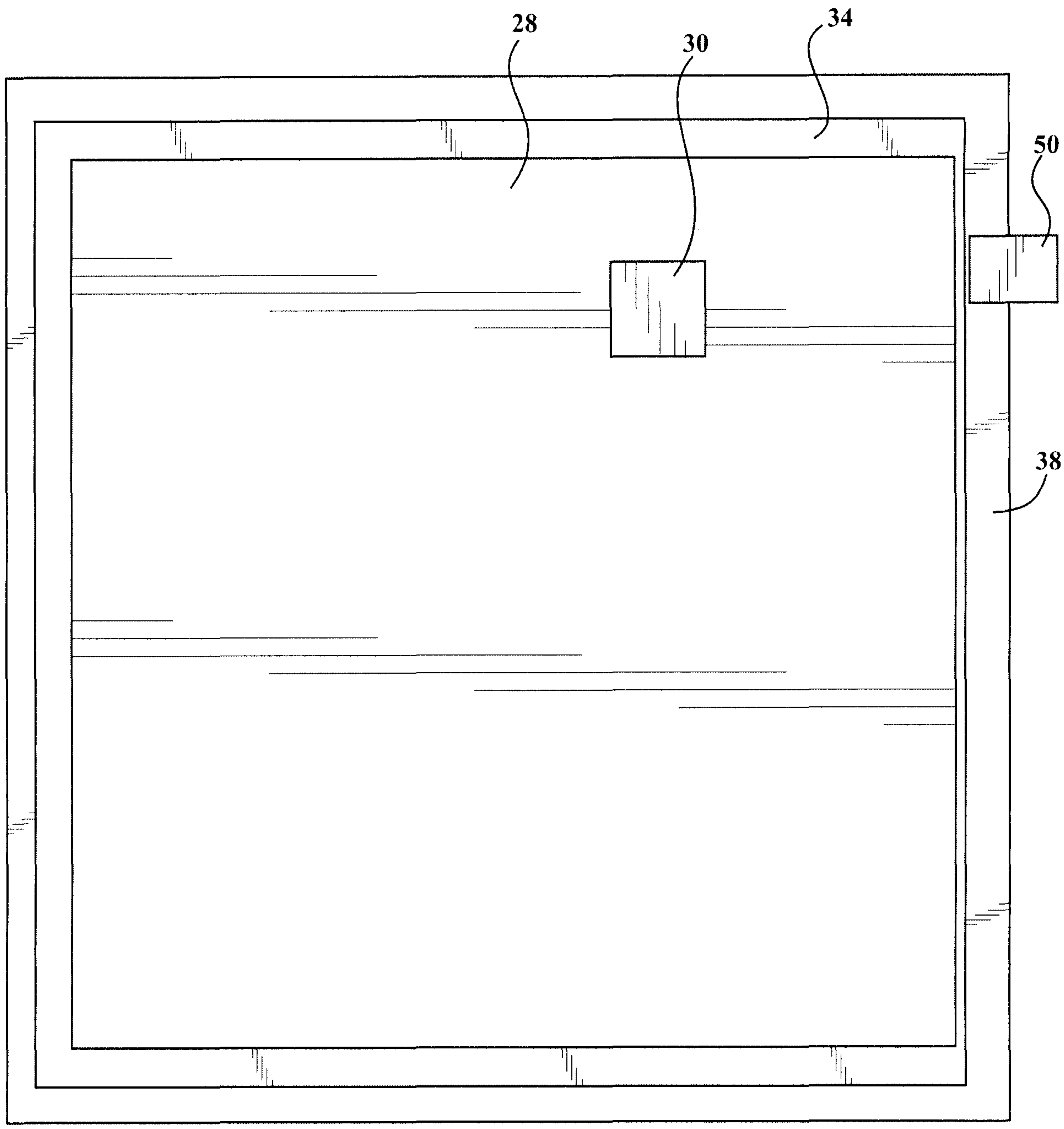

FIG. 2

FIG. 1