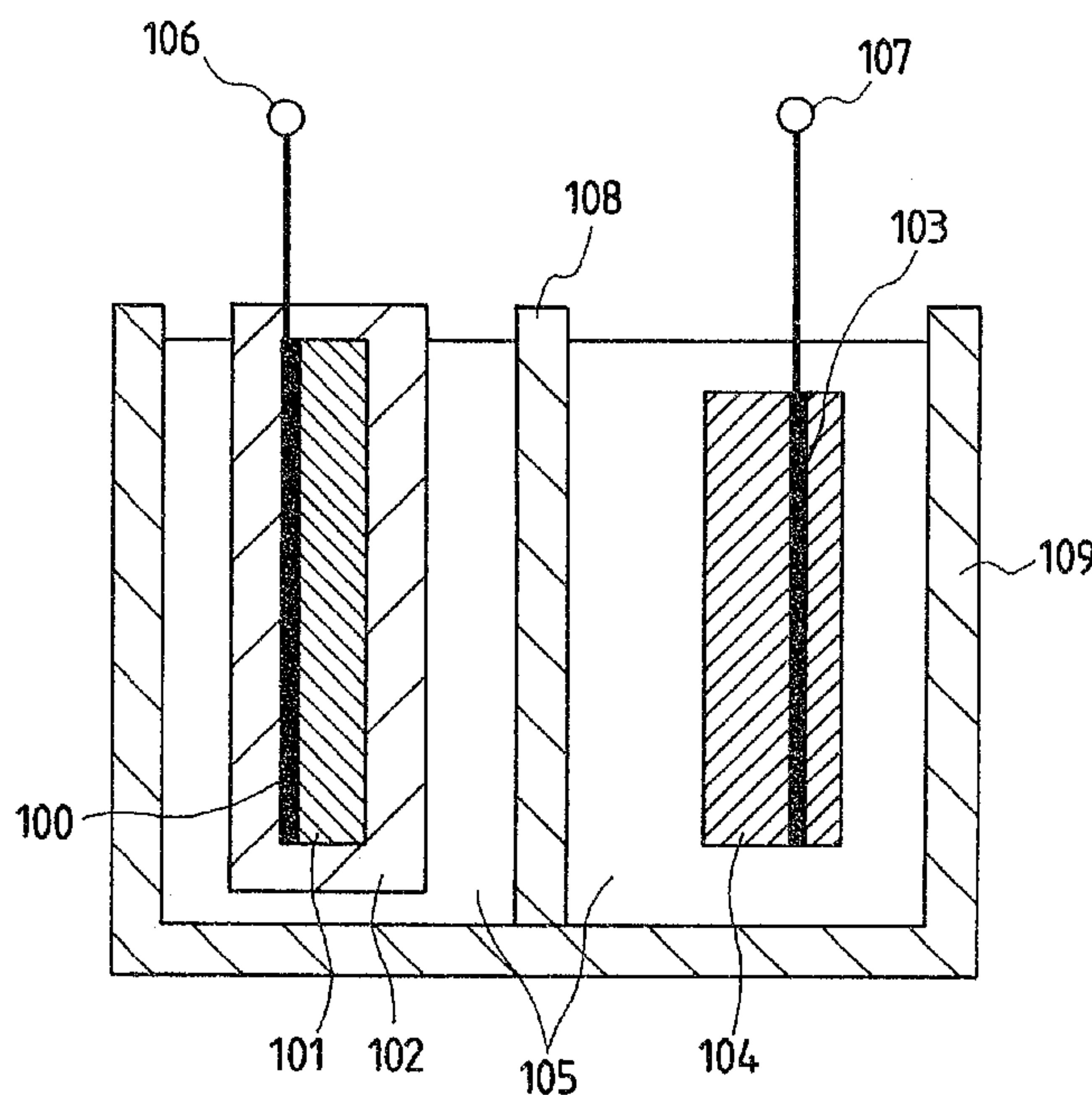




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 (54) Title: SECONDARY BATTERY



(57) **Abrégé/Abstract:**

A secondary battery exhibiting a long cycle life and comprising a negative electrode active material made of lithium or zinc is provided, the battery at least having a negative electrode made of lithium or zinc serving as the negative electrode active material, an electrolyte (electrolyte solution), a separator, a positive electrode made of a positive electrode active material, a collecting electrode and a battery case, wherein at least the surface of the negative electrode is covered with a film having a structure which allows ions relating to the battery reactions to pass through. Since growth of dendrite of lithium or zinc at the time of the charge can be prevented, short circuit between the negative electrode and the positive electrode can be prevented. Therefore, the charge/discharge cycle life can significantly be lengthened. As a result, a lithium secondary battery, a nickel-zinc secondary battery, an air-zinc secondary battery, a bromine-zinc secondary battery and a silver oxide-zinc secondary battery of the long cycle life can be manufactured.

ABSTRACT OF THE DISCLOSURE

A secondary battery exhibiting a long cycle life and comprising a negative electrode active material made of lithium or zinc is provided, the battery at least
5 having a negative electrode made of lithium or zinc serving as the negative electrode active material, an electrolyte (electrolyte solution), a separator, a positive electrode made of a positive electrode active
10 material, a collecting electrode and a battery case, wherein at least the surface of the negative electrode is covered with a film having a structure which allows ions relating to the battery reactions to pass through. Since growth of dendrite of lithium or zinc at the time
15 of the charge can be prevented, short circuit between the negative electrode and the positive electrode can be prevented. Therefore, the charge/discharge cycle life can significantly be lengthened. As a result, a lithium secondary battery, a nickel-zinc secondary battery, an
20 air-zinc secondary battery, a bromine-zinc secondary battery and a silver oxide-zinc secondary battery of the long cycle life can be manufactured.

Secondary Battery

BACKGROUND OF THE INVENTION5 Field of the Invention

The present invention relates to a secondary battery which can repeatedly be used, and more particularly to a reliable secondary battery capable of preventing short circuit occurring due to dendrite even if the battery is repeatedly charged and discharged.

10

Related Background Art

Since global warming is expected to take place due to the greenhouse effect caused from an increase in CO₂ and so forth, construction of thermal power plants encounters problems. Accordingly, it has been considered feasible to perform so-called load levelling for the purpose of effectively using generators by accumulating electric power at night in secondary batteries at homes to level the load.

15

20 There arises another desire for a development of secondary battery which exhibits a high energy density for use in an electric car that does not exhaust air contamination substances. Further, development of a high performance secondary battery has been needed for use as a power source for portable equipment, such as a book-type personal computer, a word processor, a video camera and a portable telephone.

25

A locking chair type lithium ion battery capable

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of serving as the foregoing high performance secondary battery and comprising a positive electrode active material comprising lithium ions introduced into an interlayer compound thereof and a negative electrode active material comprising carbon has been developed and partially put into practical use.

However the lithium ion battery has not achieved the high energy density that is the original characteristics of the lithium battery which uses the metal lithium as the positive electrode active material. The reason why a large capacity lithium accumulator of the type that uses the lithium metal as the positive electrode has not been put into practical use is that generation of dendrite of the lithium (tree branch like crystal) which is the main cause of a short circuit cannot be prevented yet.

The lithium battery, nickel-zinc battery and the air-zinc battery encounter the difficulty that lithium or zinc is, as described above, deposited on the surface of the negative electrode at the time of charge. At this time, the current density is locally raised on the negative electrode surface depending upon the surface condition, causing lithium or zinc to be selectively deposited in the foregoing place. The deposited metal grows (dendrite) in the form of tree branch with the progress of the charge and discharge cycles while penetrating a separator until it reaches the positive electrode, causing a short circuit to occur.

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The dendrite reaction mechanism is considered as follows. Since lithium or zinc that deposits at the time of charge has a considerable reactivity, it reacts with electrolyte solution or water or the like in the electrolyte solution, causing an insulating film to be formed which has a large resistance. Therefore, the current density in the foregoing portion is raised at the time of the next charge, resulting in that the dendrite can further easily grow. It leads to a fact that a short circuit takes place between the negative electrode and the positive electrode, resulting in that the charge cannot be performed.

If the short circuit has taken place considerably, the energy of the battery will be consumed in a very short time, causing heat to be generated. As a result, the solvent of the electrolyte solution can be decomposed, resulting in generation of gas. Therefore, gas is generated, causing the internal pressure to be raised. In this case, an accident of an exposure or fire can be generated for the worst. Therefore, there has been a desire for a long life deposition of lithium that does not easily cause the internal short circuit even if the charge and the discharge are repeated.

Also nickel-zinc batteries and air-zinc batteries generate dendrite of zinc due to repetition of charging and discharging, the dendrite penetrating the separator. As a result the zinc negative electrode and the positive electrode encounter a short circuit. Therefore, the

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foregoing conventional technology suffers from an excessively short cycle life.

SUMMARY OF THE INVENTION

5 An object of the present invention is to provide a lithium, lithium alloy, zinc or zinc alloy secondary battery capable of overcoming the foregoing problems experienced with the conventional secondary batteries and exhibiting a long cycle life.

10 In order to overcome the foregoing problems experienced with the conventional technology, the inventors of the present invention have made energetic studies. As a result, a fact was found that generation of dendrite of lithium or zinc can be prevented by
15 forming a film permitting ions relating to battery reactions to pass through on the surface of the negative electrode.

 The present invention is characterized in that a secondary battery comprises a negative electrode made of
20 a negative electrode active material, a separator, a positive electrode made of a positive electrode active material, an electrolyte solution, a collecting electrode and a battery case, wherein the surface of the negative electrode is covered with a film permitting
25 ions relating to battery reactions to pass through.

 The material of the film has a molecular structure or small apertures which do not permit the negative electrode active material which precipitates on the

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negative electrode but which permit ions relating to the battery reactions to pass through.

The present invention is characterized in that the foregoing material of the film has been electron
5 donative elements or groups for enabling the ions relating to the battery reactions to be easily conducted in the film.

The electron donative element is exemplified by oxygen atoms, nitrogen atoms, sulfur atoms and
10 transition metal atoms respectively having a paired electron, a non-paired electron or electron d. The electron donative group is exemplified by a ring compound and a compound having a carbon double bond having electron π or an aromatic ring.

15 The film formed on the surface of the negative electrode according to the present invention is characterized in that it cannot be dissolved by the electrolyte.

20 The inventor of the present invention found a fact that treatment of the surface of the negative electrode with a nitrogen compound or a halogen compound, which is active in a gas phase, will prevent the generation of lithium dendrite.

25 According to the present invention, there is provided a secondary battery having a negative electrode active material composed of lithium, a separator, a positive electrode active material, an electrolyte, a collector and a battery case, wherein at least the

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surface of the lithium negative electrode opposing the positive electrode is treated with reactive and gaseous material containing nitrogen or a halogen element.

According to the present invention, there is provided a battery comprising a negative electrode, a separator, a positive electrode and an electrolyte, wherein one or more layers selected from a group consisting of a conductor layer, a semiconductor layer and an insulating layer are formed between the negative electrode and the separator.

If the negative electrode active material is lithium or lithium alloy, the foregoing layer is formed into a micropore structure having small apertures permitting at least lithium ions to pass through. If zinc or zinc alloy is used, the small apertures permit hydride ions to pass through.

The small apertures permitting ions to pass through may be realized by the molecular structure of the material or by a manufacturing method. The small apertures can be easily formed by, for example, injecting an electrolyte into the foregoing layer at the time of forming the layer to manufacture the battery, the electrolyte being eluting to form the micropores. Another method may be employed in which a foaming material is added at the time of forming the foregoing layer and then the micropores are formed by heat treatment or the like.

The structure of the stacked layers may be a single

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layer or a multi-layer composed of two or more layers or composed of a conductor layer, a semiconductor layer, an insulating layer and a composite layer containing two or more types of elements or compounds.

5 Further, a fact was found that the separator partially including a film-shape member (hereinafter sometimes called a "metal oxide film") of a metal oxide formed by a mold made of a bimolecular film forming compound is able to prevent short circuit in the battery
10 occurring between the negative electrode and the positive electrode even if dendrite is generated in the negative electrode.

According to the present invention, there is provided a secondary battery comprising a negative
15 electrode made of a negative electrode active material, a positive electrode made of a positive electrode active material and a separator which separating the positive electrode active material and the negative electrode active material from each other, wherein at least a
20 multi-layer metal oxide is present between the positive electrode and the negative electrode.

Another fact was found that an arrangement that surface of the positive electrode is covered with a thin film made of an insulating material or a semiconductor
25 which is free from electron conduction and which permits ions relating to battery reactions will prevent short circuit in the battery between the negative electrode and the positive electrode even if dendrite is generated

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in the negative electrode.

According to the present invention, there is provided a secondary battery at least comprising a negative electrode, a separator, a positive electrode,
5 an electrolyte, a collector and a battery case, wherein at least the surface of the positive electrode opposing the negative electrode is covered with one or more thin film layers selected from a group consisting of an insulating layer, a semiconductor layer, a layer
10 composed of an insulating material and a semiconductor which permit ions relating to the battery reactions to pass through.

Another fact was found that the utility of a positive electrode made of a compound of one or more
15 types of transition metals, whose crystal grain size of 500Å or less, provides a secondary lithium battery having high capacity, large energy and long cycle life.

According to the present invention, there is provided a lithium secondary battery at least comprising
20 a negative electrode active material, a separator, a positive electrode active material through which ions can be introduced/discharged due to charge/discharge, an electrolyte which is an ion conductor, a collecting electrode and a battery case, wherein the main component
25 of the positive electrode active material 13104 is a compound of one or more type of transition metal and a group 6A element and having a crystal grain size of 500Å or less.

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The main component material of the positive electrode active material has a structure of an aggregate selected from a group consisting of amorphous, microcrystal, a mixture of amorphous, microcrystal and a mixture of amorphous, microcrystal and multi-crystal.

The arrangement that the positive electrode active material of the lithium secondary battery is made of compound of the transition metal having a structure of the aggregate selected from a group consisting of amorphous, microcrystal, a mixture of amorphous and a microcrystal and a mixture of an amorphous, a microcrystal and a multi-crystal, and the group 6A element and having a crystal grain size of 500 Å or less, more preferably 200 Å enables the following effects to be obtained:

(1) Since the reactive area of the positive electrode active material can be enlarged, the electrochemical reactions at the time of charge and discharge can be made smooth, and therefore the chargeable capacity can be enlarged.

(2) The introduction and the discharge of lithium ions at the time of the charge and the discharge prevent the distortion of the positive electrode active material, causing the cycle life to be lengthened.

It is preferable that the specific area of the positive electrode active material mainly composed of the compound of the transition metal and the group 6A element be 50 m²/g or more in a state before the material

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is formed into the positive electrode, more preferably
100 m²/g or more.

The employment of the compound of the transition
metal and the group 6A element containing hydrogen will
5 improve in the charge and discharge cycle
characteristics.

By subjecting the positive electrode active
material to a lipophilic treatment using an organic
metal compound, the solid-liquid reactions between the
10 electrolyte and the positive electrode active material
can be made further smooth at the time of charge and the
discharge.

The compound of the transition metal and the group
6A element is exemplified by a metal oxide such as a
15 nickel oxide, a cobalt oxide, a titanium oxide, an iron
oxide, a vanadium oxide, a manganese oxide, a molybdenum
oxide, a chrome oxide or a tungsten oxide, a metal
sulfide such as a molybdenum sulfide, an iron sulfide or
a titanium sulfide, a hydride such as an oxy iron
20 hydride or their mixtures.

By employment of metal lithium having a film
through which lithium ions are able to pass to form the
negative electrode active material of the secondary
battery, a lithium secondary battery exhibiting a long
25 life and a high energy density can be obtained.

According to the present invention, there is
provided a method of manufacturing a positive electrode
active material of a lithium secondary battery at least

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comprising the step of forming a compound of a transition metal and a group 6A element, the raw material of which is one or more types of materials selected from a group consisting of the transition metal, the salt of the transition metal, an organic metal compound of the transition metal, a hydride of the transition metal hydroxide, a hydrogated transition metal, a carbonyl compound of a transition metal and a transition metal oxide and which has a structure of an aggregate having a crystal grain size of 500 Å or less, more preferably 200 Å or less and selected from a group consisting of amorphous, microcrystal, a mixture of amorphous and microcrystal and a mixture of amorphous, microcrystal and multi-crystal.

According to the present invention, there is provided a method of manufacturing a positive electrode active material which is a compound of a transition metal and a group 6A element, the method comprising the steps of:

employing one or more types of reactions selected from a group consisting of a reaction between a salt of the transition metal and alkali, a hydrolysis decomposition reaction of an organic transition metal compound and a reaction between the transition metal and alkali to prepare a hydride of the transition metal;

employing a dehydrating reaction or decomposition of the salt of the transition metal or the organic transition metal compound in a gas phase or a reaction

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between the salt of the transition metal or the decomposed material of the organic transition metal compound or vapor of the transition metal and the group 6A element or the group 6A compound;

5 melting one or more types of materials selected from a group consisting of the transition metal and the transition metal compound to be allowed to react with one or more types of materials selected from a group consisting of the group 6A element and the compound of
10 the group 6A element; and

rapidly cooling the materials to form an aggregate having a crystal grain size of 500 Å or less and formed into a structure selected from a group consisting of amorphous, microcrystal, a mixture of amorphous and
15 microcrystal and a mixture of amorphous, microcrystal and multi-crystal.

In another aspect, the present invention provides a secondary battery comprising: a negative electrode having a negative electrode active material, a positive
20 electrode substantially made of a positive electrode active material; a separator arranged between the negative electrode and the positive electrode; an electrolyte provided between said positive and negative electrodes; and a film with a thickness of 50Å and 100
25 μm and of a molecular structure of large voids and fine holes covering at least separator side of said negative electrode for operating to preclude a contact between said negative electrode and said electrolyte

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substantially through which passes ion which contributes to the battery operation.

BRIEF DESCRIPTION OF THE DRAWINGS

5 Fig. 1 is a basic structural view which illustrates a secondary battery according to the present invention;

 Fig. 2 is a schematic cross sectional view which illustrates a flat battery to which the present invention is applied;

10 Fig. 3 is a schematic cross sectional view which illustrates an example of a cylindrical battery to which the present invention is applied;

 Fig. 4 is a schematic view which illustrates an example of a partial structure of a negative electrode covered with a film through which ions relating to
15 battery reactions are able to pass;

 Fig. 5 is a basic structural view which illustrates another embodiment of the secondary battery according to the present invention;

20 Fig. 6 is a schematic structural view which illustrates an apparatus for subjecting lithium for use in the secondary battery according to the present invention to surface treatment;

 Fig. 7 is a schematic structural view which
25 illustrates an apparatus for subjecting lithium for use in the secondary battery according to the present invention to surface treatment;

 Fig. 8 is a schematic view which illustrates an

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effect of the present invention;

Figs. 9A to 9H are views which illustrate examples of layer stacking patterns according to the present invention including a conductor layer, a semiconductor layer and an insulating layer between the negative electrode and the separator thereof;

Fig. 10 is another basic structural view which illustrates the secondary battery according to the present invention;

Fig. 11 is a schematic cross sectional view which illustrates another cylindrical battery to which the present invention is applied;

Fig. 12 is another basic structural view which illustrates the secondary battery according to the present invention; and

Fig. 13 is another basic structural view which illustrates the secondary battery according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Structure of Battery

A secondary battery according to the present invention comprises a negative electrode, a separator, a positive electrode, an electrolyte and a collector. Fig. 1 is a basic structural view which illustrates the secondary battery. Referring to Fig. 1, reference numeral 100 represents a negative collector, 101 represents a negative electrode substantially made of

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negative electrode active material, 102 represents a shell, 103 represents a positive collector, 104 represents a positive electrode substantially made of positive electrode active material, 105 represents an electrolyte solution (electrolyte), 106 represents a negative terminal, 107 represents a positive terminal, 109 represents a case for the secondary battery, and 108 represents a separator. Figs. 5, 10 and 12 illustrate another basic structure in which a multi-layer oxide film 10102, an ion permeable film 10102 and a layer 5102 applied with lithium surface treatment in place of the film 102. If the lithium battery comprises the negative electrode 101 made of the negative electrode active material which is lithium or lithium alloy, lithium ions in the electrolytic solution 105 are introduced into the space between the layers of the positive electrode active material of the positive electrode 104 through the permeable film due to the discharge reaction in a case of the structure shown in Fig. 12. Simultaneously, lithium ions are dissolved and discharged from the negative electrode active material 101 into the electrolyte 105 through the film 102 and the multi-layer metal oxide 10102. In the charging reaction, lithium ions in the electrolyte solution 105 are, in the form of lithium metal, precipitated into the negative electrode active material through the film 102 (dendrite can easily grow if the film 102 is not present). Simultaneously, lithium between the layers of the

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positive electrode active material 104 is dissolved and discharged into the electrolyte solution 105. Although lithium ions precipitated during the charging reaction are in a very active state to react with small-quantity water, oxygen, impurities or solvent in the electrolyte contained, the structure in which the surface of the negative electrode 101 is covered with the film 102 prevents direct contact between the precipitated lithium and the electrolyte solution. Therefore, the generation of dendrite, which causes the battery short circuit to occur, can be prevented.

In a case of an alkali battery comprising the negative electrode active material 101 made of zinc or zinc alloy, the discharge reaction takes place in such a manner that hydroxyl ions in the electrolyte solution 105, similarly to the above, react with the negative electrode active material 101 of the negative electrode 101 through the film 102. Simultaneously hydroxyl ions are discharged into the electrolyte solution 105 from the positive electrode active material of the positive electrode 104. The charging reaction is performed in such a manner that hydroxyl ions are discharged from the negative electrode 101 into the electrolyte solution 105 through the film 102 (if the film 102 is not present at this time, zinc ions in the electrolyte solution 105 easily cause dendrite to grow on the negative electrode). Simultaneously, hydroxyl ions in the electrolyte solution 105 react with the positive

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electrode 104. Similarly to the case where the negative electrode active material is lithium, the presence of the film 102 prevents generation of zinc dendrite at the time of charging.

5 Therefore, the present invention is able to prevent short circuits in the battery, lengthen the life of the secondary battery and improve the safety.

 If the foregoing negative electrode active material is lithium or lithium alloy, lithium ions are used in
10 the reactions in the battery. In the case of the alkali battery containing zinc as the negative electrode active material, hydroxyl ions are used in the reactions. The batteries comprising zinc as the negative electrode active material is typified by nickel-zinc battery, air-
15 zinc battery and bromine-zinc battery (however, the bromine-zinc battery comprises zinc ion as the negative side ion that are used in the inside reactions).

Method of Forming Negative Electrode

 The negative electrode can be formed by any one of the
20 following methods as well as the method for forming the same by directly covering the surface of the negative electrode active material with a coating material by a dipping method, a spraying method or a CVD method.

 It is effective to employ a method in which a
25 conductive and porous matrix (the base), for example, sponge-like or fiber metal or carbon, having communication holes is covered with a coating material through which ions for use in the reactions in the

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battery can be passed through, and then lithium or zinc, which is the negative electrode active material, is caused to electrochemical precipitate and adhere so that the negative electrode is formed. If a porous and
5 conductive matrix has a wide specific area, the current density per unit area at the time of the charge and the discharge can be lowered. Therefore, the growth of the dendrite can be prevented and accordingly the charging/
discharging efficiency can be improved.

10 It is preferable that the film made of a coating material, through which ions can be passed through, the small apertures serving as the space, in which the lithium can be precipitated, be formed into a 3D net shape.

15 Another effective method may be employed which has steps of directly immersing a porous and conductive matrix in the melted negative electrode active material, taking out the matrix, covering the surface of the conductive matrix with the negative electrode active
20 material or electrochemically covering the same with the negative electrode active material, and applying a coating material through which ions for use in the reactions in the battery can be passed to the surface.

25 Fig. 4 is a schematic view which illustrates a partial structure of a negative electrode formed by covering a conductive matrix 400 with a negative electrode active material 401 and a coating material 402 through which ions for use in the reactions in the

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battery can be passed.

Material for Covering the Surface of Negative Electrode

The coating material for covering the surface of the negative electrode will now be described (1 to 7).

5 1. Film Having an Inorganic Glass Structure

By covering the surface of the negative electrode active material with the film having an inorganic glass structure, through which ions for use in the reactions in the battery can be passed, the reactions between
10 lithium and water or oxygen can be prevented, causing easiness in handling if the negative electrode active material is lithium. Further, the direct contact between the lithium and the electrolyte solution does not take place. Therefore, the growth of the polymer film formed
15 from the solvent of the electrolyte solution on the surface of lithium can be prevented. If the negative electrode active material is zinc, the elution of zinc into the electrolyte solution can be prevented. As a result, formation of dendrite can be prevented and
20 therefore the cycle life against charge and discharge can be lengthened. Since the film having the inorganic glass structure is flame retardant or incombustible, safety in an emergency breakage or the like can be improved. The foregoing inorganic glass may be made any
25 one of a metal oxide selected from a group consisting of silica, titanium oxide, alumina, zirconia oxide, magnesium oxide, tantalum oxide, molybdenum oxide, tungsten molybdenum, tin oxide, indium oxide, iron

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oxide, chrome oxide, aluminum phosphate, iron phosphate, silicon phosphate and their mixtures. In particular, it is preferable to employ silica, titanium oxide, alumina, zirconia oxide or aluminum phosphate.

5 A sol-gel method is one of adequate methods for forming the inorganic glass. however, the fact that lithium has a low melting point of 181°C causes a necessity to arise for the operation of directly applying the foregoing material to the surface of
10 lithium to be performed at low temperature. Since lithium reacts with water and alcohol, the operation must be performed in a circumstance in which no water and alcohol is present (the case in which the inorganic glass is previously applied to the conductive matrix or
15 the case where the negative electrode active material is zinc are excluded).

 Therefore, the sol-gel method, which is the typical inorganic coating method at low temperature, must be performed with any particular means. The raw material
20 for the material having the inorganic glass structure is obtained in such a manner that an acid or a base and water are added to a solution of alcohol of an organic metal compound such as a metal alkoxide to hydrolyze the raw material so as to form colloid particles having
25 metal atom-oxygen atom bonds, and then the solvent is substituted by a non-hydric solvent except alcohol.

 The surface coating of the negative electrode active material is formed in a manner comprising steps

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of directly applying the foregoing colloid solution, or
applying a solution, in which a monomer or an organic
polymer or both organic polymer and a crosslinking
material are dissolved in the colloid solution, and
5 polymerizing it or drying and hardening it. By combining
the organic polymers, strength against cracks and
separations can be improved. If the electrolyte for
forming the battery is dissolved in the colloid solution
to form the film, wettability with the electrolytic
10 solution can be improved, causing ions to be moved
easily.

As an alternative to alkoxide, any one of the
following organic metal compound may be employed: acetyl
acetone salt, an alkyl metal compound, acetyl acetone
15 metal salt, naphthene acid metal salt, and octyl acid
metal salt.

The organic polymer for combining the organic
polymers is exemplified by epoxy resin, polyester,
polyimide, polyethylene, polypropylene, polyurethane,
20 polystyrene, polyethylene glycol, nylon, fluorine resin
and silicon resin.

The polymer crosslinking material is exemplified by
diisocyanate, polyisocyanate prepolymer, block
isocyanate, organic peroxide, polyamine, oxims, nitroso
25 compound, sulfur or sulfur compound, selenium, magnesium
oxide, lead oxide and zinc oxide. As an alternative to
using the crosslinking material, a method may be
employed in which radial rays or electron rays or

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ultraviolet rays are applied to polymerize or crosslink the polymer.

As an application method, a dipping method, screen printing, spraying or a roll coating method may be employed. The viscosity of the liquid to be applied must adequately be adjusted to be adaptable to the application method.

In order to facilitate the movement of the charge at the time of the charging operation, powder or fiber or whisker of conductive material such as carbon or titanium may be mixed with the foregoing film forming solution.

It is preferable that the thickness of the film to be formed on the surface of the negative electrode active material ranges from 50 Å to 100 μ, further preferably ranges from 100 Å to 10 μ. The optimum thickness of the film differs depending upon the density or the void ratio of the film and considerably differs depending upon the type of the electrolytic solution.

The thickness of the film can be adjusted by changing the concentration of the main material in the coating liquid for forming the film.

2. Polymer Film of Derivative of Aromatic Hydrocarbon Compound

By covering the surface of the negative electrode active material with a polymer film of a derivative of an aromatic hydrocarbon compound, the reaction between lithium and water or oxygen can be prevented in the case

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where the negative electrode active material is lithium. It leads to a fact that handling can be facilitated. Further, the contact between lithium and electrolyte solution can be prevented. Therefore, the growth of a polymer film, which is formed from the solvent of the electrolytic solution, on the surface of lithium can be prevented. If the negative electrode active material is zinc, elution of zinc into the electrolyte solution is prevented by the film.

As a result, formation of dendrite can be prevented and therefore the life against the charge and discharge cycle can be lengthened. The derivative of the aromatic hydrocarbon for forming the charge moving complex with lithium is one or more derivatives selected from a group consisting of naphthalene, anthracene, phenanthlene, naphthacene, pyrene, triphenylene, perillene, picene, benzopyrene, coronene and ovalene. The polymer for use to form the coating material can be prepared by polymerization or copolymerization of vinyl monomer, monomer of acetylene derivative or dicarboxylic acid and a monomer such as glycol. The polymerization of the vinyl monomer can be performed by radical or ion polymerization. The monomer of the acetylene derivative can be polymerized while using a chloride of tungsten as a catalyzer. The dicarboxylic acid and diamine can be polycondensed and the dicarboxylic acid and glycol can as well as be polycondensed. The monomer of the aromatic derivative for forming the polymer is exemplified by 2 -

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vinyl naphthalene, 2 - vinyl pyridine, 9 - vinyl
anthracene, 9, 10 - anthracene dipropionic acid, 9, 10 -
bis (phenyl ethyl) anthracene and 5, 12 - bis (phenyl
ethynyl) naphthalene. It is preferable to use 2 - vinyl
5 naphthalene or 9 - vinyl anthracene.

A starting material for the radical polymerization
is exemplified by azobisisobutyronitril (AIBN),
benzoylperoxide (BPO) and t-butylhydroperoxide. A
starting material for the cation polymerization is
10 exemplified by an acid such as H_2SO_4 , H_3PO_4 , $HClO_4$, CCl_3 or
 CO_2H and Friedel-Craft catalyzes such as BF_3 , $AlCl_3$, $TiCl_4$
or $SnCl_4$. A large ring compound having an aromatic ring
can be polymerized by dehydrogenation in which the
Friedel-Craft catalyzer and an oxidizer are combined to
15 each other. A starting material for the anion
polymerization may be an alkaline metal compound or an
organic metal compound.

As an alternative to the foregoing method, a
polymer into which an aromatic group can be obtained by
20 subjecting the side chain of each polymer to a
substitution reaction with a derivative of an aromatic
compound. Another method may be employed in which an
electrolytic polymerization reaction is caused to take
place in an electrolytic solution containing a monomer
25 mixed therein to form directly a polymer of an aromatic
compound on the surface of lithium.

When the surface of lithium is applied with a
coating by using the foregoing polymer solution, it is

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preferable to use a polymer solution dehydrated and deoxidized sufficiently in inactive gas dehydrated sufficiently. It is preferable to use a solvent in the foregoing solution which has been dehydrated with active alumina, molecular sieve, phosphorus pentoxide or calcium chloride. As an alternative to this, it is preferable depending upon the type of the solvent that the solvent be distilled under presence of alkaline metal in inactive gas to remove impurities and to be dehydrated (however, the necessity of strictly controlling water can be eliminated when the polymer is previously applied to the conductive matrix or when the negative electrode active material is zinc).

An electrolyte may previously be mixed when the foregoing film is formed. It leads to a fact that wettability between the electrolytic solution and the film can be improved, causing ions to easily pass through the film. In order to facilitate the movement of the charge at the time of charging, conductive powder, such as carbon or titanium, fiber or whisker may be mixed at the time of forming the film.

Since the performance of the battery deteriorates if the polymer coating film is dissolved in an organic solvent of the electrolyte, it is preferable to be crosslinked in such a manner, for example, ultraviolet rays, electron rays or radial rays are applied or a crosslinking material, such as a radical generating agent, is used.

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It is preferable that the thickness of the film to be formed on the surface of the negative electrode active material ranges from 50 Å to 100 μ, more preferably ranges from 100 Å to 10 μ.

5 The optimum thickness of the film differs depending upon the density or the void ratio of the film and considerably differs depending upon the type of the electrolyte solution. The thickness of the film can be adjusted by changing the concentration of the main
10 material in the coating liquid for forming the film.

3. Organic Metal Compound

When the surface of lithium and the organic metal compound react with each other, bonding with lithium atoms takes place so that a film having a surface which
15 is organic-bonded is formed. As a result, the wettability (the lipophilic property) is improved, causing lithium ions to be easily introduced/discharged at the time of the charge and discharge. Further, the surface coating film prevents the direct contact between
20 lithium and the organic solvent, causing the formation, on the surface of lithium, of a polymerized film of the organic solvent, which increases the resistance in the battery, can be prevented. As a result, formation of dendrite can be prevented, and therefore life against
25 the charge and discharge cycle can be lengthened.

Further, reactions between lithium and water during the manufacturing process can be prevented and accordingly handling can be made easier. If the content of lithium

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in the film is high in the lithium battery according to the present invention, rapid reactions of lithium at an emergency breakage can be prevented.

The foregoing organic metal compound may be a material selected from a group consisting of: metal alkoxide, alkaline metal compound, acetyl acetone metal salt, naphthene acid metal salt, or oxtyl acid metal salt of metal, such as titanium, aluminum, silicon, zirconium, tantalum, magnesium, indium, tin, molybdenum, tungsten or germanium. Among the foregoing organic metal compounds, it is preferable to use a metal compound of silicon or titanium or aluminum because of easy forming of the film and excellent stability of the formed film.

The organic silicon compound may be alkoxysilane, alkylsilane, halogenated silane, siloxane, silane containing vinyl group, amino group, epoxy group, methacrylic group or mercaptal group introduced thereto, hydrogen - denatured, vinyl - denatured, hydroxyl group denatured, amino - denatured, carboxylic group denatured, chloro - denatured, epoxy denatured, methachryloxy - denatured, mercapto - denatured, fluorine - denatured, long - chain - alkyl denatured or phenyl - denatured polysiloxane, alkylene oxide denatured siloxane copolymer, silicon - denatured copolymer, alkoxysilane - denatured polymer, silicon - denatured urethane or silicon - denatured nylon.

The organic titanium compound may be alkoxytitanium, titanium chelate, titanium acylate or

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titanium polymer.

The organic aluminum compound may be alkoxyaluminum, alkylaluminum or a halogenated aluminum.

5 The organic silicon-titanium compound may be a tyranopolymer of a silicon polymer crosslinked to the main chain of a polycarbosilane skeleton with a titanium compound.

10 Also a material prepared by introducing a derivative of an organic metal compound into a polymer by substitution may be used as the coating material.

15 The film may be formed by directly applying the organic compound or by applying it after diluted with a solvent if the organic compound is in the form of liquid. If the organic compound is in the form of a solid, a solution dissolved in a solvent can be applied. The organic compound may be applied by dipping, screen printing, spraying or roll coating. The viscosity of the foregoing coating liquid must adequately be adjusted to be suitable for the employed coating method.

20 By mixing the organic metal compound at the time of forming the film, the wettability of the electrolyte solution can be improved and accordingly ions can easily be introduced/discharged at the time of the charge and the discharge. Further, the movement of the charge can
25 be made easier at the time of the battery charge by mixing powder or fiber or whisker of conductive material such as carbon or titanium at the time of applying the organic metal compound.

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It is preferable that the thickness of the film to be formed on lithium ranges from 50 Å to 100 μ, more preferably 100 Å to 10 μ. The optimum thickness of the film differs depending upon the density or the void ratio of the film and considerably differs depending upon the type of the electrolyte solution. The thickness of the film can be adjusted by changing the concentration of the main material in the coating liquid for forming the film.

4. Fluororesin Coating Material

By using fluorine resin of a type having an ether bond to cover the surface of lithium, the surface coating process can be completed easily and the contact between lithium and the film can be improved.

The presence of oxygen atoms of the fluorine resin having the ether bond makes easier the coordination of lithium ions, enabling lithium ions to be moved easily in the fluorine resin.

Further, the surface coating film prevents the direct contact between the lithium metal and the organic solvent, and therefore the formation of a polymerized film of the organic solvent, which increases the internal resistance of the battery, on the surface of lithium can be prevented.

As a result, the formation of dendrite can be prevented and therefore the life against the charge and discharge cycle can be lengthened.

By covering the surface of lithium with the

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fluorine resin, reactions of lithium with water or oxygen can be prevented, causing handling to be facilitated.

5 Since the fluorine resin is a flame retardant resin, it exhibits safety at the time of an emergency fire accident.

10 The fluorine resin for covering the surface of lithium is exemplified by: a copolymer with a vinyl monomer, such as vinyl ether, dioxysol, dioxyne or dioxycene having an ether bond with fluoroethylene or dime monomer derivative or a copolymer with a vinyl monomer, such as vinyl ether, dioxysol or dioxyne, dioxycene having a fluorized ether bond with a dime compound, such as ethylene. In particular, it is
15 preferable to use a copolymer with vinyl ether having an ether bond with fluoroethylene. The fluoroethylene may be a fluoroethylene derivative such as tetrafluoroethylene, chlorotrifluoroethylene, vinylidene fluoride or vinyl fluoride. The fluoroethylene copolymer
20 containing the ether bond can be polymerized by a solution, suspension, block or emulsion polymerization. As a starting material, a peroxide, alkyl boron, light or radial rays may be employed.

25 The fluoro-resin can be coated on lithium metal by any one of the following methods.

a. A solution of the fluoro-resin is applied by spraying, screen printing, by using a coater or by dipping.

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b. The fluoro-resin is directly coated to the surface of lithium by a vacuum evaporation method such as sputtering.

5 c. A polymer film is directly formed by plasma polymerization under an atmosphere of monomer which is the raw material for the fluoro-resin.

10 If the lithium surface is coated by using the fluoro-resin solution, it is preferable to use, in an inactive gas dehydrated sufficiently, a fluoro-resin solution dehydrated and deoxidized sufficiently. It is preferable to use a solvent in the foregoing solution which has been dehydrated with active alumina, molecular sieve, phosphorus pentoxide or calcium chloride. As an alternative to this, it is preferable depending upon the type of the solvent that the solvent be distilled under presence of alkaline metal in inactive gas to remove impurities and to be dehydrated. However, the necessity of strictly controlling water can be eliminated when lithium is electrochemically inserted and allowed to adhere between the fluoro-resin and the conductive matrix.

20 An electrolyte may previously be mixed when the foregoing film is formed. It leads to a fact that wettability between the electrolyte solution and the film can be improved, causing ions to easily pass through the film. In order to facilitate the movement of the charge at the time of charging, conductive powder, such as carbon or titanium, fiber or whisker may be

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mixed at the time of forming the film.

Since the performance of the battery deteriorates if the fluoro-resin film is dissolved in an organic solvent of the electrolyte solution, it is preferable that the film is crosslinked.

As an alternative to the foregoing method of coating the lithium surface with the fluoro-resin solution, another method may be employed in which a fluorocompound, such as tetrafluoroethylene is polymerized with the main raw material with plasma to be applied to the surface. It is preferable to employ another method for improving the contact and strength of the film in which oxygen, hydrogen, helium, argon, nitrogen, silane, hydrocarbon or the like is mixed with the fluorocompound which is the main material. The plasma can effectively be generated by a DC or RF glow discharge method, a microwave discharge method or a laser beam irradiation method.

It is preferable that the thickness of the film to be formed on the surface of lithium ranges from 50 Å to 100 μ, more preferably ranges from 100 Å to 10 μ. The optimum thickness of the film differs depending upon the density or the void ratio of the film and considerably differs depending upon the type of the electrolyte solution. The thickness of the film can be adjusted by changing the concentration of the main material in the coating liquid for forming the film.

5. Large Ring Compound

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By coating the surface of the negative electrode active material with a large ring compound through which ions for use in the reactions in the battery can be passed, the reactions between lithium and water or oxygen can be prevented if the negative electrode active material is lithium. As a result, handling can easily be performed. Further, the direct contact between lithium and the electrolyte solution can be prevented, and therefore the growth of a polymer film on the surface of lithium to be formed from the solvent of the electrolyte solution can be prevented. If the negative electrode active material is zinc, the dissolution of zinc into the electrolyte solution can be prevented. As a result, the formation of dendrite can be prevented, causing the life against the charge and discharge cycle can be lengthened.

The large ring compound is a large ring compound having heteroatoms composed of one or more types of atoms selected from a group consisting of oxygen, nitrogen and sulfur. In order to cause ions for use in the reactions in the battery to be passed satisfactorily, a compound having one or more structures selected from a group consisting of ring polyether, ring polyamide, ring polythioether, azacrown ether, ring thioether, thiocrown ether, cryptand, cycrum, nonactyne and bariomicine each having a hole having a radius larger than the radius of ions to be used in the reactions in the battery, thyracrown, cyclodextrin,

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cyclophane, phtharocyanine and porphyrin each of which is crown ether having silicon atoms. It is preferable to use crown ether polymer, bariomicine, phthalocyanine or porphylin.

5 By covering the surface of the negative electrode active material with the large ring compound, the movement of ions for use in the battery reactions between the electrolyte solution and the negative electrode active material can be made easier. Therefore,
10 local generation of zinc or lithium dendrite on the negative electrode can be prevented. Further, reactions between fresh lithium or zinc generated at the time of the charge with the solvent of the electrolyte solution can be prevented.

15 The surface coating of the large ring compound to be applied to the surface of the negative electrode active material can be performed in any of the following methods.

a. A polymer solution obtained, by
20 polymerization, from the derivative of the large ring compound is applied by dipping, spraying, screen printing and coater coating.

b. A mixture of the binder polymer and the derivative of the large ring compound is applied, and
25 then it is crosslinked so that the film is formed.

c. The derivative of the large ring compound is, as a monomer, dissolved in an electrolyte solution, an electric field is applied to the solution, and then the

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film is formed on the surface of the negative electrode active material or the conductive matrix by electrolytic polymerization.

5 d. Lithium is immersed in a solution of the derivative of the large ring compound, which can be anion-polymerized by lithium, so that the polymer film is formed.

10 e. A polymer is applied, the polymer being obtained by heating and condensing a large ring compound having an aromatic ring and formaldehyde in a formic acid.

f. The film is formed by sputtering the large ring compound or the polymer of the same or by plasma-polymerizing the same.

15 An electrolyte may be mixed at the time of forming the foregoing film. As a result, the wettability between the electrolyte solution and the film can be improved, causing ions to be easily passed through the film. In order to facilitate the movement of the charge at the
20 time of the charging operation, powder or fiber or whisker of conductive material such as carbon or titanium may be mixed at the time of forming the film.

25 As the polymer for use in the coating solution, poly [(dibenzo - 18 - crown - 6) - coformaldehyde] or the like can be used. A polymer for coating can newly be prepared by the following polymerization reactions. By condensation polymerization of a large ring compound having, at the terminative group thereof, carboxylic

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group or amino group or a hydroxyl group, polyamide can be obtained if the carboxylic group and the amino group react with each other. Polyester can be obtained if the carboxylic group and the hydroxyl group react with each other. The vinyl compound of the large ring compound or dime of the large ring compound enables an additive polymer to be obtained by radical polymerization, cation polymerization or anion polymerization. The starting material of the radical polymerization may be azobisisobutylnitril (AIBN), benzoylperoxide (BPO) or t-butylhydroperoxide. A starting material for the cation polymerization is exemplified by an acid such as H_2SO_4 , H_3PO_4 , $HClO_4$, CCl_3 or CO_2H and Friedel-Craft catalyzer such as BF_3 , $AlCl_3$, $TiCl_4$ or $SnCl_4$. A large ring compound having an aromatic ring can be polymerized by dehydrogenation in which the Friedel-Craft catalyzer and an oxidizer are combined to each other. A starting material for the anion polymerization may be an alkaline metal compound or an organic metal compound.

As the monomer of the large ring compound for use in the polymerization may be crown ether/(+) - 18 - crown - 6 - tetracarboxylic acid, 1, 5, 9, 13, 17, 21 - hexathiacyclotetrakosan - 3, 11 - 19 - triol, 1, 5, 9, 13 - tetrathiacyclohexadecan - 3, 11 - diol, 1 - aza - 12 - crown - 4, 1 - aza - 15 - crown - 5, 1 - aza - 18 - crown - 6, 1, 4, 10, 13 - tetraoxyso - 7, 16 - diazocyclooctadecan, 1, 4, 10 - trioxa - 7, 13 - diazacyclopentadecan, or 6, 8 - dioxabicyclo [3. 2. 1] -

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octane - 7 - on. As an alternative to this, dibenzocrown ether can be used.

In the foregoing polymerization, a copolymer of two more types of derivatives of the large ring compounds or
5 a copolymer of the large ring compound and another monomer may be used as well as the polymer of the derivatives of the large ring compounds. A polymer obtainable by introducing the derivative of the large ring compound into a polymer by substitution may be
10 employed.

When a battery is manufactured, a polymer must be selected so as not to be dissolved in the solvent of the electrolyte solution or the polymer crosslinking reactions are caused to proceed so as not to be dissolved
15 in the electrolyte solution.

The derivative of the large ring compound having, at the terminative group thereof, carboxylic group or amino group or a hydroxyl group or having a vinyl bond or a dime bond and a crosslinking material are mixed in
20 the polymer serving as the binder, and then the mixed material is hardened. The crosslinking material is selected from a group consisting of diisocyanate, a polyisocyanate prepolymer, block isocyanate, an organic peroxide, polyamine, oxims, a nitroso compound, sulfur,
25 a sulfur compound, selenene, a magnesium oxide, a lead oxide and a zinc oxide. The organic peroxide is exemplified by dicumyl - peroxide, 2, 5 - dimethyl - 2, 5 - di - (t - butyl - peroxy) hexane, 1, 3 - bis - (t -

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butyl - peroxy isopropyl) benzene, 1, 1 - bis - (t-butyl - peroxy) - 3, 3, 5 - trimethyl - cyclohexane, n-butyl - 4, 4 - bis - (t-butylperoxy) valerate, 2, 2 - bis - (t-butyl - peroxide) butane, t-butyl - peroxy - benzene, and vinyl - tris - (t-butyl - peroxy) silane. As an accelerating agent, a guanidine, aldehyde - amine, aldehyde - ammonia, thiazol, sulfonamide, thiourea, thiuram, dithiocarbamate, xanthate accelerating agent is used.

Another coating method using the binder polymer is exemplified by a method in which a mixture of the large ring compound and the binder polymer is applied, and then radial rays, electron rays or ultraviolet rays are applied to cause the applied material to be crosslinked.

As a method for covering the negative electrode active material by the electrolytic polymerization, a monomer, such as dibenzocrown ether, is mixed in the electrolyte solution, and then the electrolytic polymerization is performed while using the negative electrode active material or the conductive matrix as an anode. The solvent of the electrolyte solution is exemplified by acetonitril (CH_3CN), benzonitril ($\text{C}_6\text{H}_5\text{CN}$), propylene carbonate (PC), dimethylformamide (DMF), tetrahydrofuran (THF), nitrobenzene ($\text{C}_6\text{H}_5\text{NO}_2$), dichloroethane, diethoxyethane, chlorobenzene, γ - butyrolactone and dioxolan and their mixture. It is preferable that the solvent be dehydrated with active alumina, molecular sieve, phosphorus pentoxide or

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calcium chloride. As an alternative to this, it is preferable depending upon the type of the solvent that the solvent be distilled under presence of alkaline metal in inactive gas to remove impurities and to be
 5 dehydrated. The supporting electrolyte is an acid, such as H_2SO_4 , HCl or HNO_3 or salt composed of monovalent metal ion (Li^+ , K^+ , Na^+ , Rb^+ or Ag^+) or tetraammonia ion (tetrabutyl ammonia ion (TBA^+) and tetraethyl ammonia ion (TEA^+)) and Lewis acid ion (BF_4^- , PF_6^- , AsF_6^- or ClO_4^-). It
 10 is preferable that the foregoing salt is refined by recrystallization or it is heated under lowered pressure to sufficiently dehydrate and deoxidize the salt.

As the monomer, crown ether/benzo - 15 - crown -
 5, crown ether/benzo - 18 - crown - 6, crown ether/N -
 15 phenylaza - 15 - crown - 5, crown ether/dibenzo - 18 - crown - 6, crown ether/dibenzopyridino - 18 - crown - 6,
 crown ether/dibenzo - 24 - crown - 8, 1, 13 - bis (8 - quinolylyl) - 1, 4, 7, 10, 13 - pentaoxidodecan, 5, 6 -
 benzo - 4, 7, 13, 16, 21, 24 - hexaoxa - 1, 10 -
 20 diazabicyclo [8. 8. 8] - hexakosan, 5, 6 - 14, 15 - dibenzo - 4, 7, 13, 16, 21, 24 - hexaoxa - 1, 10 -
 diazabicyclo [8. 8. 8] - hexakosan, bis [(benzo - 15 - crown - 5 -) - 15 - ilmethyl] pimelate, crown
 ether/dibenzo - 30 - crown - 10, N, N' - dibenzyl - 1,
 25 4, 10, 13 - tetraoxa - 7, 16 - diazacyclooctadecan, dilithiumphthalocyanin, 4' - nitrobenzo - 15 - crown -
 5, 3, 6, 9, 14 - tetrathiabicyclo [9. 2. 1] tetradeca - 11, 13 - dime and their mixture.

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Since the performance of the battery deteriorates if the polymer film for covering the surface of the negative electrode active material is dissolved in the electrolyte solution, it is preferable to be crosslinked.

It is preferable that the thickness of the film to be formed on the surface of lithium ranges from 50 Å to 100 μ, further preferably ranges from 100 Å to 10 μ. The optimum thickness of the film differs depending upon the density or the void ratio of the film and considerably differs depending upon the type of the electrolyte solution. The thickness of the film can be adjusted by changing the concentration of the main material in the coating liquid for forming the film.

6. Polymer (polyphosphazene) Film in Which Phosphor Atoms and Nitrogen Atoms are Alternately Bonded in a Phosphor-Nitrogen Double Bond Manner

The surface of the negative electrode active material is covered with a polymer (polyphosphazene) film through which ions for use in the reactions in the battery can be passed and in which phosphor atoms and nitrogen atoms are alternately phosphor-nitrogen double bond. As a result, lithium and the electrolyte solution do not come in contact with each other if the negative electrode active material is lithium. Therefore, formation of the polymer film from the solvent of the electrolyte solution on the surface of lithium can be prevented. If the negative electrode active material is

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zinc, elution of zinc into the electrolyte solution can be prevented. As a result, formation of dendrite can be prevented, and therefore the life against charge and discharge cycle can be lengthened.

5 Since the lithium battery according to the present invention comprises the polyphosphazene film covering lithium is a flame retardant film, safety against emergency breakage can be improved.

10 The polymer for use as the covering material can be obtained by heating a dichloropolyphosphazene trimer to 200 to 300°C and by ring-opening polymerization. The dichloropolyphosphazene trimer can be synthesized from phosphorus pentachloride and ammonia chloride or ammonia. Any one of the following catalyzer is used at
15 the time of the polymerization: benzoic acid, sodium benzoate, 2, 6 - di - p - cresol, water, methanol, ethanol, nitromethane, ether, heteropoly acid, sulfur, zinc, tin and sodium. Further, various type of polyorganophosphazene can be obtained by substituting
20 chloride atoms of polydichlorophosphazene by an organic reagent or an organic metal reagent.

25 If the surface of lithium is coated with the foregoing polymer solution, it is preferable that the polymer solution dehydrated and deoxidized sufficiently be used in inactive gas dehydrated sufficiently (however, the necessity of strictly controlling water can be eliminated when the polymer is previously applied to the conductive matrix or when the negative electrode

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active material is zinc).

It is preferable to use a solvent in the foregoing solution which has been dehydrated with active alumina, molecular sieves, phosphorus pentoxide calcium chloride. As an alternative to this, it is preferable depending upon the type of the solvent that the solvent be distilled under presence of alkaline metal in inactive gas to remove impurities and to be dehydrated (however, the necessity of strictly controlling water can be eliminated when the polymer is previously applied to the conductive matrix or when the negative electrode active material is zinc).

An electrolyte may previously be mixed when the foregoing film is formed. It leads to a fact that wettability between the electrolyte solution and the film can be improved, causing ions to easily pass through the film. In order to facilitate the movement of the charge at the time of charging, conductive powder, such as carbon or titanium, fiber or whisker may be mixed at the time of forming the film.

Since the performance of the battery deteriorates if the polymer coating film is dissolved in an organic solvent of the electrolyte, it is preferable to be crosslinked in such a manner, for example, ultraviolet rays, electron rays or radial rays are applied or a crosslinking material, such as a radical generating agent, is used.

It is preferable that the thickness of the film to

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be formed on the surface of the negative electrode active material ranges from 50 Å to 100 μ, more preferably ranges from 100 Å to 10 μ.

5 The optimum thickness of the film differs depending upon the density or the void ratio of the film and considerably differs depending upon the type of the electrolyte solution. The thickness of the film can be adjusted by changing the concentration of the main material in the coating liquid for forming the film.

10 7. Other Organic Polymer Film

The surface of the negative electrode is covered with an organic polymer containing one or more types of elements selected from a group consisting of oxygen, nitrogen and sulfur and permitting ions relating to the battery reactions to pass through. The direct contact of fresh negative electrode active materials precipitated during the charging reactions can be prevented due to the foregoing cover film. Therefore, the negative electrode is not covered with a substance prepared due to the reactions with the electrolyte solution and having low conductivity. As a result, the growth of dendrite can be prevented.

The organic polymer containing oxygen is exemplified by cellulose, alkyl cellulose, nitrocellulose, acetyl cellulose, chitin, chitosan, polyethylene glycol, polyethylene oxide, polypropylene oxide, polyvinyl alcohol, polyvinyl acetate, polylactide, polylactone, poly - 3 - hydroxyalcanoate,

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polyglycol acid, polyacetic acid, polydioxanon, glycol acid - lactone copolymer, polyethylene terephthalate, polyphenylene oxide, polyether etherketone and the like. It is preferable to use acetyl cellulose, chitin or
5 polyvinyl alcohol.

The organic polymer containing nitrogen is exemplified by collagen, chitin, chitosan, polyurethane, polyimide, polyether imide and the like.

The organic polymer containing sulfur is
10 exemplified by polyphenylene sulfide, polysulfon and polyethersulfon.

The negative electrode is covered with the foregoing organic polymer film formed in such a manner that the solution of the organic polymer is applied and
15 dried and then a crosslinking reactions are caused to occur. Another method of forming the film may be employed in such a manner that the organic polymer is used as a target in a sputtering method. Another method may be employed in which a monomer serving as the
20 organic polymer is plasma-polymerized to form the film.

The application may be completed by dipping, spraying or screen printing.

The crosslinking reactions can be performed by any one of the following methods: irradiation of ultraviolet
25 rays, electron rays or radial rays; or decomposition of a radical generating material such as azobisbutylonitryl or peroxy benzoil. The reason why the organic polymer of the film is crosslinked is that elution of the film into

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the electrolyte solution must be prevented.

The thickness of the film must range so far as ions in the electrolyte solution relating to the battery reactions are able to pass through the same. It differs depending upon the material and the void ratio of the film and the type of the ion. It is preferable that the mean thickness ranges from 10 Å to 100 μ, more preferably 100 Å to 10 μ. If the ion permeability through the film is unsatisfactory, an electrolyte may be mixed at the time of forming the film.

If the electrolytic solution of the battery is a water soluble solution and it is not hydrophilic, it is preferable to perform a treatment using a silane coupling material or a titanate coupling material to attain hydrophilic characteristics.

Although the various covering materials and coating methods have been described while employing the negative electrode active material is directly covered with the film, another method may be employed in which the conductive matrix is previously covered with the coating material and then the negative electrode active material is introduced.

Negative Electrode Active Material

As the negative electrode active material, lithium, lithium alloy, zinc or zinc alloy is used. The lithium alloy may contain one or more types of elements selected from a group consisting of magnesium, aluminum, titanium, tin, indium, boron, gallium, potassium,

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sodium, calcium, zinc and lead and the like. The zinc alloy may contain one or more types of elements selected from a group consisting of aluminum, indium, magnesium, tin, titanium, copper, lead, tin, lithium and mercury and the like.

The negative electrode active material for the alkali-zinc battery may be zinc, zinc alloy, zinc oxide or zinc hydroxide, the negative electrode active material being uniformly kneaded with a bonding material or a kneading solution to obtain paste. The paste is applied to a collector followed by drying them so that a negative plate is obtained.

The bonding material is exemplified by polyvinyl alcohol, a cellulose material such as methyl cellulose or carboxymethyl cellulose, a polyolefin material such as polyethylene, a fluororesin such as polytetrafluoroethylene and a polyamide resin such as nylon.

The kneading solution may be an organic solvent such as ethylene glycol or water containing oxo acid salt such as sodium phosphate or the like.

The collector may be an iron plate applied with nickel plating and having apertures, a foam metal or nickel mesh or the like.

25 Positive Electrode

The positive electrode is formed by mixing a positive electrode active material, conductive powder and a bonding material on the collector. In order to

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easily form the positive electrode active material, a solvent-resisting resin, such as polypropylene or polyethylene or fluoro-resin is used as the bonding material if necessary. In order to further easily collect electric currents, the conductive powder is mixed at the time of the formation. The material of the conductive powder is exemplified by various carbon, copper, nickel and titanium and the like.

Positive Electrode for Lithium Secondary Battery

The positive electrode active material of the lithium secondary battery is made of a compound having layers through which lithium ions can be passed, the compound being a transition metal such as a metal oxide exemplified by manganese oxide, vanadium oxide, molybdenum oxide, chrome oxide, cobalt oxide, nickel oxide, titanium oxide, iron oxide, and tungsten oxide or a metal sulfide exemplified by titanium sulfide, molybdenum sulfide, iron sulfide and shebrell phase sulfide ($\text{MyMo}_6\text{S}_{8-x}$ (M: metal such as copper, cobalt or nickel)). The transition metal element may be an element having partially shell d or shell f. The metal selenide is exemplified by niobium selenide. The metal hydroxide is exemplified by oxyhydroxide. The conductive polymer is exemplified by polyacetylene, polyparaphenylene, polyaniline, polythiophene, polypyrrol and polytriphenylamine. The composite oxide is exemplified by $\text{LiMn}_{2-x}\text{M}_x\text{O}_4$ and $\text{LiCo}_x\text{Ni}_{1-x}\text{O}_2$.

The positive electrode is manufactured in such a

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manner that paste obtained by adding a bonding material, such as polyethylene, polypropylene or a fluoro-resin, to the positive electrode active material 104 is pressed against the positive electrode collector 103. In order to improve the collecting performance of the positive electrode, it is preferable to add conductive powder to the paste.

The conductive powder may be a carbon material such as acetylene black or metal such as copper, nickel or titanium. The collector 103 may be fiber-like, porous or mesh-shape carbon material, stainless steel, titanium, nickel, copper, platinum or gold.

Positive Electrode for Nickel-Zinc Battery

The positive electrode of the nickel-zinc battery is categorized to a paste type electrode formed by directly charging nickel hydroxide powder into the collector and a sintering type formed by immersing nickel hydroxide into a small apertures of the nickel sintered plate.

The paste type positive electrode is formed in such a manner that paste obtained by uniformly kneading an additive, such as nickel or cobalt, with a bonding material or a kneading solution is applied to the collector followed by drying them.

The bonding material and the collector are made of materials of the same type as those of the zinc negative electrode.

The sintered type positive electrode is

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manufactured in such a manner that a sintered plate
obtained by sintering nickel powder on the nickel-plated
iron plate having apertures is immersed in a mixed
solution of nickel salt serving as a main active
5 material and cobalt salt serving as an additive and then
caused to react with an alkali solution of, for example,
sodium hydride so that nickel hydroxide is impregnated
into the sintered plate.

Positive Electrode for Air-Zinc Secondary Battery

10 The positive electrode of the air-zinc secondary
battery is made of a material composed of an air
electrode, a water-repellent film and a diffuser paper
sheet.

The catalyzer of the air electrode is prepared in
15 such a manner that silver, manganese dioxide, nickel-
cobalt composite oxide or platinum is added to a carbon
material, such as porous carbon (active carbon) or
carbon black, porous nickel, copper oxide or the like
having a specific area of 200 to 1000 m²/g.

20 The water-repellent film is provided to prevent
leakage of the electrolyte solution passed through the
air electrode to the outside of the battery. The water-
repellent film is made of a fluororesin such as
polytetrafluoroethylene. The diffuser paper sheet is
25 provided for the purpose of uniformly supplying oxygen
to the overall surface of the air electrode, the
diffuser paper sheet being made of cellophane or the
like.

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A zinc-bromine battery comprising the negative electrode active material which is zinc includes bromine to serve as the positive electrode active material.

Coating of Positive Electrode

5 In order to prevent generation of dendrite causing the short circuit at the time of the charge, the surface of the positive electrode is covered with a film through which ions for use in the reactions in the battery can be passed so that the life of the battery against the
10 cyclic usage can be lengthened.

 The coating material may be a polymer of the derivative of a large ring compound, a polymer of the derivative of an aromatic hydrocarbon, fluororesin, silicon resin, titanium resin, polyolefin, inorganic
15 oxide, nitride, carbide or halide. It is effective to improve the safety of the lithium secondary battery to cover the positive electrode with a flame retardant or noncombustible material, such as fluororesin, polyphosphazene, an inorganic oxide, nitride, carbide or
20 halide.

 If the film through which ions for use in the reactions in the battery can be passed is a multi-layer metal oxide film formed by using a bimolecular film as a
25 mold, an effect of a separator can be obtained and an effect of preventing the short circuit between the negative electrode and the positive electrode can further be improved.

Electrolyte

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The electrolyte is used as it is or in the form of a solution in which it is dissolved in a solvent or after it has been solidified by adding a gelatinizing material, such as a polymer, to the solution. Generally
5 an electrolyte solution, in which the electrolyte is dissolved in a solvent, is held in a porous separator.

The conductance of the electrolyte must be raised as much as possible because it relates to the internal resistance of the battery and considerably affects the
10 current density at the time of the charge and the discharge. It is preferable that the conductance at 25°C be 1×10^{-3} S/cm or higher, more preferably 5×10^{-3} S/cm or higher.

[In a Case Where Negative Electrode Active Material is
15 Lithium or Lithium Alloy]

The electrolyte is made of an acid, such as H_2SO_4 , HCl or HNO_3 , a salt composed of Lewis acid ion (BF_4^- , PF_6^- , AsF_6^- or ClO_4^-) or their mixture. Further, positive ions, such as sodium ions, potassium ions,
20 tetraalkylammonium ions, and the Lewis acid ions may be used together. It is preferable that the foregoing salt is heated under lowered pressure to sufficiently dehydrate and deoxidize the salt.

The solvent of the electrolyte is exemplified by
25 acetonitril (CH_3CN), benzonitril (C_6H_5CN), propylene carbonate (PC), ethylene carbonate (EC), dimethyl formamide (DMF), tetrahydrofuran (THF), nitrobenzene ($C_6H_5NO_2$), dichloroethane, diethoxyethane, chlorobenzene,

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γ - butyrolactone, dioxolan, sulforan, nitromethane,
dimethylsulfide, dimethylsuloxide, dimethoxyethane,
methyl formate, 3 - methyl - 2 - oxydazolidinone, 2 -
methyln tetrahydrofuran, sulfur dioxide, phosphoryl
5 chloride, thionyl chloride, sulfonyl chloride, dimethyl
formaldehyde, γ - butyrolactone and tetrahydrofuran and
their mixture.

It is preferable that the foregoing solvent be
dehydrated with active alumina, molecular sieve,
10 phosphorus pentoxide or calcium chloride. As an
alternative to this, it is preferable depending upon the
type of the solvent that the solvent be distilled under
presence of alkaline metal in inactive gas to remove
impurities and to be dehydrated.

15 It is preferable to gel the electrolyte solution to
prevent leakage of the electrolyte solution. As the
gelling material, it is preferable to use a polymer of a
type which swells when it absorbs the solvent of the
electrolyte solution, the gelling material being a
20 polymer exemplified by a polyethylene oxide, polyvinyl
alcohol and an polyacryl amide.

[In a Case Where the Negative Electrode Active Material
is Zinc or Zinc Alloy]

As the electrolyte solution, salt of alkali or zinc
25 borate is used which is a sole or a mixed solution of
potassium hydroxide, sodium hydroxide, lithium hydroxide
or ammonium hydroxide.

It is preferable to gel the electrolyte solution to

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prevent leakage of the electrolyte solution. As the gelling material, it is preferable to use a polymer of a type which swells when it absorbs the solvent of the electrolyte solution, the gelling material being a
5 polymer exemplified by a polyethylene oxide, polyvinyl alcohol and an polyacryl amide.

In a case of a battery such as a bromine - zinc battery except for the alkali battery, a salt such as zinc borate is used.

10 The solid electrolyte is manufactured in such a manner that a polymer compound of a polyethylene oxide (PEO) type and salt of the electrolyte are dissolved in the foregoing non-water-soluble solvent to be gelled and then they are developed on, for example, a flat board to
15 evaporate the non-water-soluble solvent. The PEO polymer compound is exemplified by polyethylene oxide or a poly (methoxyethoxyphosphazene) crosslinked by polyethylene oxide or isocyanate.

The electrolyte solution for the alkali-zinc
20 secondary battery may be a solution of sodium hydroxide, potassium hydroxide or lithium hydroxide or their mixture.

Separator

The separators (108, 208 and 308) are provided to
25 prevent short circuits between the positive electrode and the negative electrode. They also act to hold the electrolyte solution.

The separator must meet the following conditions.

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(1) The separator cannot be dissolved in the electrolyte solution and must be stable with respect to the same.

(2) The separator is able to absorb a large quantity of the electrolyte solution and must exhibit satisfactory holding force.

(3) The separator must have small apertures through which lithium ions and hydroxide ions can be passed.

(4) The separator must have small apertures each having a size which is able to prevent the penetration of dendrite.

(5) The separator must be mechanically strong so as not to be broken or deformed excessively when it is wound.

The material that is able to meet the foregoing conditions is exemplified by a unwoven fabric or a micropore structure of glass, polypropylene, polyethylene, or fluoro-resin.

Also a metal oxide film having small apertures or a resin film formed by combining metal oxides may be used. If a metal oxide film in the form of a multilayer structure is used, dendrite cannot easily pass through it and therefore an effect of preventing the short circuits can be obtained. If a fluoro-resin film which is a flame retardant or a glass or a metal oxide film which is a noncombustible material is used, the safety can further be improved.

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Since the electrolyte solution of the alkali-zinc secondary battery is a water-type solvent, a hydrophilic separator must be used which is exemplified by a non-woven fabric or a micropore structure of nylon, polypropylene or hydrophilic polypropylene.

Collector

Collectors 100, 103, 200 and 300 are made of fiber, porous or mesh-like carbon, stainless steel, titanium, nickel, copper, platinum or gold.

Shape and Structure of Battery

The battery is formed into a flat, cylindrical, square (rectangular) or a sheet shape battery. The spiral and cylindrical structure is enabled to have a large electrode area by winding while interposing the separator between the negative electrode and the positive electrode so that a large electric current can be caused to flow at the time of the charge and the discharge. The rectangular type battery enables an accommodation space for accommodating the secondary battery to be used effectively. The structure may be a single-layer structure and a multi-layer structure.

Figs. 2 and 3 illustrate the schematic cross sectional views which respectively illustrate an example of a single-layer flat battery and a spiral and cylindrical battery. Referring to Figs. 2 and 3, reference numeral 201 and 301 represent negative electrodes covered with films, and 200 and 300 represent

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collectors for the negative electrodes 201 and 301. Reference numeral 203 and 303 represent positive electrode made of the positive electrode active material. Reference numeral 304 represents a collector for the positive electrode, and 206 and 306 represent negative terminals (caps for the negative electrodes 201 and 301). Reference numeral 207 and 307 represent outer cases (cases serving as positive electrode cases and battery cases), 208 and 308 represent separators which hold the electrolyte solution, 210 and 310 represent insulating packings, and 311 represents an insulating plate.

Referring to Fig. 5, reference numeral 5201 and 5301 represent lithium members subjected to surface treatment. In the structure shown in Fig. 5, reference numeral 201 and 310 represent lithium members subjected to surface treatment.

The batteries shown in Figs. 2 and 3 are manufactured in such a manner that the separators 208 and 308 are held between the negative electrodes 201, 301 subjected to the surface treatment and the positive electrodes 203 and 303 to be placed in the positive electrode cases 207 and 307 followed by injecting the electrolyte solution. Then, the negative electrode caps 206, 306, the insulating packing 210 and 310 are assembled so that the batteries are manufactured.

In the case of the lithium battery, it is preferable that the preparation of the material and

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assembling of the battery are performed in dry air from which water has sufficiently be removed or in a dry inactive gas.

Battery Case (Outer Case)

5 The battery case may be a metal outer case also serving as an output terminal or a plastic resin case. The positive electrode cases 207, 307, the negative electrode caps 206 and 306 are made of stainless steel, and in particular, titanium clad stainless steel or
10 copper clad stainless steel or a steel plate applied with nickel-plating.

 Although the structures shown in Figs. 2 and 3 comprises the positive electrode cases 207 and 307 also serving as the battery cases and the output terminals.
15 The battery case may be made of metal such as aluminum or zinc, plastic such as polypropylene or a composite material of metal, glass fiber and plastic as well as the stainless steel.

Insulating Packing

20 The insulating packings 210 and 310 may be made of fluoro-resin, polyamide resin, polysulfon resin or rubber.

Cap

 The capping method may be a bonding method, welding
25 method, soldering method or a glass sealing method as well as a caulking method using a gasket such as an insulating packing.

Insulating Plate

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The insulating plate 311 for insulating the inside of the battery may be made of an organic resin or ceramics.

Safety Valve

5 A safety valve (not shown in Figs. 2 and 3) using rubber, a spring or a metal ball may be used to serve as a safety means to act if the internal pressure in the battery has been raised.

10 The basic structure of another embodiment of the lithium secondary battery according to the present invention comprises a side opposing at least the positive electrode, the side being composed of a lithium negative electrode subjected to treatment using a reactive gas containing nitrogen or halogen, a separator, a positive electrode active material, electrolyte and a collector. Fig. 5 is a basic structural view which illustrates the lithium secondary battery according to the present invention. Referring to Fig. 5, reference numeral 100 represents a collector for a negative electrode, 101 represents a negative electrode active material (lithium or lithium alloy), 102 represents a surface treatment layer for the lithium portion, 103 represents a collector for the positive electrode, 104 represents a positive electrode active material, 105 represents an electrolyte solution, 106 represents a negative terminal, 107 represents a positive terminal, 108 represents a separator, and 109 represents a battery case. In the discharge reactions,

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lithium ions in the electrolyte solution 105 are introduced into the interlayer of the positive electrode active material 104.

5 Simultaneously, lithium ions are eluted from the lithium negative electrode 101 into the electrolyte solution 105 by way of a treatment-applied surface 5102. In the charging reactions, lithium ions in the electrolyte solution 105 are, lithium metal ions are precipitated to the lithium negative electrode 101 by
10 way of the treatment-applied surface 5102.

Simultaneously, lithium in the interlayer of the positive electrode active material 104 is eluted into the electrolyte solution 105.

Surface Treatment for Lithium Negative Electrode

15 The nitrogen compound for treating the surface of lithium or the lithium alloy is exemplified by nitrogen, ammonia and nitrogen trifluoride. If nitrogen is used as the nitride, it must be activated as to be formed into a plasma form by DC or high frequency discharge or by
20 laser beam application. Also other nitrides are enabled to have improved reactivity when formed into plasma.

The halogen compound is exemplified by fluorine, chlorine, bromine, iodine, hydrogen fluoride, hydrogen chloride, hydrogen bromide, chlorine trifluoride,
25 methane tetrafluoride, methane tetrachloride, methane trifluoride, methane fluoride trichloride, sulfur hexafluoride and boron trichloride. The inactive gas such as carbon halide must be formed into plasma as to

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have improved reactivity. It is preferable that the very active gas such as fluorine, chlorine, hydrogen fluoride, hydrogen chloride or chloride trifluoride be diluted with inactive gas such as argon gas or helium gas.

5 The nitrogen compound and the halogen compound may be mixed with each other or contain oxygen gas, hydrogen gas, argon gas, helium gas, xenon gas or the like added thereto to improve the activity of the reactive gas or to control the activity. The negative electrode may be treated with plasma of hydrogen gas or argon gas prior to treating the surface of the negative electrode so that a fresh negative electrode surface is caused to appear.

15 More specifically, according to the present invention, there is provided a secondary battery manufactured in such a manner that active nitrogen plasma or fluorine plasma or hydrogen fluoride is brought into contact with the surface of lithium to cause reactions to take place, an inactive thin film made of lithium nitride or lithium fluoride and allowing lithium ions to pass through is formed on the surface of lithium, and the lithium portion is used as the negative electrode. As a result, the direct contact of lithium precipitated at the time of the charge with the electrolyte solution is prevented so that the generation of dendrite at the time of the charge is prevented. Therefore, a lithium battery exhibiting a long life

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against the charge and discharge cycle can be obtained. Further, the application of the foregoing treatment to the surface of lithium prevents the reactions between lithium and water. Further, handling can be made easier.

5 It is preferable that the thickness of the treatment layer to be formed on the surface of lithium ranges from 10 Å to 1 μ, more preferably 50 Å to 1000 Å. The thickness is adjusted by the reaction time or the concentration of the reaction gas.

10 It is preferable that the concentration of nitrogen atoms or halogen atoms in the treatment layer formed on the surface of lithium be gradually lowered from the surface to the inside portion of lithium.

Positive Electrode Active Material

15 The positive electrode active material 5104 may be a material into which lithium can be introduced into the interlayer thereof, the material being exemplified by a metal oxide such as a nickel oxide, cobalt oxide, titanium oxide, iron oxide, vanadium oxide, manganese
20 oxide, molybdenum oxide, chrome oxide or tungsten oxide, or a metal sulfide such as molybdenum sulfide, iron sulfide or titanium sulfide, a hydroxide such as oxy iron hydroxide, or a conductive polymer such as polyacetylene, polyaniline, polypyrol or polythiophene.

25 In order to make easier the formation of the positive electrode active material, solvent-resisting resin, such as polypropylene, polyethylene or fluoro-resin is used as a bonding material if necessary.

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In order to further facilitate collection of electric current, it is preferable to mix conductive powder at the time of molding the positive electrode active material. The conductive powder may be carbon black,
5 copper, nickel or titanium.

Fig. 8 illustrates an example a pattern of stacked layers according to the present invention in which a conductive layer, a semiconductor layer and an insulating layer are formed between the negative
10 electrode and the separator. Referring to Fig. 8, reference numeral 001 represents a negative electrode, 002 represents a dendrite, 003 represents the conductive layer or the semiconductor layer, 004 represents a separator, 005 represents an insulating layer, 006
15 represents an electrolyte solution, and 007 represents a positive electrode.

Fig. 8 is a schematic view which illustrates an effect of the present invention in an example in which the insulating layer through which lithium ions can be
20 passed and a conductive layer are stacked on the surface of the lithium negative electrode.

When the charging mode, lithium (or zinc) is precipitated on to the negative electrode 001. At this time, a portion in which the current density is high is
25 locally generated on the negative electrode 001 depending upon the projections and pits of the surface and upon the thickness of the insulating film. Lithium (or zinc) is selectively precipitated, causing the

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dendrite 002 to grow. With proceeding of the charging or discharging cycle, the dendrite 002 reach the conductive layer 003, When a short circuit state between the dendrite 002 and the conductive layer 003 is realized, the current density at the negative electrode is lowered at the time of the charge. Therefore, the further growth of the dendrite 002 is prevented, and therefore penetration of the dendrite 002 through the separator 004 to reach the positive electrode 007 can be prevented.

By covering the negative electrode with the ion permeable insulating layer 005, active lithium (or zinc) precipitated at the time of the charge cannot easily react with the electrolyte solution. Therefore, the generation of the growth of the insulating film can be prevented.

Figs. 9A to 9H illustrate various examples in which one or more types of layers selected from the ion permeable conductor, semiconductor and insulating material are formed between the negative electrode and the separator. Reference numerals shown in Figs. 9A to 9H are the same as those shown in Fig. 8. The present invention is not limited to the structure shown in Figs. 9A to 9H.

It is preferable that the conductive layer to be formed between the negative electrode and the separator be made of carbon, Ni, Ti, Pt, Al, Pb, Cr, Cu, V, Mo, W, Fe, Co, Zn or Mg, more preferably made of carbon, Ni or

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Ti.

If the semiconductor layer is formed in place of the conductive layer, a similar effect obtainable from the conductive layer can be obtained. If the
5 semiconductor layer is employed, the current density at the time of the growth of dendrite is higher than that in the case where the conductive layer is formed. However, the conductivity is lowered as compared with the case where the conductive layer is formed.

10 Therefore, an advantage can be realized that the easy conduction with the positive electrode is prevented.

The semiconductor layer may be made of diamond, Si, nickel oxide, copper oxide, manganese oxide, titanium oxide, zinc oxide, zirconium oxide, tungsten oxide,
15 molybdenum oxide or vanadium oxide.

The insulating layer may be made of a halide such as lithium fluoride or magnesium fluoride, a nitride such as silicon nitride, a carbon such as silicon carbide, or a polymer such as polyethylene,
20 polypropylene or fluororesin.

The forming method and materials of the conductive layer, the semiconductor layer, the insulating layer and the composite layer will now be described. When lithium is used, the following two desires must be met.

25 If water is left in the raw material, water and lithium react with each other. Therefore, water must be previously removed by a method by dehydration using active alumina, molecular sheave, phosphorus pentaoxide

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or calcium chloride. If a solvent is used, it is sometime preferable that the solvent be distilled under presence of alkaline metal in inactive gas to remove impurities and to be dehydrated.

5 The temperature at which the foregoing layer is applied to the surface of the negative electrode must be lower than a level at which the negative electrode active material is melted.

Conductive Layer

10 As a typical example of the conductive layer, manufacturing method of carbon conductive layer or a metal conductive layer made of, for example, Ni or Ti, will now be described.

Carbon

15 The form of the carbon crystal is categorized to crystal, amorphous, and a mixture of them. The carbon to be applied may be carbon powder or carbon fiber or a carbon paper sheet or the like obtainable by paper machining.

20 The surface of the negative electrode can be covered with carbon by any one of the following methods.

(1) A solution obtained by uniformly dispersing carbon powder or carbon fiber in an organic solvent such as toluene or xylene is, under inactive atmosphere of
25 Ar, is applied to the surface of the negative electrode by a spraying method, screen printing method, a coater method or a dipping method followed by drying the solution, and then carbon are pressed against the

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surface.

(2) The carbon paper is stacked on the surface of the negative electrode, and then the carbon is pressed against the surface.

5 (3) A vacuum evaporation method such as sputtering using carbon as the target is performed so that the surface of the negative electrode is covered with carbon.

10 (4) A CVD (Chemical Vapor Deposition) method is performed under the presence of an organic compound which is the raw material of carbon so that the negative electrode is covered with carbon.

15 In the foregoing coating method, the carbon powder or the carbon fiber must be pressed against the surface so that the contact is improved. The pressing work is performed by using a pressing machine or a roller press. The temperature at the time of the pressing work must be lower than a level at which the negative electrode active material is melted. It is preferable that the thickness of the coating range from 10 to 100 μm , more preferably from 50 μm or thinner in order to prevent reduction of the quantity of the contained negative electrode active material.

20 The pressing method to be performed after the carbon paper has been stacked may be a method using a pressing machine or a roller press, a method in which the positive electrode plate and the negative electrode plate are wound while interposing the separator, and a

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method in which winding pressure or stacking pressure is applied while interposing the carbon paper at the time of stacking the carbon paper. The latter method is able to eliminate a process of previously pressing the carbon paper against the negative electrode and the carbon paper can be pressed in the winding or the stacking process. It is preferable that the carbon paper having a thickness ranging from 150 to 300 μm be pressed to have a thickness ranging from 75 to 150 μm .

10 The sputtering coating method is performed in such a manner that carbon is used as the target in an inactive atmosphere of argon and DC or RF discharge is performed so that the surface of the negative electrode is covered with carbon.

15 The raw material of the CVD carbon coating method may be saturated hydrocarbon such as methane, unsaturated hydrocarbon such as acetylene, ethylene, propylene or benzene, carbon monoxide, alcohol or acetone. The exciting method is exemplified by a method using plasma, laser or heating filament. It is preferable that the thickness of the carbon applied be 1 μm or thinner, more preferably 1000 \AA .

25 In the case of the plasma CVD method, the power source for the glow discharge may be a high frequency or a DC power source. The high frequency source may be a usual band source such as radio frequency (RF), VHF or microwave source. The wavelength of the radio waves is typified by 13.56 MHz, while that of the microwave is

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typified by 2.45 GHz.

If the laser CVD is employed, an ultraviolet ArF excimer laser or infrared ray CO₂ is used as the laser beam source.

5 Metal Such as Ni or Ti

The metal such as Ni or Ti is applied to the surface of the negative electrode by a sputtering method as is employed to apply carbon, a CVD method, an electron beam evaporation method or a cluster ion beam
10 evaporation method.

The target for use in the sputtering method may be Ni or Ti or the like, when a composite film is formed, two or more kinds of targets are used to perform either or both of the targets are subjected to the sputtering
15 process. The sputtering method must be performed under an inactive atmosphere of argon similarly to carbon.

The CVD coating method employs the following materials as the raw materials.

As the raw material for Ni and Ti, a solution in
20 which organic metal such as acetylacetonate complex of nickel (or titanium) is dissolved in non-water-soluble solvent such as hexane, acetone or toluene or a solution in which a halide such as nickel chloride (or titanium) is dissolved in a non-water-soluble solvent such as
25 ethanol is subjected to bubbling in a carrier gas (hydrogen or the like) and then the solution is introduced into the CVD reaction chamber to cause the CVD reactions to take place so that coating is

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performed.

When a composite film of Ni and carbon is formed, a hydrocarbon such as methane is used together with a metal compound.

5 Semiconductor Layer

The semiconductor layer is exemplified by diamond Si, nickel oxide, copper oxide, cobalt oxide, manganese oxide, titanium oxide, zinc oxide, zirconium oxide, tungsten oxide, molybdenum oxide or vanadium oxide. The coating method may be a sputtering method, an electron beam evaporation method, a plasma CVD method, a light CVD method, a laser CVD method or a heat CVD method.

Si

As the target for use in the sputtering method, Si or the like is used.

In the CVD method, the raw material for Si may be hydroxide gas such as SiH_4 or Si_2H_6 , fluorine gas such as SiHF_3 , SiH_2F_2 or SiH_3F , or a chlorine gas such as SiHCl_3 , SiH_2Cl_2 or SiHCl_3 . If the foregoing raw material is in the form of liquid, it is heated as to be in the form of vapor or subjected to bubbling by a carrier gas before it is introduced. If a composite film of Si and carbon material is formed, hydrocarbon such as methane is used together with the foregoing gas. A compound comprising carbon, P or B may be adequately mixed.

Oxide such as Nickel Oxide and Titanium Oxide

The nickel oxide and titanium oxide can be prepared by a sol-gel method in which alkoxide such as nickel or

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titanium or organic metal is dissolved in alcohol and then it is hydrolyzed, an anodic oxidation method in which a solution in which nickel salt or titanium salt is dissolved is electrolyzed, or a CVD method or an
5 electron beam evaporation method to introduce oxygen gas into the reaction chamber.

Insulating Layer

As the insulating layer, a halide, a nitride, a carbide or resin such as polyethylene (PE),
10 polypropylene (PP) or fluororesin is used. As the coating method, a sputtering method, a plasma CVD method or a coating method is used.

Other resins may be used such that a resin obtained by gasifying a monomer of an organic polymer and by
15 plasma polymerizing it or a resin obtained by sputtering an organic polymer or a film of an organic polymer may be used. In this case, the resin member must have small aperture through which ions can be passed and must not react with the electrolytic solution.

20

Nitride

In the sputtering method, a target comprising nitride exemplified by silicon nitride or lithium nitride is used. As an alternative to this, Si or Li is
25 used as the target, nitrogen gas or ammonia is used as the reaction gas and sputtering is performed in the foregoing state.

PE and PP

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In the plasma CVD method, SiH_4 or Si_2H_6 and ammonia, nitrogen gas or NF_3 are used together as the raw materials.

In the sputtering method, a PE or PP target is used
5 to perform sputtering to cover the insulating layer.

In the plasma polymerization method, ethylene is used as the raw material in the case of PE, while propylene is used in the case of PP.

Fluororesin

10 In the sputtering method, the target comprises a polymer or a copolymer such as polytetrafluoroethylene, polytrifluoroethylene, vinyl fluoride, vinylidene fluoride or dichlorodifluoroethylene.

As the raw material gas for use in the plasma
15 polymerization method, tetrafluoroethylene, trifluoroethylene, vinyl fluoride, vinylidene fluoride or dichlorofluoroethylene is used.

A fluororesin film having micropores can be used.

Composite Layer

20 The composite layer is selected from a group consisting of the foregoing conductor, semiconductor and insulating material. By using two or more types of raw materials, the composite layer is formed by a sputtering method of a CVD method. As an alternative to this, two
25 or more types of powder selected from a group consisting of conductor powder, semiconductor powder and insulating material powder are melted in a melted or dissolved resin so that the film for use as the composite film is

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manufactured.

Another structure may be employed as a preferred structure in which the concentrations (content) of the conductor, semiconductor and the insulating material in the composite layer are change continuously or
5 discontinuously in the direction of the thickness of the layer.

The apertures in the layer can be formed in such a manner that: an electrolyte is mixed with the raw
10 material at the time of applying the conductor, semiconductor and the insulating material by the sputtering method or the CVD method to add the electrolyte into the conductor, semiconductor and the insulating material. The foregoing electrolyte is eluted
15 into the electrolyte solution of the battery so that a micropore structures are formed in the conductor, semiconductor and the insulating material. Since lithium ions and hydroxide ions can easily be introduced and discharged in the micropores, the charging and
20 discharging efficiencies can be improved. Since the pore has a small size, the growth of the dendrite can be prevented, and therefore the life against the charging and discharging cycle can be lengthened.

Stacked Structure

25 The conductor, semiconductor and the insulating material layers may be formed into a single layer or a multi-layer composed of two or more layers.

The stacking method comprises a step of stacking a

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film selected from the group consisting of the conductor, semiconductor and the insulating material between the negative electrode and the separator. The film is stacked on the surface of the negative
5 electrode, or stacked between the negative electrode and the separator in a non-contact manner or stacked on the surface of the separator. As an alternative to this, the negative electrode or the separator or a substance through which ions can be passed may be used as the base
10 on which the conductor, semiconductor and the insulating material are stacked by a sputtering method or a CVD method.

Thickness

The optimum thickness of the single, multi-layer or
15 the composite layer composed of the one or more types of layers selected from the group consisting of the conductor, semiconductor and the insulating material differs depending upon the void ratio, the aperture distribution, the material of the layers and the number
20 of layers. If the material includes a large volume gaps as the polymer material, it is preferable the thickness be 10 μm or thinner, more preferably 1 μm or thinner. If a precise material such as the inorganic compound is used, it is preferable to make the thickness to be 1 μm
25 or thinner, more preferably 1000 Å or thinner.

Multi-Layer Metal Oxide

The multi-layer metal oxide 10102 must contain one or more types of materials selected from a group

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consisting of alumina, titanium oxide, silica, selenium oxide, zirconia oxide, magnesium oxide, chrome oxide, calcium oxide, tin oxide, indium oxide and germanium oxide.

5 The multi-layer metal oxide film is formed by molding a bimolecular film in a mold. By forming the metal oxide film by using the bimolecular film, a metal oxide film having small apertures and a large specific area and formed into a multi-layer film structure can be
10 obtained.

Method of Preparing Multi-Layer Metal Oxide

 The preparation is usually in such a manner that: a sol in which very fine particles of the metal oxide is, in a collide manner, dispersed in a solvent, such as
15 water, is added to a supersonic dispersion solution of water or buffer solution of a film forming compound for forming a bimolecular film selected depending upon the type of the sol and upon the surface charge so that a uniformly-dispersed solution is prepared; then it is
20 developed on a fluororesin film or a glass plate followed by developing the solution; and a cast film is manufactured. If the uniformly-dispersed film cannot be obtained, the any one of the following methods is employed:

25 (1) A cast film is formed by adding a low-melting point organic solvent, such as alcohol, chloroform, acetone or tetrahydrofuran, is added to the film forming compound and dispersing the materials, and then water or a buffer

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solution is added to the solution from which the solvent has been gradually evaporated, and then the mixture is dispersed with ultrasonic waves.

(2) Water or a buffer solution is added to the cast film described in (1), and the material is heated to a level higher than the phase transition temperature of the film.

(3) The film forming compound is dissolved in an organic solvent, such as diethylether or ethylalcohol, and the solution is injected into water and a buffer solution.

As a method of obtaining the bimolecular film which serves as the mold of the film shape of the metal oxide, the mechanical strength can be improved by any one of the following methods:

(a) The film forming compound is impregnated into a porous polymer film to form the bimolecular solid film.

(b) A hydrophobic polymer or a hydrophilic polymer and the film forming compound are dissolved in a solvent, and the solution is developed so that a cast film is obtained.

(c) A solution of a polymer electrolyte having a charge opposing that of the ionic film forming compound is mixed with a solution in which the ionic film forming compound is dispersed so that sedimentation of polyion complex is obtained, and then the polyion complex is dissolved in an organic solvent followed by developing it so that the cast film is obtained.

Alternatively, any one of the following methods may

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be employed: a chloric acid (surface active agent) method which is used at the time of preparing ribosome; a freezing-melting method; an inverse-phase evaporation method; and a macro-ribosome preparation method.

5 The film forming compound may be a compound having both hydrophobic group and a hydrophilic group (substance having amphipathic property) is used. The film forming compound may be an ammonia compound, an anion compound, a nonion compound and a polymerable
10 compound depending upon the molecular structure. The hydrophobic group of the film forming compound is categorized to a hydrocarbon, fluorine carbide, unsaturated hydrocarbon, and unsaturated fluorine carbide. A material containing a chromophore structure
15 introduced thereto in order to improve the molecular orientation in the film forming compound may be used.

 The film forming compound is exemplified by
p - octyloxyaniline hydrochloride,
p - (octyloxy) - p' - hydroxyazobenzene,
20 p - (10 - octyloxy) - p' - octyloxyazobenzene,
dodecyl - N - [p - {p - (10 -
bromodecyloxy)phenylazo}benzoil]L - alaninate, L -
glutamic acid didodecylester hydrochloride, N - [11 -
bromoundecanoyl] - L glutamic acid didodecylester,
25 dimethyldihexadecylammonium bromide, N - [β -
(trimethylammonio)etyloxybenzoil] didodecyl - L -
glutamic acid bromide,
dioctadecylmethyldimethylammomonium bromide, N - [11 -

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hydroxyundecanoyl] - L - glutamic acid
 ditetradecylester, N - [11 - phospholoundecanoyl] - L -
 acid ditetradecylester, 1, 2 - bis
 (hexadecyloxycarbonyl) ethane - 1 - sulfonic acid
 5 sodium, N - [(2 - oxo - 1, 3 , 2 - oxazaphosphoryl) - 11
 - oxadodecanoyl] - L - glutamic acid didoecylester, N -
 [(2 - trimethylammonio - ethylphosphonate)undecanoyl] -
 L - glutamic acid didodecylester, N - [(2 - ammomonio -
 ethylphosphonate)undecanoyl] - L - glutamic acid
 10 didodecyl ester and 1, 3 - hexadecyl - 2 - polyethylene
 glycolylglyceline.

It is preferable that the surface of the multi-
 layer metal oxide film of a non-water-soluble battery of
 a type comprising the negative electrode active material
 15 which is lithium is subjected to lipophillic treatment
 using an organic metal compound such as a silane
 coupling material or titanate coupling agent.

In order to lower the current density at the
 leading portion of the dendrite at the time of the
 20 charge and to prevent the growth of dendrite, the
 surface of the multi-layer metal oxide film on the
 negative electrode side may be applied with a conductive
 material by evaporation or plating.

Very Fine Particle Sol of Metal Oxide

25 The dispersed sol of very fine particles of the
 metal oxide is usually obtained by an acid, a base and
 water are added to an alcohol solution of an organic
 metal compound such as metal alkoxide as to be

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hydrolyzed to form colloid of the very fine particles of the metal oxide. The dispersion medium of the very fine particle sol is obtained by substituting to an organic solvent if necessary.

5 The alkoxide is typified by tetramethoxysilane, tetraethoxysilane, aluminum isopropoxide, and titanium isopropoxide. Another metal organic compound such as acetyl acetone complex salt, alkyl metal compound, acetylacetone metal salt, naphthenate metal salt or
10 octylate metal salt may be used.

 The very fine particles of the metal oxide can be obtained by another method for obtaining the same from the gas phase reaction of the vapor of the organic metal compound or the metal. The obtained very fine particles
15 of the oxide are dispersed in a solvent so that a dispersed sol is prepared.

 If the negative electrode active material is lithium or lithium alloy, lithium ions relate to the battery reactions. In the case of an alkali battery
20 comprising the negative electrode active material which is zinc, hydroxyl ions relate to the same. The typical battery of a type comprising the negative electrode active material which is zinc is exemplified by a nickel-zinc battery and an air-zinc battery.

25 By covering the surface of the positive electrode
104 of the battery with a film 12102 which is made of an insulating material or a semiconductor through which ions relating to the battery reactions can be passed,

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dendrite of lithium or zinc grown from the negative electrode 101 through the separator 108 during the repetition of the charge and the discharge are not substantially brought into contact with the conductor or a collector in the positive electrode 104. As a result, short circuits in the battery can be prevented, and therefore the life of the secondary battery can be lengthened. Further, the safety can be improved.

Covering of Positive Electrode of Secondary Battery

As the insulating material of the coating material of the positive electrode of the secondary battery, any one of the following materials may be used which is selected from a group consisting of a polymer of the derivative of a large ring compound, a polymer of the derivative of an aromatic hydrocarbon, fluororesin, silicon resin, titanium resin, polyolefin, inorganic oxide, nitride, carbide and halide. It is effective for the positive electrode of the lithium secondary battery to be covered with the polymer of the derivative of the large ring compound, the polymer of the derivative of the aromatic hydrocarbon or the fluororesin.

Polymer of Derivative of Large Ring Compound

The large ring compound is a ring compound of a type comprising hetero-atoms of one or more types selected from a group consisting of oxygen, nitrogen, sulfur and phosphorus. The large ring compound is a ring polyether having hole each having a radius larger than the radius of the lithium ion. The large ring compound

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has one or more structures selected from a group consisting of ring polyamine, ring polythioether, azacrown ether, ring thioether, thiocrown ether, cryptand, cyclam, nonactine, variomicine, thyracrown
5 which is a crown ether containing silicon atoms, cyclodextrin, cyclofan, phthalocyanin and porphyrin compound.

The surface of the positive electrode is covered with the large ring compound by any one of the following
10 methods.

a. A polymer solution obtainable from polymerization of the derivative of the foregoing large ring compound is applied by a coating method such as dipping, spraying, screen-printing or coating
15 application method.

b. A mixture in which the derivative of the large ring compound is mixed with the polymer serving as the binder is applied and then crosslinked to form the film.

c. The derivative of the large ring compound is
20 used as a monomer to be dissolved in an electrolyte solution, and then an electric field is applied to electrolyze and polymerize the material so that the film is formed on the surface of the positive electrode.

d. The molded positive electrode is immersed in a
25 solution of the derivative of the large ring compound, which anion-polymerizes, so that the polymer film is formed.

e. A polymer obtainable by heating and condensing

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the large ring compound having an aromatic ring and formaldehyde in a formic acid is applied.

f. The film is formed by sputtering of a polymer of the large ring compound or the derivative of the large ring compound or by plasma-polymerizing the large ring compound.

An electrolyte may be mixed at the time of forming the film. As a result, the wettability between the electrolyte solution and the film can be improved, causing ions to easily pass through the film.

The polymer for uses as the coating solution may be poly [(dibenzo - 18 - crown - 6) - co - formaldehyde] or the like. The coating polymer can be newly formed by the following polymerizing reactions: a large ring compound having a carboxylic group or an amino group or a hydroxyl group at the terminal group thereof is condensed and polymerized so that polyamide is obtained if the carboxylic group and the amino group react with each other. If the carboxylic group and the hydroxyl group react with each other, polyester can be obtained. The vinyl compound of the large ring compound or diene of the large ring compound can be obtained in the form of an addition polymer by radical polymerization, cation polymerization or anion polymerization. The starting material in the radical polymerization may be azobisisobutyronitril (AIBN), benzoylperoxide (BPO) or t - butylhydroperoxide. A starting material for the cation polymerization is exemplified by an acid such as

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H₂SO₄, H₃PO₄, HClO₄, CCl₃CO₂H and Friedel-Craft catalyzer such as BF₃, AlCl₃, TiCl₄ or SnCl₄. A large ring compound having an aromatic ring can be polymerized by dehydrogenation in which the Friedel-Craft catalyzer and an oxidizer are combined to each other. A starting material for the anion polymerization may be an alkaline metal compound or an organic metal compound.

As the monomer of the large ring compound for use in the polymerization may be crown ether/(+) - 18 - crown - 6 - tetracarboxylic acid, 1, 5, 9, 13, 17, 21 - hexathiacyclotetrakosan - 3, 11 - 19 - triol, 1, 5, 9, 13 - tetrathiacyclohexadecan - 3, 11 - diol, 1 - aza - 12 - crown - 4, 1 - aza - 15 - crown - 5, 1 - aza - 18 - crown - 6, 1, 4, 10, 13 - tetraoxyso - 7, 16 - diazocyclooctadecan, 1, 4, 10 - trioxa - 7, 13 - diazacyclopentadecan, or 6, 8 - dioxabicyclo [3. 2. 1] - octane - 7 - on. As an alternative to this, dibenzocrown ether can be used.

In the foregoing polymerization, a copolymer of two more types of derivatives of the large ring compounds or a copolymer of the large ring compound and another monomer may be used as well as the polymer of the derivatives of the large ring compounds. A polymer obtainable by introducing the derivative of the large ring compound into a polymer by substitution may be employed.

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When a battery is manufactured, a polymer must be selected so as not to be dissolved in the solvent of the electrolyte solution or the polymer crosslinking reactions are caused to proceed so as not to be dissolved in the electrolyte solution.

The derivative of the large ring compound having, at the terminative group thereof, carboxylic group or amino group or a hydroxyl group or having a vinyl bond or a dime bond and a crosslinking material are mixed in the polymer serving as the binder, and then the mixed material is hardened. An accelerating material may be mixed at this time. The crosslinking material is selected from a group consisting of diisocyanate, a polyisocyanate prepolymer, block isocyanate, an organic peroxide, polyamine, oxims, a nitroso compound, sulfur, a sulfur compound, selenene, a magnesium oxide, a lead oxide and a zinc oxide. The organic peroxide is exemplified by di-cumyl-peroxide, 2, 5-dimethyl-2, 5-di-(t-butyl-peroxy) hexane, 1, 3-bis-(t-butyl-peroxy isopropyl) benzene, 1, 1-bis-(t-butyl-peroxy)-3, 3, 5-trimethyl-cyclohexane, n-butyl-4, 4-bis-(t-butylperoxy) valerate, 2, 2-bis-(t-butyl-peroxide) butane, t-butyl-peroxy-benzene, and vinyl-tris-(t-butyl-peroxy) silane. As an accelerating agent, a guanidine, aldehyde-amine, aldehyde-ammonia, thiazol, sulfonamide, thiourea, thiuram, dithiocarbamate, xanthate accelerating agent is used.

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Another coating method using the binder polymer is exemplified by a method in which a mixture of the large ring compound and the binder polymer is applied, and then radial rays, electron rays or ultraviolet rays are applied to cause the applied material to be crosslinked.

As a method for covering the positive electrode by the electrolytic polymerization, a monomer, such as dibenzocrown ether, is mixed in the electrolyte solution, and then the electrolytic polymerization is performed while using the negative electrode active material or the conductive matrix as an anode. The solvent of the electrolyte solution is exemplified by acetonitril (CH_3CN), benzonitril ($\text{C}_6\text{H}_5\text{CN}$), propylene carbonate (PC), dimethylformamide (DMF), tetrahydrofuran (THF), nitrobenzene ($\text{C}_6\text{H}_5\text{NO}_2$), dichloroethane, diethoxyethane, chlorobenzene, γ - butyrolactone and dioxolan and their mixture.

It is preferable that the solvent be dehydrated with active alumina, molecular sieve, phosphorus pentoxide or calcium chloride.

The supporting electrolyte is an acid, such as H_2SO_4 , HCl or HNO_3 or salt composed of monovalent metal ion (Li^+ , K^+ , Na^+ , Rb^+ or Ag^+) or tetraammonia ion (tetrabutyl ammonia ion (TBA^+) and tetraethyl ammonia ion (TEA^+)) and Lewis acid ion (BF_4^- , PF_6^- , AsF_6^- or ClO_4^-). It is preferable that the foregoing salt is refined by recrystallization or it is heated under lowered pressure to sufficiently dehydrate and deoxidize the salt.

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As the monomer, crown ether/benzo - 15 - crown - 5,
crown ether/benzo - 18 - crown - 6, crown ether/N -
phenylaza - 15 - crown - 5, crown ether/dibenzo - 18 -
crown - 6, crown ether/dibenzopyridino - 18 - crown - 6,
5 crown ether/dibenzo - 24 - crown - 8, 1, 13 - bis (8 -
quinolyl) - 1, 4, 7, 10, 13 - pentaoxidodecan, 5, 6 -
benzo - 4, 7, 13, 16, 21, 24 - hexaoxa - 1, 10 -
diazabicyclo [8. 8. 8] - hexakosan, 5, 6 - 14, 15 -
dibenzo - 4, 7, 13, 16, 21, 24 - hexaoxa - 1, 10 -
10 diazabicyclo [8. 8. 8] - hexakosan, bis [(benzo - 15 -
crown - 5 -) - 15 - ilmethyl] pimelate, crown
ether/dibenzo - 30 - crown - 10, N, N' - dibenzyl - 1,
4, 10, 13 - teraoxa - 7, 16 - diazacyclooctadecan,
dilithiumphthalocyanin, 4' - nitrobenzo - 15 - crown -
15 5, 3, 6, 9, 14 - tetrathiabicyclo [9. 2. 1] tetradeca -
11, 13 - dime and their mixture.

Since the performance of the battery deteriorates
if the polymer film for covering the surface of the
negative electrode active material is dissolved in the
20 electrolyte solution, it is preferable to be
crosslinked.

It is preferable that the thickness of the film
to be formed on the surface of lithium ranges from 10 Å
to 100 μ, further preferably ranges from 50 Å to 10 μ.
25 The optimum thickness of the film differs depending upon
the density or the void ratio of the film and
considerably differs depending upon the type of the
electrolyte solution. The thickness of the film can be

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adjusted by changing the concentration of the main material in the coating liquid for forming the film.

Polymer of Derivative of Aromatic Hydrocarbon

As the derivative of the aromatic hydrocarbon for forming the charge moving complex is one or more types of derivatives selected from a group consisting of naphthalene, anthracene, phenanthlene, naphthacene, pyrene, triphenylene, perillene, picene, benzopyrene, coronene and ovalene.

The polymer for use to form the coating material can be prepared by polymerization or copolymerization of vinyl monomer, monomer of acetylene derivative or dicarboxylic acid and diamine, and dicarboxylic acid and glycol. The polymerization of the vinyl monomer can be performed by radical or ion polymerization. The monomer of the acetylene derivative can be polymerized while using a chloride of tungsten as a catalyzer. The dicarboxylic acid and diamine can be polycondensed and the dicarboxylic acid and glycol can as well as be polycondensed.

The monomer of the aromatic derivative for forming the polymer is exemplified by 2 - vinyl naphthalene, 2 - vinyl pyridine, 9 - vinyl anthracene, 9, 10 - anthracene dipropionic acid, 9, 10 - bis (phenyl ethyl) anthracene and 5, 12 - bis (phenyl ethynyl) naphthalene.

A starting material for the radical polymerization is exemplified by azobisisobutyronitryl (AIBN), benzoylperoxide (BPO) and t - butylhydroperoxide. A

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starting material for the cation polymerization is exemplified by an acid such as H_2SO_4 , H_3PO_4 , $HClO_4$, CCl_3 or CO_2H and Friedel-Craft catalyzer such as BF_3 , $AlCl_3$, $TiCl_4$ or $SnCl_4$. A large ring compound having an aromatic ring
5 can be polymerized by dehydrogenation in which the Friedel-Craft catalyzer and an oxidizer are combined to each other. A starting material for the anion polymerization may be an alkaline metal compound or an organic metal compound.

10 As an alternative to the foregoing method, a polymer into which an aromatic group can be obtained by subjecting the side chain of each polymer to a substitution reaction with a derivative of an aromatic compound. Another method may be employed in which an
15 electrolytic polymerization reaction is caused to take place in an electrolyte solution containing a monomer mixed therein to form directly a polymer of an aromatic compound on the surface of positive electrode.

When the surface of the positive electrode is
20 applied with a coating by using the foregoing polymer solution, it is preferable to use a polymer solution dehydrated and deoxidized sufficiently in inactive gas dehydrated sufficiently. It is preferable to use a solvent in the foregoing solution which has been
25 dehydrated with active alumina, molecular sieves, phosphorus pentoxide or calcium chloride. As an alternative to this, it is preferable depending upon the type of the solvent that the solvent be distilled under

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presence of alkaline metal in inactive gas to remove impurities and to be dehydrated.

An electrolyte may previously be mixed when the foregoing film is formed. It leads to a fact that wettability between the electrolyte solution and the film can be improved, causing ions to easily pass through the film.

Since the performance of the battery deteriorates if the polymer coating film is dissolved in an organic solvent of the electrolyte, it is preferable to be crosslinked in such a manner, for example, ultraviolet rays, electron rays or radial rays are applied or a crosslinking material, such as a radical generating agent, is used.

15 Fluororesin

The fluororesin for covering the surface of the positive electrode is exemplified by ethylene tetrafluoride-ethylene copolymer, ethylene tetrafluoride chloride, ethylene tetrafluoride - per - fluoroalkylvinyl ether copolymer, ethylene tetrafluoride - propylene hexafluoride copolymer, vinylidene fluoride resin, vinyl fluoride resin, and ethylene tetrafluoride resin. Since the foregoing materials are not dissolved in a solvent, it is preferable to employ sputtering or plasma polymerization to cover the surface of the positive electrode with the fluororesin.

Among the fluororesins, those having an ether bond is able to facilitate the surface covering because they

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can easily be dissolved in a solvent and to improve the affinity with lithium ions. The fluoro-resin having the ether bond is exemplified by: a copolymer of ethylene fluoride and vinyl monomer such as vinyl ether, dioxysol, dioxyne or dioxycene having an ether bond or dienemonomer derivative or a copolymer with a vinyl monomer, such as vinyl ether, dioxysol or dioxyne, dioxycene having a fluorized ether bond with a dime compound, such as ethylene. The fluoroethylene may be a fluoroethylene derivative such as tetrafluoroethylene, chlorotrifluoroethylene, vinylidene fluoride or vinyl fluoride. The fluoroethylene copolymer containing the ether bond can be polymerized by a solution, suspension, block or emulsion polymerization. As a starting material, a peroxide, alkyl boron, light or radial rays may be employed.

The fluoro-resin can be coated on lithium metal by any one of the following methods.

- a. A solution of the fluoro-resin is applied by spraying, screen printing, by using a coater or by dipping.
- b. The fluoro-resin is directly coated to the surface of lithium by a vacuum evaporation method such as sputtering.
- c. A polymer film is directly formed by plasma polymerization under an atmosphere of monomer which is the raw material for the fluoro-resin.

If the lithium surface is coated by using the

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fluororesin solution, it is preferable to use, in an inactive gas dehydrated sufficiently, a fluororesin solution dehydrated and deoxidized sufficiently. It is preferable to use a solvent in the foregoing solution which has been dehydrated with active alumina, molecular sheave, phosphorus pentaoxide or calcium chloride. As an alternative to this, it is preferable depending upon the type of the solvent that the solvent be distilled under presence of alkaline metal in inactive gas to remove impurities and to be dehydrated.

An electrolyte may previously be mixed when the foregoing film is formed. It leads to a fact that wettability between the electrolyte solution and the film can be improved, causing ions to easily pass through the film.

Since the performance of the battery deteriorates if the fluororesin film is dissolved in an organic solvent of the electrolyte solution, it is preferable that the film is crosslinked.

As an alternative to the foregoing method of coating the surface with the fluororesin solution having the ether bond, another method may be employed in which ethylene fluoride and vinyl monomer are used as the main raw material as to be plasma-polymerized so that the surface is covered. In order to easily cause the plasma polymerization to take place easily or to improve the contact of the film and the strength of the same, it is preferable to add, to the fluorine compound serving as

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the raw material, oxygen, hydrogen, helium, argon, nitrogen, silane, hydrocarbon or the like. The plasma can effectively be generated by a DC or RF glow discharge method, a microwave discharge method or a laser beam irradiation method. The fluororesin having the ether bond may be sputtered to cover the surface of the positive electrode.

It is preferable that the thickness of the film to be formed on the surface of lithium ranges from 10 Å to 100 μ , more preferably ranges from 50 Å to 10 μ . The optimum thickness of the film differs depending upon the density or the void ratio of the film and considerably differs depending upon the type of the electrolyte solution. The thickness of the film can be adjusted by changing the concentration of the main material in the coating liquid for forming the film. If the plasma polymerization or sputtering is performed, the thickness can be adjusted by controlling the deposition time period.

20 Silicon Resin

The organic silicon compound may be any one of a material selected from a group consisting of alkoxysilane, alkylsilane, halogenated silane, siloxane, silane containing vinyl group, amino group, epoxy group, methacrylic group or mercaptal group introduced thereto, hydrogen - denatured, vinyl - denatured, hydroxyl group denatured, amino - denatured, carboxylic group denatured, chloro - denatured, epoxy denatured,

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methachryloxy - denatured, mercapto - denatured,
fluorine - denatured, long-chain-alkyl denatured or
phenyl - denatured polysiloxane, alkylene oxide
denatured siloxane copolymer, silicon - denatured
5 copolymer, alkoxysilane - denatured polymer, silicon -
denatured urethane or silicon - denatured nylon.

If the organic compound is liquid, the film can be
formed by a direct coating method or the organic
compound is diluted in a solvent and then applied. If
10 the organic compound is solid, a solution dissolved in a
solvent may be applied. The application method may be a
dipping method, a screen printing method, a spraying
method, a roll coating method or the like. The viscosity
of the coating solution must adequately be adjusted to
15 be adaptable to the coating method.

Titanium Polymer

A titanium polymer obtained by causing an organic
titanium compound to act on an organic polymer may be
used. For example, a thiranopolymer of silicon polymer
20 formed by cross linking the main chain of a
polycarbosilane skeleton with the titanium organic
compound may be used.

As an alternative to the titanium polymer, a
material obtained by introducing the derivative of an
25 organic metal compound, such as an organic aluminum
compound, into a polymer by substitution reactions may
be used as the coating material.

Polyphosphazene

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Polyphosphazene which is a polymer in which phosphor atoms and nitrogen atoms alternately form phosphor-nitrogen double bonds can be obtained by heating a dichloropolyphosphazene trimer to 200 to 300°C and by ring-opening polymerization. The dichloropolyphosphazene trimer can be synthesized from phosphorus pentachloride and ammonia chloride or ammonia. Any one of the following catalyzer is used at the time of the polymerization: benzoic acid, sodium benzoate, 2, 6 - di - p - cresol, water, methanol, ethanol, nitromethane, ether, heteropoly acid, sulfur, zinc, tin and sodium.

Further, various type of polyorganophosphazene can be obtained by substituting chloride atoms of polydichlorophosphazene by an organic reagent or an organic metal reagent.

If the surface of positive electrode is coated with the foregoing polyphosphazene, it is preferable that the polymer solution dehydrated and deoxidized sufficiently be used in inactive gas dehydrated sufficiently. It is preferable to use a solvent in the foregoing solution which has been dehydrated with active alumina, molecular sieve, phosphorus pentoxide or calcium chloride. As an alternative to this, it is preferable depending upon the type of the solvent that the solvent be distilled under presence of alkaline metal in inactive gas to remove impurities and to be dehydrated.

An electrolyte may previously be mixed when the

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foregoing film is formed. It leads to a fact that wettability between the electrolyte solution and the film can be improved, causing ions to easily pass through the film.

5 Since the performance of the battery deteriorates if the polymer coating film is dissolved in an organic solvent of the electrolyte, it is preferable to be crosslinked in such a manner, for example, ultraviolet rays, electron rays or radial rays are applied or a
10 crosslinking material, such as a radical generating agent, is used.

 It is preferable that the thickness of the film to be formed on the surface of lithium ranges from 10 Å to 100 μ, more preferably ranges from 50 Å to 10 μ. The
15 optimum thickness of the film differs depending upon the density or the void ratio of the film and considerably differs depending upon the type of the electrolyte solution. The thickness of the film can be adjusted by changing the concentration of the main
20 material in the coating liquid for forming the film.

Polyolefin

 As polyolefin, polyethylene or polypropylene may be used. Polyolefin is used in such a manner that the positive electrode is dipped in a solution dissolved in
25 a solvent such as tetrahydrofuran or o-dichlorobenzene, the positive electrode is then dried and crosslinked by ultraviolet, electrons, radial rays or the like so that the film is formed on the surface of the positive

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electrode.

The film can be formed by sputtering or plasma CVD method. In the material in the plasma CVD method, ethylene gas or propylene gas may be used.

5 Inorganic Oxide

The inorganic glass is made of a material, such as silica, titanium oxide, alumina, zirconia oxide, magnesium oxide, tantalum oxide, molybdenum oxide, tungsten molybdenum, tin oxide, indium oxide, iron
10 oxide, chrome oxide, aluminum phosphate, iron phosphate, silicon phosphate and their mixtures. A sol-gel method is one of adequate methods for forming the inorganic glass. The raw material for the material having the inorganic glass structure is obtained in such a manner
15 that an acid or a base and water are added to a solution of alcohol of an organic metal compound such as a metal alkoxide to hydrolyze the raw material so as to form colloid particles having metal atom-oxygen atom bonds, and then the colloid solution is directly applied to the
20 surface of the positive electrode. As an alternative to this, a solution in which a monomer or an organic polymer or the organic polymer and a crosslinking material are dissolved in the collide solution is applied, and then the solution is polymerized or dried
25 and polymerized so that the film is formed. By forming the composite organic polymer, strength against cracks and separation can be improved. If the electrolyte forming the lithium battery is dissolved in the collide

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solution to form the film, the wettability with the electrolyte solution can be improved and ions are enabled to move easily.

As an alternative to alkoxide, any one of the following organic metal compound may be employed: acetyl acetone complex salt, an alkyl metal compound, acetyl acetone metal salt, naphthene acid metal salt, and octyl acid metal salt.

The organic polymer for combining the organic polymers is exemplified by epoxy resin, polyester, polyimide, polyethylene, polypropylene, polyurethane, polystyrene, polyethylene glycol, nylon, fluorine resin and silicon resin.

The polymer crosslinking material is exemplified by diisocyanate, polyisocyanate prepolymer, block isocyanate, organic peroxide, polyamine, oxims, nitroso compound, sulfur or sulfur compound, selenium, magnesium oxide, lead oxide and zinc oxide.

As an alternative to using the crosslinking material, a method may be employed in which radial rays or electron rays or ultraviolet rays are applied to polymerize or crosslink the polymer.

As an application method, a dipping method, screen printing, spraying or a roll coating method may be employed. The viscosity of the liquid to be applied must adequately be adjusted to be adaptable to the application method.

Another method of forming the film by the glass

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inorganic oxide may be employed, for example, any one of the following evaporation method or a CVD method may be employed: a sputtering method, an electron beam evaporation method, a plasma CVD (Chemical Vapor
5 Deposition) method, and a laser CVD method.

The sputtering process and the electron beam evaporation can be performed by a method in which the oxide material is directly evaporated or by a method in which silicon or metal vapor and oxygen gas are caused
10 to react with each other to form the film.

The plasma CVD method and the laser CVD method is performed in such a manner that oxygen gas and any one of a hydroxide or halide of silicon or metal and an organic metal compound are used as the raw materials to
15 be decomposed by discharge or laser so that the film is formed.

The inorganic oxide can be used to form the film by another method, that is, an electrochemical method comprising the steps of forming a metal film made of
20 aluminum titanium, tantalum, niobium by sputtering or electron beam, anode-oxidizing the film by using an oxalic acid, a phosphoric acid or ammonia borate as an electrolyte solution to form the oxide film.

A film forming method may be employed which
25 utilizes the equilibrium reaction in the water solution to precipitate and cause the oxide film to grow on the surface of the dipped substrate. In this case, silica (a silicon oxide), titanium oxide or vanadium oxide film

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can be formed. A specific method of forming the silica film comprises the step of dipping the positive electrode in a solution in which silica is saturated in a water solution of hydrofluosilicic acid to form the
5 film.

Nitride

The nitride can be obtained from silicon nitride, titanium nitride, aluminum nitride or boron nitride or the like. The nitride film can be formed on the positive
10 electrode by sputtering, an electron beam evaporation method, a plasma CVD method or a laser CVD method.

The sputtering and the electron beam evaporation methods are categorized to a method in which the nitride material is directly evaporated and a method in which
15 vapor of silicon, titanium or aluminum and nitrogen plasma generated from nitrogen gas or ammonia gas are caused to react with each other to form the film.

The plasma CVD method and the laser CVD method respectively comprise the step of decomposing the raw
20 material gas, such as nitrogen gas, ammonia gas or nitrogen trifluoride and a hydroxide such as silicon, titanium or aluminum, halide or an organic metal compound by discharge or laser to form the film.

Carbide

25 The carbide can be obtained from a material exemplified by amorphous carbon, silicon carbide, titanium carbide, vanadium carbide and tungsten carbide.

The carbide film can be formed by a similar method

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employed to form the nitride.

The sputtering and the electron beam evaporation methods are categorized to a method in which the material from which the carbide is obtained is directly evaporated and a method in which silicon, titanium, vanadium or tungsten and carbon are used as the raw materials to form the film.

The plasma CVD method and the laser CVD method respectively comprise the step of, by laser, decomposing the material, such as hydrocarbon, from which carbon is obtained and a hydroxide such as silicon, titanium, vanadium or tungsten or a halide or an organic metal compound to form the film.

Halide

The halide can be obtained from a material selected from a group consisting of lithium fluoride, magnesium fluoride, sodium fluoride, potassium fluoride, barium fluoride or lithium chloride.

The halide film can be formed by a sputtering method or an electron beam evaporation method. A CVD method such as the plasma CVD method or the laser CVD method may be employed.

Semiconductor

The semiconductor for covering the positive electrode is made of a material exemplified by diamond (carbon), silicon, nickel oxide, copper oxide, vanadium oxide, tin oxide and zinc oxide.

Alkali metal, phosphorus or boron may be added as

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impurities.

The semiconductor film may be formed by sputtering, electron beam evaporation, plasma CVD or laser CVD as well as the foregoing method of forming the inorganic acid film.

Covering of Positive Electrode of Nickel-Zinc Secondary Battery or Air-Zinc Secondary Battery

The material and the method of covering the positive electrode of a nickel-zinc secondary battery or air-zinc secondary battery may be the same as those employed to cover the positive electrode of the lithium secondary battery. Also a polymer of a type which is dissolved in an organic solvent but which is not dissolved in water may be used. If the covering material has water repellent characteristics, a hydrophilic group must be introduced or must be subjected to hydrophilic treatment using a silane coupling material.

Thickness of Film Covering the Surface of Positive Electrode

The thickness of the film for covering the surface of the positive electrode can be controlled by adjusting the concentration of the solution if the surface is covered by utilizing the liquid layer reactions performed by the polymer solution or the sol-gel method. The same can be controlled by adjusting the deposition time if sputtering, the electron beam evaporation, the CVD method or the plasma polymerization is employed.

Aperture in Coating Film on Positive Electrode Surface

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impurities.

The semiconductor film may be formed by sputtering, electron beam evaporation, plasma CVD or laser CVD as well as the foregoing method of forming the inorganic acid film.

Covering of Positive Electrode of Nickel-Zinc Secondary Battery or Air-Zinc Secondary Battery

The material and the method of covering the positive electrode of a nickel-zinc secondary battery or air-zinc secondary battery may be the same as those employed to cover the positive electrode of the lithium secondary battery. Also a polymer of a type which is dissolved in an organic solvent but which is not dissolved in water may be used. If the covering material has water repellent characteristics, a hydrophilic group must be introduced or must be subjected to hydrophilic treatment using a silane coupling material.

Thickness of Film Covering the Surface of Positive Electrode

The thickness of the film for covering the surface of the positive electrode can be controlled by adjusting the concentration of the solution if the surface is covered by utilizing the liquid layer reactions performed by the polymer solution or the sol-gel method. The same can be controlled by adjusting the deposition time if sputtering, the electron beam evaporation, the CVD method or the plasma polymerization is employed.

Aperture in Coating Film on Positive Electrode Surface

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The apertures and the void ratio of the coating film for covering the surface of the positive electrode can be controlled by adjusting the concentration of the solution or the drying condition if covering is performed by using the polymer solution or by utilizing the sol-gel method. Further, any one of the following methods may be employed: a method for forming the film while causing foam to be generated by adjusting the concentration of the foaming material; a method having the steps of forming a film in which the content of the electrolyte is adjusted, and dissolving the electrolyte; a method for controlling the evaporation rate; and a method for adjusting the mixture ratio of the reactive materials.

If the negative electrode is covered with the coating material of a type employed to cover the positive electrode, growth of dendrite from the negative electrode can be prevented. Therefore, short circuits in the battery can be prevented in effect obtainable from covering the positive electrode. As a result, the battery cycle can further be lengthened.

Then, a positive electrode according to the present invention composed of transition metal and group 6A element will now be described.

25 Transition Metal Element

The transition metal element in the positive electrode active material according to the present invention may be an element having partially shell d or

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shell f and selected from a group consisting of T, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Wn, Tc, Re, Fe, Ru, Os, Co, Rh, Ir, Ni, Pd, Pt, Cu, Ag and Au. Any one of the first transition system metal is mainly used which is exemplified by Ti, V, Cr, Mn, Fe, Co, Ni or Cu. A compound of the transition metal and the group 6A element is manufactured by a material exemplified by the transition metal, the salt of the transition metal, an oxide of the transition metal and a hydroxide of the transition metal.

Group 6A Element

The positive electrode active material according to the present invention comprises the group 6A element exemplified by O, S, Se, Te and Po. Among the foregoing elements, O or S is mainly employed. A compound of the transition metal and the group 6A element can be manufactured by a material exemplified by a compound of a hydroxide, halide, halide oxide or oxide of sulfur, selene, tellurium, polonium.

Additive Element

By adding elements except the transition metal, the distortion of the positive electrode active material occurring due to the introduction/discharge of lithium ions can be relaxed. The element can be effectively added by a method comprising the step of adding the salt, the halide or an organic metal compound of one or more types of elements selected from a group consisting of lithium, magnesium, sodium, potassium, aluminum,

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zinc, calcium, barium, lead, indium, boron, silicon,
tin, phosphor, arsenic, antimony, bismuth, chlorine and
fluorine. It is preferable that the atom ratio of the
additive element with respect to the transition metal
5 element be 1 or less.

Method of Manufacturing Compound of Transition Metal and
Group 6A Element

The compound of the transition metal and the group
6A element according to the present invention is
10 manufactured by any one of methods categorized to a
method in which the compound is prepared from the
solution of the salt of the transition metal or the
organic transition metal compound by way of a hydroxide,
a method comprising the steps of melting the transition
15 metal or the transition metal compound and rapidly
cooling it, and a method in which the transition metal
compound is caused to react in a gas phase.

The method of preparing the transition metal oxide
from the hydroxide is exemplified by a method comprising
20 the step of baking or drying hydroxide in air or in an
oxygen atmosphere to prepare powder. A specific example
of preparing the transition sulfide from the hydroxide
is exemplified by a method comprising the step of baking
a hydroxide in a hydrogen reduction atmosphere in which
25 a hydrogen sulfide is mixed to prepare powder.

The rapid cooling method for preparing the
transition metal oxide comprises the steps of melting
the transition metal compound, such as the transition

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metal or the transition metal oxide, and spraying oxygen gas containing inactive gas mixed thereto to a rotating disc to prepare the powder.

The method of preparing the transition metal oxide by the gas phase reactions comprises the step of oxidizing or hydrolyzing the salt of the transition metal or causing vapor of the transition metal to react with the group 6A element or a compound of the group 6A element or decomposing the organic transition metal compound to prepare the powder.

It is preferable that each process be performed at 400°C or lower, more preferable 300°C or lower.

The liquid phase reaction method, the gas phase reaction method and the melting and rapid cooling method will now be described.

Liquid Phase Reaction

A method of preparing the hydroxide for use in the main reaction in the method of manufacturing the material from the solution by way of the hydroxide is exemplified by:

Method of Preparing Hydroxide

It is preferable that the transition metal hydroxide be prepared by reactions between the salt of the transition metal and alkali or by hydrolysis of the organic transition metal compound or by reactions between the transition metal and alkali. It is preferable that the preparation temperature be 150°C or lower, more preferably 100°C or lower.

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Reactions between Salt of Transition Metal and Alkali

By causing alkali to react with the salt of the transition metal, a hydroxide of the transition metal is sedimentated to be prepared. By mixing salts of two or
5 more types of the transition metals, a hydroxide of a composite transition metal can be obtained.

The salt of the transition metal is typified by a carbonate, a nitrate, a halide, a sulfate, a sulfamate, acetate, oxalate, citrate, tertrate, formate or
10 ammonate.

The alkali may be lithium hydroxide, sodium hydroxide, potassium hydroxide or ammonia hydroxide. As an alternative to this, urea or thiourea may be used which raises the pH by generating hydroxide ions when
15 heated.

It is preferable that an organic acid or inorganic acid or an amine is, in a small quantity, added or an organic solvent such as alcohol is added at the time of causing alkali to react with the water solution of the
20 transition metal salt in order to fine the sediment particles of the hydroxide.

By vibrating the sediment with ultrasonic waves, the sediment particles can be fined. Therefore, the specific area can be enlarged.

25 Hydrolysis Reaction of Organic Transition Metal Compound

The hydroxide of the transition metal can be prepared by hydrolyzing an organic metal compound of the transition metal, such as alkoxide, acetyl acetate,

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octylate or naphthalate.

The hydrolysis of alkoxide is specifically performed in such a manner that alkoxide of the transition metal is dissolved by water, alcohol or ethanol amine or the like, and an inorganic acid such as hydrochloric acid or an organic acid such as acetic acid or ammonia hydroxide or amine is added.

The alkoxide of the transition metal may be a material selected from a group consisting of

Mn(OC₂H₅)₂, Mn(OC₃H₇)₂, Mn(OC₄H₉)₂, Ni(OC₂H₅)₂, Ni(OC₃H₇)₂, Ni(OC₄H₉)₂, Co(OC₂H₅)₂, Co(OC₃H₇)₂, Co(OC₄H₉)₂, Ti(OC₂H₅)₂, Ti(OC₃H₇)₂, Ti(OC₄H₉)₂, Fe(OC₂H₅)₂, Fe(OC₃H₇)₂, Fe(OC₄H₉)₂, Cu(OC₂H₅)₂, Cu(OC₃H₇)₂, Cu(OC₄H₉)₂, VO(OCH₃)₃, VO(OC₂H₅)₃, VO(OC₃H₇)₃, VO(OC₄H₉)₃ and Y(OC₄H₉)₃.

The acetylacetonate of the transition metal is exemplified by Cu(C₅H₇O₂)₂, Co(C₅H₇O₂)₂, (H₂O)₂, Co(C₅H₇O₂)₃, Ni(C₅H₇O₂)₂(H₂O)₂, Mn(C₅H₇O₂)₂(H₂O)₂, Cr(C₅H₇O₂)₃, VO(C₅H₇O₂)₂, Fe(C₅H₇O₂)₃, Ti(OC₄H₉)₂(C₅H₇O)₂, La(C₅H₇O₂)₃, Y(C₅H₇O₂)₃, and Zr(C₅H₇O₂)₄.

The octylate of the transition metal is exemplified by Cu(C₇H₁₅COO)₂, Ni(C₇H₁₅COO)₂, Fe(C₇H₁₅COO)₂, Mn(C₇H₁₅COO)₂, Co(C₇H₁₅COO)₂, Zr(C₇H₁₅COO)₂, Y(C₇H₁₅COO)₂, and La(C₇H₁₅COO)₂.

The naphthate of the transition metal is exemplified by the salt of naphthate expressed by a general formula C_nH_{2n-2}O₂, that is, cobalt naphthenate, copper naphthenate, manganese naphthenate, iron naphthenate, nickel naphthenate, vanadium naphthenate, yttrium naphthenate and lanthanum naphthenate.

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The alcohol is exemplified by methyl alcohol, ethyl alcohol, isopropyl alcohol, ethylene glycol and propylene glycol.

Dehydrating Reaction

5 In order to obtain the oxide of the transition metal by dehydration from the transition metal hydroxide prepared by the foregoing solution reactions, it is preferable that the transition metal hydroxide is immersed in an organic solvent such as alcohol or
10 acetone which is mixed with water to sufficiently substitute water, and then it is dried in a vacuum state at 100°C or higher. As an alternative to this, heating and dehydration is performed by using microwaves. If the drying temperature is too high, crystallization is
15 enhanced and therefore the hydroxide groups are decreased. Therefore, it is preferable that the temperature be 400°C or lower. It is preferable that the frequency of the microwaves be a frequency which can easily be absorbed by water.

20 In order to enlarge the specific area, another method may be employed in which the dehydration is performed by freezing and drying.

Hydrogen Treatment

25 Hydrogen is mixed into the dried atmosphere at the time of drying the transition metal oxide followed by performing heat treatment. As an alternative to this, a method is employed in which the transition metal hydroxide or the transition metal oxide is subjected to hydrogen plasma treatment. The hydrogen plasma can be

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generated by a hydrogen gas discharge method or by a method of exciting and decomposing the hydrogen gas by laser beams.

Introduction of Group 6A Element Except Oxygen

5 A method is employed in which the transition metal hydroxide or the transition metal oxide is treated with hydrogen sulfide or hydrogen selenide or the group 6A element is mixed at the time of preparing the transition metal hydroxide.

10 Gas Phase Reaction Method

As a method of preparing a compound of the transition metal and the group 6A element, a gasified transition metal salt or an organic transition metal compound or vapor of the transition metal and the group 15 6A element or the group 6A element compound are caused to react with each other in the gas phase to prepare powder. Another method may be employed in which the gasified transition metal salt or the organic transition metal compound containing the group 6A element is 20 decomposed in the gas phase to prepare the compound of the transition metal and the group 6A element.

If the transition metal salt or the organic transition metal compound is in the form of solid, it is heated as to be formed into vapor or it is heated as to 25 be formed into liquid. Then, carrier gas is bubbled as to be introduced into the reaction chamber. If the transition metal salt or the organic transition metal compound is in the form of liquid, it may be heated as to be formed into vapor or carrier gas is bubbled as to

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be introduced into the reaction chamber.

The salt of the transition metal may mainly be a halide such as a chloride. As an alternative to this, a carbonate, a nitrate, a sulfate, sulfonate, acetate, citrate, tertrate, formate or ammonate. The chloride is exemplified by VOCl_3 , MnCl_2 , MoCl_5 , TiCl_4 , NiCl_2 , CoCl_2 , FeCl_3 , WCl_6 , YCl_3 and ZrCl_4 .

The raw material from which the group 6A element can be obtained is exemplified by the group 6A element, the hydroxide of the group 6A element and the halide of the group 6A element.

By mixing hydrogen gas in the foregoing gas phase reaction, a compound of the transition metal and the group 6A element containing hydrogen can be prepared.

In the foregoing gas phase reaction, it is preferable to employ any one of the following methods: a heat CVD (Chemical Vapor Deposition) method, a plasma CVD method, a laser CVD method, a filament method, a reactive sputtering method and the electron beam method.

Sputtering is performed by heat in the heat CVD method, by charge in the plasma CVD method, by heat energy or light energy of laser beams in the laser CVD method, by heat of a filament made of tungsten or the like in the filament method, and in the reactive sputtering method in the reactive gas atmosphere, and by electron beam heating in the electron beam method. As a result, gas phase reactions are respectively performed so that the material is prepared. It is preferable that the raw material be in the form of solid in the reactive

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sputtering method or the electron beam method.

Rapid Cooling Method

In this case, any one of the following methods may be employed: a gun method comprising the steps of
5 generating, while breaking a Mylar film, shock waves by helium gas, in which oxygen or hydrogen sulfide is mixed, as to be sprayed to the transition metal or the transition metal compound melted with high frequency waves, and causing blown compound powder to impact
10 against a cooling steel plate in the form of a slide disposed below so that the temperature is rapidly cooled; a method in which a molten bath is dispersed by spraying with inactive gas jet in which oxygen or hydrogen sulfide is mixed; and an atomization method in
15 which molten bath of the transition metal or the transition metal compound is sprayed in an atmosphere containing the group 6A element such as oxygen or group 6A element compound such as hydrogen sulfide as to be formed into powder. By mixing hydrogen gas into the
20 inactive gas, hydrogen can be introduced into the product.

It is preferable that the rapid cooling rate be 10^1 to 10^8 K, more preferable 10^2 to 10^8 K.

25 The melting and heating furnace may be a crucible furnace, an induction furnace, an arc furnace or an electron beam furnace.

The method of causing the alkali to directly react with the transition metal is exemplified by a method in which metal such as vanadium is caused to react with

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molten alkali to prepare an oxide.

Conductor Core

When conductor powder is mixed at the time of preparing the compound of the transition metal and the group 6A element to cause the compound of the transition metal and the group 6A element to grow while using the conductor powder as the core, the collecting efficiency can be raised. Therefore, the introduction and discharge of lithium ions can be made easier, and therefore the battery capacity can be enlarged.

The conductor powder may be made of one or more types of materials selected from a group consisting of carbon, titanium, nickel, cobalt, iron, chrome, manganese, vanadium, platinum, paradium, copper, silver, gold, zinc, tin, indium, lead, tungsten and molybdenum. It is preferable to use one or more types of elements selected from a group consisting of carbon, titanium, nickel, cobalt, iron, chrome, manganese, vanadium and platinum.

The shape of the conductor powder is formed into one or more types of shapes selected from a group consisting of a spherical shape, a flake shape, a needle shape and a fiber shape. As a result, also the compound powder of the transition metal and the group 6A element can be formed into the spherical, flake, needle or fiber shape. Therefore, the efficiency of the electron movement between the positive electrode active material can be raised, and therefore the charging and discharging efficiency can be improved.

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It is preferable that the diameter of the conductor powder be 10 Å to 100 μ when measured by an electron microscope, more preferably 10 Å to 10 μ.

Crushing of Positive Electrode Active Material

5 The prepared positive electrode active material must be crushed as to have an adequate grain size if obtained positive electrode active material is in the form of a block.

10 It is preferable to crush the positive electrode active material by using, while combining, means selected from a group consisting of a compression crushing machine, a shearing crushing machine, an impact crushing machine, a roll mill, a roller mill, a high-speed rotational mill, a ball mill, a medium stirring mill, a jet mill, a mortar and a stamping mill.

Coating Film Made of Conductor

20 The prepared compound of the transition metal and the group 6A element is covered with a conductor thin film by chemical plating (non-electrolytic plating) or by evaporation. As a result of the foregoing process, the current collecting efficiency can be raised, the introduction/discharge of lithium ion can be facilitated and the battery capacity can be enlarged.

25 The conductor thin film may be made of one or more types of materials selected from a group consisting of carbon, titanium, nickel, cobalt, iron, chrome, manganese, vanadium, platinum, paradium, copper, silver, gold, zinc, tin, indium, lead, tungsten and molybdenum. It is preferable to use one or more types of elements

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selected from a group consisting of carbon, titanium, nickel, cobalt, iron, chrome, manganese, vanadium and platinum.

The chemical plating method is a method in which metal ions are deoxidized by a deoxidizer such as formaldehyde to precipitate the metal film.

The evaporation is performed by any one of the following methods: a method in which vapor of metal is generated by electron beams or laser beams as to be applied to the subject; a method in which a carbon or metal target is sputtered as to be applied to the subject; a method in which hydrocarbon or organic solvent or an organic metal compound is decomposed by discharge or laser or heat as to be applied to the subject. The decomposition of the hydrocarbon and the organic solvent enables a carbon film to be formed, while the decomposition of the organic metal compound enables a metal film to be formed.

It is preferable that the thickness of the conductor film ranges from 50 Å to 1 μ.

Lipophilic Treatment

The positive electrode active material is subjected to the lipophilic treatment in such a manner that the organic metal compound is immersed in a solution, in which an organic solvent is dissolved, and then it is dried.

It is preferable that the organic metal compound for use in the lipophilic treatment be an organic metal compound such as silane coupling material or organic

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titanate. If dilution is performed, the dilution concentration with respect to the solvent ranges from 0.05 to 2 wt%.

The silane coupling material is exemplified by
 5 vinyltrimethoxysilane, vinylmethoxysilane, N - (2 -
 aminoethyl) 3 - aminopropylmethyl dimethoxysilane, N - (2
 - aminoethyl) 3 - aminopropyltrimethoxysilane, 3 -
 aminopropyltriethoxysilane, 3 -
 glycidoxypropyltrimethoxysilane, 3 -
 10 glycidoxypropylmethyldimethoxysilane, 2 - (3,4 -
 epoxycyclohexyl) ethyltrimethoxysilane, 3 -
 chloropropylmethyldimethoxysilane, 3 -
 chloropropyltrimethoxysilane, 3 -
 methacryloxytrimethoxysilane, 3 -
 15 mercaptotrimethoxysilane, and N - [2 -
 (vinylpenzylamino) ethyl] - 3 -
 aminopropyltrimethoxysilane.

The organic titanate is exemplified by tetra - i -
 propoxytitanium, tetra - n - butoxytitanium, tetrakis (2
 20 - ethylhexyloxy) titanium, tetrastearoyloxytitanium,
 di - i - proxy•bis (acetylacetate) titanium,
 dihydroxy•bis (lactato)titanium, titanium - i -
 propoxyoctylene glycol, titanium stearate, propane
 dioxytitanbis (ethylacetoacetate), propanedioxytitanium
 25 (acetylacetonate) (ethylacetoacetate), oxotitanbis
 (monoammonium oxalate), tri - n -
 butoxytitanmonostearate, and titan polymer.

Analysis of Transition Metal and Group 6A Element
Measurement of Size of Crystal Grain

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The size of crystal grains was evaluated from the peak half width and the angle of diffraction of X-ray diffraction curve in accordance with the following Scherrer's Formula:

5
$$t = 0.9\lambda / B \cos \theta_B \quad (\text{Scherrer's Formula})$$

where t: size of crystal grain

λ : wave length of X-ray beam

B: peak half width

θ_B : angle of diffraction

10 It is preferable that the average size of the crystal grain of the positive electrode active material which is the compound of the transition metal and the group 6A element for use in the secondary battery according to the present invention be 500 Å or less when
15 calculated by using the foregoing Scherrer's Formula, more preferably 200 Å or less.

Observation of Crystal Structure

The crystal structure of the positive electrode active material and the group 6A element prepared by the
20 method according to the present invention can be observed in such a manner that the waveform of the radial distribution function can be observed by X-ray diffraction, the diffraction pattern can be observed by reflecting high speed electron beam diffraction (RHEED)
25 and the waveform of the X-ray diffraction curve can be observed.

The radial distribution function can be obtained by Fourier transforming the dispersion intensity of measured X-ray or neutron beam. The radial distribution

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function is expressed by the presence possibility of atoms with respect to an arbitrary atom or a function of the deviation distance from an average numerical density. If the specimen is made of amorphous material, a moderate peak curve can be obtained. If the specimen is crystal material, a discontinuous a sharp peak can be obtained.

The RHEED enables a halo pattern to be observed if the specimen is made of amorphous material, enables a ring pattern to be observed if the specimen is made of microcrystal material and enables a spot pattern to be observed if the specimen is made of a multi-crystal material.

The dispersion angle and the dispersion intensity obtainable in the X-ray small angle dispersion method also enables of fluctuation of ununiform density peculiar to the amorphous material.

Further, the differential thermal analysis enables heat absorption or heat generation due to the structural relaxation or the crystallization structural change occurring to the temperature rise to be observed if the specimen is amorphous material. If a hydroxide group is present, heat absorption due to dehydration can be observed.

By using the foregoing means, the structure of the compound of the transition metal and the group 6A element prepared by the manufacturing method according to the present invention can be analyzed so that the amorphous structures the microcrystal structure and the

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multi-crystal structure are confirmed.

Analysis of Hydrogen

The compound of the transition metal containing hydrogen and the group 6A element is subjected to
5 qualitatively analyzed by SIMS (Secondary Ion Mass Spectrometry) analysis.

Manufacturing of Positive Electrode

The positive electrode is manufactured in such a
10 manner that the bonding material, and conductive powder if necessary, is mixed with the powder of the compound of the transition metal and the group 6A element manufactured by the foregoing method, and then formed into the positive electrode together with the collector.
15 It is preferable that the foregoing forming process be performed in dry air from which water has sufficiently be removed, more particularly under inactive gas atmosphere.

The conductive powder acts to enhance the electron
20 conduction and facilitate the current collection because the active material, which is the compound of the transition metal and the group 6A element, does not substantially have the electron conductivity.

The conductive powder may be carbon material, such
25 as acetylene black, ketchen black or graphite powder, or metal, such as nickel, titanium, copper or stainless steel. It is preferable that the mixture ratio of the conductive powder with respect to the positive electrode active material be 1 or less.

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The bonding material bonds the positive electrode active material powder to one another and prevents generation of cracks in the charge and discharge cycle to prevent the separation from the collector. The bonding material may be one or more types of resin which are stable against the organic solvent and which are selected from a group consisting of fluororesin, polyethylene, polypropylene and silicon resin. It is preferable that the foregoing resin be in the form of liquid or solution or having a low melting point. Further, it is preferable that the solvent be removed and the resin is crosslinked during the process of manufacturing the positive electrode. As a result, the content of the bonding material in the positive electrode can be lowered and the capacity of the battery can be improved. The liquid resin or the resin which can be dissolved in the solvent is exemplified by fluororesin having an ether bond and silicon resin. If the fluororesin having the ether bond is used, the concentration can be lowered when it is dissolved in a solvent. Therefore, the content in the positive electrode can be lowered as much as possible and the void ratio can be raised. Further, the state is very stable after crosslinking has been performed so that a satisfactory effect can be obtained upon the charge and discharge cycle.

It is also preferable that dehydration is performed with heat generated by microwaves and a vacuum drier is used to dehydrate the positive electrode after the

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positive electrode has been formed.

It is preferable that the mixture ratio of the bonding material with respect to the positive electrode active material be 0.1 or less.

5 Examples

Examples of the present invention will now be described. It should be noted that the present invention is not limited to the examples below.

Example 1-1

10 A flat type battery having a simple structure, exhibiting assembling easiness and having a cross sectional structure schematically shown in Fig. 2 was assembled to evaluate the characteristics of the secondary battery while mainly evaluating the life
15 against cycle operation.

First, a solution in which colloidal silica manufactured by Shokubai Kasei and subjected to hydrophobic treatment in an atmosphere of dry argon gas was dispersed in N, N - dimethylformamide was dehydrated
20 by active alumina. Then, lithium metal foil to which titanium mesh collector 200 was pressed against the reverse side was immersed in the colloidal silica solution prepared by the foregoing method, and then dried at 120°C so that a lithium negative electrode 201
25 covered with silica was manufactured.

A positive electrode active material 203 was manufactured in such a manner that a mixture of dehydrated and electrolyzed manganese dioxide and lithium carbonate was heated so that a lithium-manganese

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composite oxide was prepared. Then, tetrafluoroethylene polymer powder was mixed, and then pressed against the titanium mesh as to be formed into a designed shape.

The electrolyte solution was obtained by
5 dissolving, by 1 M (mol/l), lithium arsenate
hexafluoride salt in an equally mixed solvent of
propylene carbonate (PC) and dimethoxyethane (DME).

A separator 208 was formed in such a manner that
a separator made of polypropylene and having small
10 apertures was sandwiched by unwoven polypropylene
sheets.

The assembling process was performed in such a
manner that the separator 208 was place between the
negative electrode 201 and the positive electrode 203
15 followed by inserting them into a positive electrode
case 207 made of titanium clad stainless steel. Then, an
electrolyte solution was injected followed by sealing
the positive electrode case 207 with a negative cap 206
made of titanium clad stainless steel and an insulating
20 packing 210 made of fluororubber so that a secondary
battery was manufactured.

Comparative Example 1-1

A lithium secondary battery was manufactured by a
method similar to Example 1-1 except for excluding the
25 surface covering treatment using the metal lithium foil
performed in Example 1-1.

Comparative Example 1-2

A battery similar to that according to Example 1-1
was manufactured.

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The preparation of the materials and assembly were performed in an atmosphere of dry argon similarly to Example 1-1.

5 First, aluminum trichloride and phosphoric acid were allowed to react with each other in ethyl alcohol, and gradually heated to 100°C so that glass form aluminum phosphate was obtained. Then, it was dispersed in n-hexane so that a film forming solution was prepared. The film forming solution was applied to a 10 lithium metal foil to which the titanium mesh collector was pressed. Then, a film was formed at 120°C. Then, similar processes to those according to Example 1-1 were performed so that a lithium battery was manufactured.

Example 1-3

15 A battery similar to that according to Example 1-1 was manufactured.

The preparation of the materials and assembly were performed in an atmosphere of dry argon similarly to Example 1-1.

20 First, acetic acid and water were added to an ethyl alcohol solution of tetrabutoxytitanium to be hydrolyzed. Then, diethylamine was added so that colloidal titanium oxide was formed. Then, colloidal titanium oxide was dissolved in a xylene solution of 25 polyethylene so that a film forming solution was prepared. The film forming solution was applied to the lithium metal foil to which the stainless mesh collector was pressed followed by drying it at 100°C. Then, electron beams were applied to crosslink the

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polyethylene so that a film was formed. Then, similar processes to those according to Example 1-1 were performed so that a lithium battery was manufactured.

Example 1-4

5 A battery similar to that according to Example 1-1 was manufactured.

The preparation of the materials and assembly were performed in an atmosphere of dry argon similarly to Example 1-1.

10 A toluene solution of triethylaluminum was mixed with an isopropyl alcohol solution of tetrabutoxytitanium, followed by adding acetic acid and water as to be hydrolyzed. Then, diethylamine was added so that colloidal titanium oxide-alumina was formed.

15 Then, the colloidal titanium oxide-alumina was dispersed in a toluene solution which acrylic resin and epoxy resin were dissolved so that the film forming solution was prepared. The film forming solution was applied to a lithium metal foil to which the stainless mesh collector

20 was pressed, and then a film was formed at 80°C . Then, similar processes to those according to Example 1-1 were performed so that a lithium battery was manufactured.

Example 1-5

25 A battery similar to that according to Example 1-1 was manufactured.

The preparation of the materials and assembly were performed in an atmosphere of dry argon similarly to Example 1-1.

First, acetic acid and water were added to an

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ethyl alcohol solution of tetraethoxysilane as to be hydrolyzed. Then, diethyl amine was added so that colloidal silica oxide was formed. Then, the colloidal silica was dispersed in an acetonitril solution of polyethylene glycol, followed by adding azobisisobutylonitril and arsenic hexafluoride lithium salt so that a film forming solution was prepared. The film forming solution was applied to the lithium metal foil to which the stainless mesh collector was pressed, followed by drying it at 100°C as to crosslink polyethylene glycol so that a film was formed. Then, similar processes to those according to Example 1-1 were performed so that a lithium battery was manufactured.

Example 1-6

15 A battery similar to that according to Example 1-1 was manufactured.

First, felt-shape carbon was immersed in silica coating solution NT-G326, which was manufactured by Nissan Kagaku and to which boron tetrafluoride lithium salt was added, and taken out from it. Then, it was hardened at 110°C for 20 minutes and 300°C for 30 minutes so that silica coating was performed. The obtained felt-shape carbon covered with the silica was used as the cathode and the lithium metal was used as the anode in an electrolyte solution in which arsenic hexafluoride lithium salt was, by 1 M (mol/l), dissolved in an equal-quantity mixture solvent of propylene carbonate and dimethoxyethane dehydrated sufficiently. As a result, lithium was introduced and allowed to adhere to the

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felt-shape carbon covered with silica so that the negative electrode 201 was manufactured.

Then, similar processes to those according to Example 1-1 were performed so that a battery was
5 manufactured.

Example 1-7

A battery similar to that according to Example 1-1 was manufactured.

10 First, paste obtained by mixing zinc oxide powder, metal zinc powder and water glass was injected into foamed nickel (Celmet) manufactured by Sumitomo Denko. Then, the material was hardened at 80°C for 20 minutes and 200°C for 30 minutes so that the negative electrode 201 was formed.

15 Then, paste obtained by mixing, with nickel hydroxide, nickel powder, cobalt powder, carboxylic methyl cellulose serving as the bonding material, ethylene glycol and water was injected into the Celmet manufactured by Sumitomo Denko. Then, it was dried and
20 pressed so that the positive electrode 203 was formed.

The separator was formed in such a manner that polypropylene film subjected to hydrophilic treatment and having small apertures was sandwiched by unwoven polyamide sheets. The electrolyte solution was a 30 wt%
25 potassium hydroxide solution. The assembly was performed similarly to Example 1-1 so that a nickel-zinc secondary battery was manufactured.

Comparative Example 1-2

A nickel-zinc secondary battery was manufactured by

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a method similar to Example 1-7 except that the negative electrode was manufactured by mixing polyethylene serving as the bonding material and ethylene glycol in place of the water glass.

5 Example 1-8

A battery having a structure similar to that according to Example 1-1 was manufactured. However, a positive electrode case having small apertures for receiving oxygen in air was employed.

10 The negative electrode 201 was formed similarly to that according to Example 1-7.

The positive electrode 203 was formed in such a manner that the positive catalyzer layer was formed by adding manganese dioxide to active carbon, and a water repellent film made of polytetrafluoroethylene and cellulose-type diffusion paper were stacked on the
15 positive catalyzer layer.

The separator 208 comprises a cellophane film, while the electrolyte solution comprises a 30 wt%
20 potassium hydroxide solution.

The battery was assembled in such a manner that the separator 208 was held between the negative electrode 201 and the positive electrode 203, followed by inserting them into the positive electrode case 207
25 having small apertures for receiving oxygen in air and made of titanium clad stainless steel. Then, the electrolyte solution was injected, and sealing was performed by the negative cap 206 made of the titanium clad stainless steel and the insulating packing 210 made

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of fluorine rubber so that the air-zinc secondary battery was manufactured.

Comparative Example 1-3

5 An air-zinc secondary battery was manufactured by a method similar to that according to Example 1-8 except that the negative electrode according to Comparative Example 1-2 was used.

Evaluation of Performance of Secondary Battery

10 The performance of lithium secondary batteries according to Examples 1-1 to 1-6 and Comparative Example 1-1, the nickel-zinc secondary battery according to Example 1-7 and Comparative Example 1-2, and the airzinc secondary battery according to Example 1-8 and Comparative Example 1-3 was evaluated. The evaluation
15 was performed by a charge and discharge cycle test under the following conditions with respect to the cycle life of the batteries according to Comparative Examples 1-1, 1-2 and 1-3. The conditions for the cycle test were made as follows: the charge and discharge was performed by
20 0.2C (electric current which was 0.2 times capacity/time), pause for 30 minutes and a cut-off voltage of 1.0V was applied. A charging/discharging apparatus HJ-101M6 manufactured by Hokuto Electric was used. The charge/discharge test was commenced at
25 discharge, the battery capacity was evaluated by the quantity of the third discharge and the cycle life was evaluated by the number of cycles when the battery capacity had deteriorated to 60% or less.

The cycle life of each battery with respect to the

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cycle life of the battery according to Comparative Example 1-1 which was made to be 1 was as shown in Table 1.

As can be understood from the results of
5 comparisons made between Examples 1-1 to 1-6 and Comparative Example 1-1, between Example 1-7 and Comparative Example 1-2 and between Example 1-8 and Comparative Example 1-3, the cycle life can
10 considerably be lengthened due to use of the foil made of the negative electrode active material according to the present invention and arranged in such a manner that the surface is covered with the film having an inorganic glass structure through which lithium ions can be
15 passed.

Table 1

Secondary Battery Manufactured		Cycle Life according to the present invention
Example	Comparative Example	Cycle Life according to Comparative Example
Example 1-1	Comparative Example 1-1	2.5
Example 1-2	Comparative Example 1-1	2.0
Example 1-3	Comparative Example 1-1	1.5
Example 1-4	Comparative Example 1-1	1.5
Example 1-5	Comparative Example 1-1	3.0
Example 1-6	Comparative Example 1-1	3.4
Example 1-7	Comparative Example 1-2	1.5
Example 1-8	Comparative Example 1-3	2.0

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Example 2-1

A flat battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was assembled to evaluate the characteristics of the secondary battery while evaluating the cycle life.

First, a peroxide benzoyl was, in an atmosphere of dry argon gas, dissolved in a toluene solution of poly (2-vinyl naphthalene) manufactured by Aldrich Chemical Company, Inc. Then, a lithium metal foil to which the stainless mesh collector 200 was pressed from the reverse side was immersed in it. Then, heat treatment at 100°C was performed so that a lithium electrode 201 covered with the poly (2-vinyl naphthalene) was manufactured.

The positive electrode active material 203 comprised a lithium-manganese composite oxide prepared by heat treatment subjected to a mixture of dehydrated electrolytic manganese dioxide and lithium carbonate and a graphite mixture. Then, tetrafluoroethylene polymer powder was mixed and then pressed against a titanium mesh as to be formed.

The electrolyte solution was prepared by dissolving, by 1 M (mol/l), arsenate hexafluoride lithium salt in an equal-quantity mixture solvent of propylene carbonate (PC) and dimethoxyethane (DME).

The separator 208 was formed by sandwiching a separator made of propylene and having small apertures by unwoven polypropylene sheets.

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Comparative Example 2-1

A lithium secondary battery was manufactured by a method similar to Example 2-1 except for that the metal lithium foil surface covering treatment according to Example 2-1 was omitted.

Example 2-2

A battery similar to that according to Example 2-1 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 2-1.

First, 0.03 M azobisisobutylnitryl was added to a 5M tetrahydrofuran solution of 9-vinyl anthracene, following by performing polymerization at 45°C so that a polymer solution was obtained. Then, the polymer solution was applied to lithium metal foil to which a titanium mesh collector was pressed followed by drying the polymer solution. Then, ultraviolet rays were applied so that a lithium electrode covered with the polyvinyl anthracene film was manufactured. Then, similar processes to those according to Example 2-1 were performed so that the lithium secondary battery was manufactured.

Example 2-3

A battery similar to that according to Example 2-1 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 2-1.

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First, 9, 10-antracene dipropionic acid and ethylene glycol of the same mol and a small quantity of zinc acetate were injected into a reaction chamber followed by dehydrating and condensing them at 200°C in an argon gas flow. Then, azobisisobutlonitryl was added, and the lithium metal foil to which a stainless steel mesh collector was pressed was immersed followed by taking out it. Then, it was heated to 100°C so that a film was formed on the surface of lithium. Then, similar processes to those according to Example 2-1 were performed so that the lithium secondary battery was manufactured.

Example 2-4

A battery similar to that according to Example 2-1 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 2-1.

Tantalum pentachloride was dissolved in toluene at 80°C, and a toluene solution of 5, 12-bis(phenylethynyl) naphthalene was added followed by polymerizing them at 80°C. An obtained polymer was cleaned with methyl alcohol, dried and again dissolved in toluene so that a film forming solution was prepared. Then, a lithium metal foil to which a stainless steel mesh collector was pressed was immersed, followed by raising it and drying the same. Then, electron beams were applied to crosslink the material so that a film was formed on the surface of lithium. Then, similar

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processes to those according to Example 2-1 were performed so that the lithium secondary battery was manufactured.

Example 2-5

5 A lithium secondary battery similar to that according to Example 2-1 was manufactured except that peroxide benzoyl was dissolved in a toluene solution of poly (2-vinyl naphthalene), and then arsenate hexafluoride lithium salt was added so that the film
10 forming solution was prepared.

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Example 2-6

A battery similar to that according to Example 2-1 was manufactured.

5 The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 2-1.

Felt-form carbon, which had been dehydrated and dried, was immersed in lithium dissolved in a stainless container, followed by cooling the same so that felt-
10 form carbon was manufactured. Then, it was immersed in a toluene solution of poly (2-vinyl naphthalene) to which azobisisobutyronitril was added, followed by raising the felt carbon. It was then dried at 80°C, irradiated with ultraviolet rays to be crosslinked so that the negative
15 electrode 201 was manufactured. Then, similar processes to those according to Example 2-1 were performed so that the lithium secondary battery was manufactured.

Evaluation of Performance of Lithium Secondary Battery

The performance of lithium secondary batteries
20 according to Examples 2-1 to 2-5 and Comparative Example 2-1 was evaluated. The evaluation was performed by a charge and discharge cycle test under the following conditions with respect to the cycle life of the batteries according to Comparative Example 2-1. The
25 conditions for the cycle test were made as follows: the charge and discharge was performed by 0.2C (electric current which was 0.2 times capacity/time), pause for 30 minutes and a cut-off voltage of 1.0V was applied. A charging/discharging apparatus HJ-101M6 manufactured by

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Hokuto Electric was used. The charge/discharge test was commenced at discharge, the battery capacity was evaluated by the quantity of the third discharge and the cycle life was evaluated by the number of cycles when the battery capacity had deteriorated to 60% or less.

The cycle life of each battery with respect to the cycle life of the battery according to Comparative Example 1-1 which was made to be 1 was as shown in Table 2.

As can be understood from the results of comparisons made between Examples 2-1 to 2-5 and Comparative Example 2-1, the cycle life can considerably be lengthened due to use of the negative electrode comprising the lithium foil covered with the polymer of the derivative of the aromatic hydrocarbon compound according to the present invention.

Table 2

Manufactured Lithium Battery	Cycle Life of Example / Cycle Life of Comparative Example
Comparative Example 2-1	1.0
Example 2-1	3.0
Example 2-2	1.5
Example 2-3	2.0
Example 2-4	3.0
Example 2-5	3.5
Example 2-6	3.7

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Example 3-1

A flat battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was assembled to evaluate the characteristics of the secondary battery while evaluating the cycle life.

First, a titanium mesh collector 200 was pressed from the reverse side of the lithium metal foil in an atmosphere of dry argon gas. Then, the lithium metal foil was immersed in a dioxane solution of tetrabutoxytitanium, followed by drying it so that the lithium electrode 201 having a film formed as described above was manufactured.

The positive electrode active material 203 was prepared in such a manner that a mixture of a dehydrated and electrolyzed manganese dioxide and a lithium carbonate were heated so that a lithium-manganese composite oxide was prepared. Then, tetrafluoroethylene polymer powder was mixed, and then it was pressed against a titanium mesh as to be formed as designed.

The electrolyte solution was prepared in such a manner that arsenate hexafluoride lithium salt was, by 1 M (mol/l) was dissolved in an equal quantity mixture solvent of propylene carbonate (PC) and dimethoxyethane (DME).

The separator 208 was manufactured in such a manner that a propylene separator having small apertures was sandwiched by unwoven polypropylene sheets.

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Comparative Example 3-1

A battery similar to that according to Example 3-1 was manufactured except that the metal lithium foil surface treatment was omitted.

5 Comparative Example 3-2

A battery similar to that according to Example 3-1 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 3-1. A solution in which peroxide benzoyl was added to a hexane solution of Tirano Coat (polytitanocarbosilane) manufactured by Ube Kosan was applied to a lithium metal foil to which a titan mesh collector was pressed, followed by drying it. Then, it was heated to 80°C, and then heated to 150°C so that a lithium electrode having a Tirano Coat film formed thereon was manufactured.

Then, similar processes to those according to Example 3-1 were performed so that the lithium secondary battery was manufactured.

Example 3-3

A battery similar to that according to Example 3-1 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 3-1.

First, 2, 4, 6-trimethyl-tris (3, 3, 3-trifluoropropyl)cyclotrisiloxane was heated to 76°C in an argon gas. Then, calcium silate catalyzer was added

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and polymerization was performed so that a polymer was obtained. Then, peroxide benzoyl was added to the polymer, and then a lithium metal foil to which the stainless steel mesh collector was pressed was immersed in the solution, and rayed from the solution. Then, heat treatment at 100°C was performed so that a lithium electrode having a polysiloxane film formed thereon was manufactured.

Then, similar processes to those according to Example 3-1 were performed so that the lithium secondary battery was manufactured.

Example 3-4

A battery similar to that according to Example 3-1 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 3-1.

First, azobisisobutyronitril was added to tetramethyldivinylidisiloxane, and then a lithium metal foil to which a stainless steel mesh collector was pressed was immersed, followed by raising it. Then, ultraviolet rays were applied so that a lithium electrode covered with the polysiloxane film was manufactured.

Then, similar processes to those according to Example 3-1 were performed so that the lithium secondary battery was manufactured.

Example 3-5

A battery similar to that according to Example 3-1

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was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 3-1.

5 A lithium secondary battery was manufactured similarly to Example 3-2 except that lithium was immersed in a solution in which arsenate hexafluoride lithium salt was added to a solution in which peroxide benzoyl was added to a hexane solution of Tirano Coat
10 (polytitanocarbosilane) manufactured by Ube Kosan.

Evaluation of Performance of Lithium Secondary Battery

The performance of lithium secondary batteries according to Examples 3-1 to 3-5 and Comparative Example 3-1 was evaluated. The evaluation was performed by a
15 charge and discharge cycle test under the following conditions with respect to the cycle life of the batteries according to Comparative Example 2-1. The conditions for the cycle test were made as follows: the charge and discharge was performed by 0.2C (electric
20 current which was 0.2 times capacity/time), pause for 30 minutes and a cut-off voltage of 1.0V was applied. A charging/discharging apparatus HJ-101M6 manufactured by Hokuto Electric was used. The charge/discharge test was commenced at discharge, the battery capacity was
25 evaluated by the quantity of the third discharge and the cycle life was evaluated by the number of cycles when the battery capacity had deteriorated to 60% or less.

The cycle life of each battery with respect to the cycle life of the battery according to Comparative

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Example 1-1 which was made to be 1 was as shown in Table 3.

As can be understood from the results of comparisons made between Examples 3-1 to 3-5 and Comparative Example 3-1, the cycle life can considerably be lengthened due to use of the negative electrode comprising the lithium foil covered with the organic metal compound according to the present invention.

Table 3

Manufactured Lithium Battery	Cycle Life of Example / Cycle Life of Comparative Example
Comparative Example 3-1	1.0
Example 3-1	3.0
Example 3-2	2.5
Example 3-3	1.5
Example 3-4	2.0
Example 3-5	3.0

10 Example 4-1

A flat battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was assembled to evaluate the characteristics of the secondary battery while evaluating the cycle life.

15 First, a titanium mesh collector 200 was pressed against the lithium metal foil from the reverse side in an atmosphere of dry argon. Then, the lithium metal foil

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was immersed in a teflon AF solution which was a copolymer of tetrafluoroethylene and 2, 2-bistrifluoromethyl - 4, 5 - difluoro-1, 3 - dioxysol and which was manufactured by Dupont, followed by bring the lithium metal foil. As a result, the lithium negative electrode 201 covered with amorphous fluororesin was manufactured. The positive electrode active material 203 comprised a lithium-manganese composite oxide prepared by heating a mixture of dehydrated and electrolyzed manganese dioxide and lithium carbonate and a mixture of graphite. Then, tetrafluoroethylene polymer powder was mixed, and pressed against the titanium mesh as to be formed as designed. The electrolyte solution was prepared by dissolving, by 1 M (mol/l), arsenate hexafluoride lithium salt in an equal quantity mixture solvent of propylene carbonate (PC) and dimethoxyethane (DME). The separator 208 was manufactured in such a manner that a propylene separator having small apertures was sandwiched by unwoven polypropylene sheets. The battery was assembled in such a manner that the separator 208 was held between the negative electrode 201 and the positive electrode 203, followed by inserting them into a positive electrode case 207 made of titanium clad stainless steel, followed by injecting the electrolyte solution. Then, the negative electrode cap 206 made of the titanium clad stainless steel and the insulating packing 210 made of fluorine rubber were used for sealing so that the lithium secondary battery was manufactured.

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Comparative Example 4-1

A lithium secondary battery was manufactured under the same conditions as those according to Example 4-1 except that the metal lithium foil surface covering
5 was omitted.

Example 4-2

A battery similar to that according to Example 4-1 was manufactured.

The preparation of materials and assembling of the
10 battery were performed in an atmosphere of dry argon similarly to Example 4-1. The lithium metal foil to which a titanium mesh collector was pressed was inserted into a chamber of a sputtering apparatus, and then retained gas was exhausted to a vacuum level of 5×10^{-6}
15 Torr. Then, argon gas was allowed to flow to control the internal pressure to 3×10^{-5} Torr followed by performing RF discharge to generate plasma for use in sputtering using Neoflon PFA which was a copolymer of tetrafluoroethylene and perfluoroalkylvinyl ether and
20 manufactured by Daikin as a target. As a result, a lithium electrode having a film formed thereon was manufactured. Then, similar processes to those according to Example 4-1 were performed so that the lithium secondary battery was manufactured.

Example 4-3

A battery similar to that according to Example 2-1 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon

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similarly to Example 4-1. The lithium metal foil to which a stainless steel mesh collector was pressed was inserted into a chamber of an RF (Radio Frequency) plasma CVD apparatus, and then the retained gas was exhausted to realize a vacuum level of 2×10^{-6} Torr. Then, vinylidene fluoride was introduced into the chamber, and isobutyl vinyl ether was introduced into the chamber while using hydrogen gas as the carrier gas. While controlling the internal pressure to 1 Torr, RF discharge was caused to take place so that a plasma polymer film was formed on the surface of lithium. Then, similar processes to those according to Example 4-1 were performed so that the lithium secondary battery was manufactured.

15 Example 4-4

A battery similar to that according to Example 4-1 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 4-1. A lithium secondary battery was manufactured similarly to Example 4-1 except that the titanium mesh collector was pressed from the reverse side, and then it was immersed in a xylene solution of Lumiflon which was a copolymer of tetrafluoroethylene and non-fluorine-type vinyl ether, which was manufactured by Asahi Glass and to which isocyanate and graphite powder were added. Then, it was dried at 140°C for 10 minutes so that the lithium electrode covered with the amorphous fluororesin was manufactured.

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Example 4-5

A battery similar to that according to Example 4-1 was manufactured.

5 The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 4-1. First, coating fluororesin was prepared. An automatic crepe having a stirring machine received 200 parts of pure water, 40 parts of vinyl fluoride, 60 parts of ethylvinyl ether, 0.6 parts of
10 perofluorocarboxylic acid, 0.2 parts of persulfuric ammonium and 3 parts of water. Then, the solution was heated to 46°C while maintaining the pressure at 42.5 atmosphere to perform polymerization for 8 hours. An obtained polymer was cleaned with hot methanol, followed
15 by drying it. Then, it was dissolved in tetrahydrofuran dehydrated sufficiently, followed by adding peroxide benzoyl. Then, the lithium metal foil to which a stainless steel mesh collector was pressed was immersed followed by raising it. Then, it was heated to 100°C so
20 that a lithium electrode covered with fluororesin was manufactured.

Then, similar processes to those according to Example 4-1 were performed so that the lithium secondary battery was manufactured.

25 Example 4-6

A battery similar to that according to Example 2-1 was manufactured.

First, a lithium electrode was manufactured. The lithium metal foil to which a stainless steel mesh

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collector was pressed was injected into a vacuum chamber of a parallel and flat type plasma CVD apparatus to which a 13.56 MHz high frequency power source was connected in such a manner that it was placed perpendicular to the parallel and flat electrode. Then, retained gas was exhausted to realize a vacuum level of 10^{-5} Torr. Then, 10 sccm of tetrafluoroethylene, 2 sccm of ethylene, 2 sccm of hydrogen, 1 sccm of helium and 1 sccm of oxygen were introduced into the vacuum chamber, which was a reaction chamber, and then the internal pressure was maintained at 0.8 Torr. Then, 200 watts of high frequency power was supplied to the parallel and flat electrode so that a plasma polymer film of the fluororesin was formed on the surface of lithium. By using the lithium electrode covered with the fluororesin prepared by the foregoing method so that a lithium secondary battery was manufactured by the similar processes to those according to Example 4-1.

Evaluation of Performance of Lithium Secondary Battery

The performance of lithium secondary batteries according to Examples 4-1 to 4-6 and Comparative Example 4-1 was evaluated. The evaluation was performed by a charge and discharge cycle test under the following conditions with respect to the cycle life of the batteries according to Comparative Example 4-1. The conditions for the cycle test were made as follows: the charge and discharge was performed by 0.2C (electric current which was 0.2 times capacity/time), pause for 30 minutes and a cut-off voltage of 1.0V was applied. A

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charging/discharging apparatus HJ-101M6 manufactured by Hokuto Electric was used. The charge/discharge test was commenced at discharge, the battery capacity was evaluate the quantity of the third discharge and the cycle life was evaluate by the number of cycles when the battery capacity had deteriorated to 60% or less.

The cycle life of each battery with respect to the cycle life of the battery according to Comparative Example 4-1 which was made to be 1 was as shown in Table 4.

As can be understood from the results of comparisons made between Examples 4-1 to 4-6 and Comparative Example 4-1, the cycle life can considerably be lengthened due to use of the negative electrode comprising the lithium foil covered with the fluororesin having the ether bond according to the present invention.

Table 4

Manufactured Lithium Battery	Cycle Life of Example / Cycle Life of Comparative Example 4-1
Comparative Example 4-1	1.0
Example 4-1	3.5
Example 4-2	1.5
Example 4-3	2.0
Example 4-4	3.0
Example 4-5	2.5
Example 4-6	1.5

Example 5-1

A flat battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was assembled to evaluate the characteristics of the secondary battery while evaluating the cycle life.

In an atmosphere of dried argon gas, the titanium mesh collecting electrode 200 was pressed to the reverse side of the lithium metal foil. Then, the lithium metal foil was immersed in a tetrahydrofuran solution of Cryptofix 222 B Polymer which was a large ring compound polymer and which was manufactured by E. Merch. Then, it was dried, and then heated to 150°C so that a lithium electrode 201 covered with the large ring compound polymer was manufactured.

The positive electrode active material comprised a

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lithium-manganese composite oxide prepared by heat treatment applied to a mixture of dehydrated and electrolyzed manganese dioxide and lithium carbonate and a mixture of graphite. Then, tetrafluoroethylene polymer was mixed, and then pressed against the stainless steel mesh as to be formed as designed.

The separator 208 was manufactured in such a manner that a propylene separator having small apertures was sandwiched by unwoven polypropylene sheets.

The electrolyte solution was prepared by dissolving, by 1 M (mol/l), arsenate hexafluoride lithium salt in an equal quantity mixture solvent of propylene carbonate (PC) and dimethoxyethane (DME). Assembling of the battery were performed similarly to Example 1-1.

Comparative Example 5-1

A lithium secondary battery was manufactured similarly to Example 5-1 except that the metal lithium foil surface covering was omitted.

20 Example 5-2

A battery similar to that according to Example 5-1 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 2-1. A lithium metal foil, to which a titanium mesh collector was pressed, was placed in acetonyl solution in which 0.1 M of a monomer of benzo-15-crown-5 and 0.2 M of boron tetrafluoride tetrabutylammonium salt as to be electrolyzed and

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polymerized with a voltage level of 3 V while using a platinum electrode as the cathode electrode. As a result, a lithium electrode having a large ring compound polymer film formed thereon was manufactured.

5 Then, similar processes to those according to Example 5-1 were performed so that the lithium secondary battery was manufactured.

Example 5-3

10 A battery similar to that according to Example 5-1 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 5-1. First, (+) - 18 - crown - 6 - tetracarboxylic acid (0.4 mol), 1, 4 - butanediol (0.8 mol), tetratitanate - n - butylester (0.08 g) and butylhydroxytinoxide (0.03 g) were mixed. Then, the temperature was maintained at 220°C, and distillation was performed for 60 minutes to remove products such as water. Then, the product and titanate tetra-n-butylester (0.02 g) were injected into an automatic crepe, and the pressure was lowered and heating to 250°C was performed for 22 hours so that a polymer was obtained.

25 Trylenediisocyanate was added to the thus obtained polymer, and then the lithium metal foil, to which a titanium mesh collector was pressed, was immersed. Then, the lithium metal foil was raised, and then it was heated, and dried at 80°C so that the surface of the lithium foil was covered with a large ring compound polymer.

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Then, similar processes to those according to Example 5-1 were performed so that the lithium secondary battery was manufactured.

Example 5-4

5 A battery similar to that according to Example 2-1 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 5-1. A lithium metal foil, to which
10 a titanium steel mesh collector was pressed, was immersed in a toluene solution of 3, 3'-dibenzyl - 1, 4, 8, 11 - tetraoxacyclotetradecan to which azobisisobutylnitryl and arsenate hexafluoride lithium salt were added. Then, the lithium metal was raised from
15 the solution, and then ultraviolet rays were applied to crosslinking so that the surface of the lithium metal foil was covered.

Then, similar processes to those according to Example 5-1 were performed so that the lithium
20 secondary battery was manufactured.

Example 5-5

A battery similar to that according to Example 2-1 was manufactured.

The preparation of materials and assembling of the
25 battery were performed in an atmosphere of dry argon similarly to Example 5-1. Styrene and 4, 7, 13, 16, 21, 24 - hexaoxa - 1, 10-diazobicyclo [8.8.8] hexakosan were dissolved in a tetrahydrofuran solution of naphthalene degasified and dehydrated sufficiently. Then, graphite

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powder was mixed. The lithium metal foil, to which a titanium mesh collector was pressed, was immersed to perform polymerization reaction, followed by drying as to be hardened. As a result, the surface of lithium was covered with a large ring compound polymer.

Then, similar processes to those according to Example 5-1 were performed so that the lithium secondary battery was manufactured.

Example 5-6

A battery similar to that according to Example 5-1 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry air. A porous nickel sheet manufactured by Osaka Gas was dehydrated and dried as to be used as an anode, while a platinum electrode was used as a cathode so that electrolytic polymerization was performed in an acetonitrile solution in which 0.1 M of benzo-18-crown-6 and 0.2 M of boron tetrafluoride tetrabutylammonia salt were dissolved. As a result, a porous nickel sheet covered with a crown ether polymer was manufactured. Then, an electrolyte solution was prepared in such a manner that 1M of boron tetrafluoride lithium salt was dissolved in an equal-quantity mixture solvent of propylene carbonate and dimethoxyethane. An obtained porous nickel sheet thus covered was used as a cathode and lithium metal was used as an anode. Then, lithium was inserted between the porous nickel sheet cover and the nickel as to be allowed to adhere so that the

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negative electrode 203 was formed.

Then, similar processes to those according to Example 5-1 were performed so that the lithium secondary battery was manufactured.

5 Example 5-7

A nickel-zinc battery having a similar structure as that of the battery according to Example 5-1 was manufactured.

10 First, paste was prepared by mixing polyvinyl alcohol, phthalocyanine zinc, zinc oxide powder, zinc powder, formaldehyde, formic acid and water. The paste was applied to a nickel mesh and heated so that the negative electrode 201 was manufactured.

15 Then, paste obtained by mixing nickel powder, cobalt powder, carboxylic cellulose serving as a bonding material, ethylene glycol and water with nickel hydroxide was injected into foamed nickel (Celmet) manufactured by Sumitomo Denko. Then, it was dried and pressed so that a positive electrode 203 was formed.

20 The separator 208 was formed in such a manner that a polyamide film subjected to hydrophilic treatment and having small apertures was sandwiched by unwoven polyamide sheets. The electrolyte solution was a 30 wt% potassium hydroxide solution. The assembly was performed
25 similarly to Example 5-1 so that a nickel-zinc secondary battery was manufactured.

Comparative Example 5-2

A nickel-zinc secondary battery was manufactured except that the negative electrode 201 was formed by

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applying paste obtained by mixing zinc oxide powder, zinc powder, polyvinyl alcohol and ethylene glycol to the nickel mesh followed by drying.

Example 5-8

5 A battery having a structure similar to that according to Example 5-1 was manufactured. However, a positive electrode case having small apertures for receiving oxygen in air was used.

10 The negative electrode 201 was manufactured in such a manner that paste was applied to a nickel mesh followed by heating to dry the negative electrode 201, the paste being obtained by mixing zinc oxide powder, zinc powder, polyacrylamide, water, formaldehyde, lithium hydroxide and phthalocyanine zinc.

15 The positive electrode 203 was formed in such a manner that a positive catalyzer layer was formed by adding manganese dioxide to active carbon, and a water repellent film made of polytetrafluoroethylene and cellulose dispersed paper were stacked on the positive
20 catalyzer layer.

 The separator 209 comprised a cellophane film and the electrolyte solution comprised 30 wt% solution of potassium hydroxide.

25 Assembling was performed in such a manner that the separator 208 was held between the negative electrode 201 and the positive electrode 203, and they were inserted into the positive electrode case 207 having small apertures for receiving oxygen in air and made of titanium clad stainless steel. Then, the electrolyte

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solution was injected and sealing was performed by using the negative electrode cap 206 made of titanium clad stainless steel and the insulating packing made of fluorine rubber. As a result, an air-zinc secondary battery was manufactured.

Comparative Example 5-3

An air-zinc secondary battery was manufactured similarly to Example 5-8 except that the negative electrode according to Comparative Example 5-2 was used.

Evaluation of Performance of Lithium Secondary Battery

The performance of lithium secondary batteries according to Examples 5-1 to 5-5 and Comparative Example 5-1 was evaluated. The evaluation was performed by a charge and discharge cycle test under the following conditions with respect to the cycle life of the batteries according to Comparative Example 1. The conditions for the cycle test were made as follows: the charge and discharge was performed by 0.2C (electric current which was 0.2 times capacity/time), pause for 30 minutes and a cut-off voltage of 1.0V was applied. A charging/discharging apparatus HJ-101M6 manufactured by Hokuto Electric was used. The charge/discharge test was commenced at discharge, the battery capacity was evaluate the quantity of the third discharge and the cycle life was evaluate by the number of cycles when the battery capacity had deteriorated to 60% or less.

The cycle life of each battery with respect to the cycle life of the battery according to Comparative Example 5-1 which was made to be 1 was as shown in Table

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2.

As can be understood from the results of comparisons made between Examples 5-1 to 5-6 and Comparative Example 2-1 and those between Example 5-7 and Comparative Example 5-3, the cycle life can considerably be lengthened due to use of the negative electrode comprising the lithium or zinc covered with the large ring compound polymer according to the present invention.

Table 5

Lithium Battery Manufactured		Cycle Life of Example / Cycle Life of Comparative Example
Example	Comparative Example	
Example 5-1	Comparative Example 5-1	3.0
Example 5-2	Comparative Example 5-1	2.5
Example 5-3	Comparative Example 5-1	3.5
Example 5-4	Comparative Example 5-1	4.0
Example 5-5	Comparative Example 5-1	3.0
Example 5-6	Comparative Example 5-1	4.2
Example 5-7	Comparative Example 5-2	2.8
Example 5-8	Comparative Example 5-2	2.7

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Example 6-1

A flat battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was assembled to evaluate the characteristics of the secondary battery while evaluating the cycle life. First, the titanium collector 200 was pressed against the reverse side of the lithium metal foil in an atmosphere of dry argon gas, and then the lithium metal foil was immersed in a toluene solution PPZ-U1001 manufactured by Idemitsu. Then, it was previously dried, and ultraviolet rays were applied so that the lithium electrode 201 covered with phosphazene was manufactured.

The positive electrode active material 204 was prepared in such a manner that a lithium-manganese composite oxide was prepared by heating a mixture of dehydrated and electrolyzed manganese dioxide and lithium carbonate. Then, tetrafluoroethylene polymer powder was mixed followed by pressing to a titanium mesh as to be formed as designed.

The electrolyte solution was prepared by dissolving, by 1 M (mol/l), arsenate hexafluoride lithium salt in an equal quantity mixture solvent of propylene carbonate (PC) and dimethoxyethane (DME). The separator 208 was manufactured in such a manner that a propylene separator having small apertures was sandwiched by unwoven polypropylene sheets.

Comparative Example 6-1

A lithium secondary battery was manufactured

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similarly to Example 6-1 except that the surface covering of the metal lithium foil was omitted.

Comparative Example 6-2

5 A battery similar to that according to Example 6-1 was manufactured. The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 6-1. First, hexachlorotriphosphazene was repeatedly degasified, melted and solidified, and then it was heated to 250°C
10 as to be polymerized so that polydichlorophosphazene was obtained. Then, a tetrahydrofuran solution of aniline was added to a benzene solution of polychlorophosphazene, followed by heating and refluxed. Then, the solution was allowed to stand to remove
15 aniline hydrochloride by filtering followed by again sedimented it and drying it. Then, it was again dissolved in tetrahydrofuran so that a solution of poly [bis (phenylamino)phosphazene] was prepared. Then, the foregoing solution was applied to the lithium metal
20 foil, to which a titanium mesh collector was pressed, followed by drying the solution. Then, ultraviolet rays were applied so that a lithium electrode covered with polyphosphazene was manufactured. Then, similar processes to those according to Example 6-1 were
25 performed so that the lithium secondary battery was manufactured.

Example 6-3

A battery similar to that according to Example 5-1 was manufactured. The preparation of materials

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and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 6-1. First, a benzene solution of polydichlorophosphazene was, while being stirred, slowly dropped in a tetrahydrofuran solution of sodium alkoxide of trifluoroethanol, followed by heating and refluxing it. Then, it was neutralized, filtered, cleaned with water and ethyl alcohol, and again sedimented with acetone and water, followed by drying. As a result, polybis (trifluoroethoxy) phosphazene was obtained. The acetone solution of the polyfluorokoxyphosphazene was applied to the lithium metal foil, to which a stainless steel mesh collector was pressed. Then, it was dried, and then irradiated with electron beams so that a lithium electrode covered with polyphosphazene was manufactured. Then, similar processes to those according to Example 6-1 were performed so that the lithium secondary battery was manufactured.

Example 6-4

A battery similar to that according to Example 5-1 was manufactured. The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 6-1. First, sodium alkoxide of naphthalene ethanol was, in dioxane, prepared from naphthalene ethanol and sodium hydroxide. Then, tetra-n-butyl ammonia bromide was added to the sodium alkoxide, and then a dioxane solution of polydichlorophosphazene was added while being dripped. The thus-obtained mixed was subjected to a heating

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reactions at 80°C, and the solvent was somewhat removed. Then, it was again sedimented with tetrahydrofuran and water, and then it was refined, followed by Soxhlet-extracting it. As a result, polydiphenoxyphosphazene was
5 obtained. Then, azoisobutylnitril was added to a tetrahydrofuran solution of the obtained polymer. Then, the lithium metal foil, to which a stainless steel mesh collector was pressed, was immersed and raised from it followed by drying it and subjecting to a heat treatment
10 set to 80°C. As a result, a lithium electrode covered with polyphosphazene was manufactured. Then, similar processes to those according to Example 6-1 were performed so that the lithium secondary battery was manufactured.

15 Example 6-5

A battery similar to that according to Example 5-1 was manufactured. The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 6-1. A
20 lithium secondary battery was manufactured similarly to Example 6-1 except that arsenate hexafluoride lithium salt was added to a toluene solution of PPZ-U1001 manufactured by Idemitsu, and then lithium was immersed in the thus-prepared solution.

25 Evaluation of Performance of Lithium Secondary Battery

The performance of lithium secondary batteries according to Examples 6-1 to 6-5 and Comparative Example 6-1 was evaluated. The evaluation was performed by a charge and discharge cycle test under the following

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conditions with respect to the cycle life of the batteries according to Comparative Example 6-1. The conditions for the cycle test were made as follows: the charge and discharge was performed by 0.2C (electric current which was 0.2 times capacity/time), pause for 30 minutes and a cut-off voltage of 1.0V was applied. A charging/discharging apparatus HJ-101M6 manufactured by Hokuto Electric was used. The charge/discharge test was commenced at discharge, the battery capacity was evaluate the quantity of the third discharge and the cycle life was evaluate by the number of cycles when the battery capacity had deteriorated to 60% or less. The cycle life of each battery with respect to the cycle life of the battery according to Comparative Example 6-1 which was made to be 1 was as shown in Table 6. As can be understood from the results of comparisons made between Examples 6-1 to 6-5 and Comparative Example 6-1, the cycle life can considerably be lengthened due to use of the negative electrode comprising the lithium or zinc covered with the large ring compound polymer according to the present invention.

Table 6

Manufactured Lithium Battery	Cycle Life of Example / Cycle Life of Comparative Example 2-1
Comparative Example 6-1	1.0
Example 6-1	2.0
Example 6-2	1.5
Example 6-3	2.0
Example 6-4	3.0
Example 6-5	2.5

Example 7-1

A flat battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was assembled. The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon.

First, the titanium mesh collector 200 having a lead was pressed against the reverse side of the lithium metal foil in an atmosphere of dry argon. Then, it was immersed in a nitromethane solution of acetyl cellulose to which azobisisobutylotryl and boron tetrafluoride lithium salt. Then, it was dried, and irradiated with ultraviolet rays so that a film was formed. As a result, the lithium negative electrode 201 was manufactured.

The positive electrode active material was prepared in such a manner that a lithium-manganese oxide was

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prepared by mixing electrolyzed manganese dioxide and lithium carbonate at a ratio of 1:0.4 and by heating the mixture at 800°C. Then, ketchen black and Super Konak, which is a fluoro-resin paint manufactured by Nihon Yushi
5 were mixed to the prepared lithium-manganese oxide. Then, it was pressed against a nickel mesh as to be formed as designed followed by performing heat treatment set to 170°C. As a result, the positive electrode 203 was manufactured.

10 The separator 208 was manufactured in such a manner that a porous layer-shape alumina film, an unwoven polypropylene sheet and polypropylene separator having small apertures were sandwiched.

The electrolyte solution was prepared by
15 dissolving, by 1 M (mol/l), tetrafluoride borate lithium salt in an equal quantity mixture solvent of propylene carbonate (PC) and dimethoxyethane (DME).

The assembly was performed in such a manner that the negative electrode 201, the positive electrode 203
20 and the separator 208 were sandwiched as to be inserted into the positive electrode case 207 made of titanium clad stainless steel, and then the electrolyte solution was injected. Then, sealing was performed by the negative cap 206 made of the titanium clad stainless
25 steel and the insulating packing 210 made of fluorine rubber so that a lithium secondary battery was manufactured.

Example 7-2

A battery similar to that according to Example 7-1

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and shown in Fig. 2 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 7-1.

5 A lithium secondary battery was manufactured by a method similar to that according to Example 7-1.

10 First, the titanium mesh collector 200 having a lead was pressed against the reverse side of the lithium metal foil in an atmosphere of dry argon gas. Then, it was immersed in a tetrahydrofuran solution of a polyethylene oxide to which peroxide benzoyl was added, and then it was dried at 110°C, and ultraviolet rays were applied so that a film was formed. As a result, the lithium negative electrode 201 was manufactured.

15 The positive electrode active material was prepared in such a manner that a lithium-manganese oxide was prepared by mixing electrolyzed manganese dioxide and lithium carbonate at a ratio of 1:0.4 and by heating the mixture at 800°C. Then, ketchen black and
20 tetrafluoroethylene polymer powder were mixed with the prepared lithium-manganese oxide. Then, it was pressed against a nickel mesh as to be formed as designed followed by performing heat treatment set to 250°C. As a result, the positive electrode 203 was manufactured.

25 The separator 208 was manufactured by sandwiching a unwoven polypropylene sheet and a polypropylene separator having small apertures.

The electrolyte solution was prepared by dissolving, by 1 M (mol/l), tetrafluoride borate lithium

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salt in a solvent of propylene carbonate (PC).

Then, similar processes to those according to Example 7-1 were performed so that the lithium secondary battery was manufactured.

5 Example 7-3

A battery similar to that according to Example 7-1 and shown in Fig. 2 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon
10 similarly to Example 7-1.

First, the lithium surface film was manufactured in such a manner that lithium foil to which the nickel mesh collector 200 was pressed was placed in a sputtering apparatus. Then, a degree of vacuum of 1.5×10^{-4} pascal
15 by lowering the pressure and by degasifying the inside of the sputtering apparatus. Then, argon gas was introduced by 5 sccm, and the internal pressure in the film forming chamber was maintained at 6×10^{-1} pascal to perform sputtering while using polyether sulfon as a
20 target so that the lithium negative electrode 201 covered with chitosan having a thickness of 500 Å was obtained.

Then, similar processes to those according to Example 7-2 were performed so that the lithium secondary
25 battery was manufactured.

Example 7-4

Under the same conditions as those according to Example 7-3 except that lithium foil to which the nickel mesh collector 200 was pressed was placed in a

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sputtering apparatus. Then, a degree of vacuum of 1.5×10^{-4} pascal by lowering the pressure and by degasifying the inside of the sputtering apparatus. Then, argon gas was introduced by 5 sccm, and the internal pressure in the film forming chamber was maintained at 6×10^{-1} pascal to perform sputtering while using chitosan as a target so that the lithium negative electrode 201 covered with chitosan having a thickness of 1000 Å was obtained.

10 Then, similar processes to those according to Example 7-2 were performed so that the lithium secondary battery was manufactured.

Example 7-5

15 A flat nickel-zinc secondary battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was manufactured.

The negative electrode was manufactured in such a manner that ethylene tetrafluoride polymer powder serving as a bonding material was added to a mixture of zinc powder and zinc oxide powder as to be pressed against the two sides of a copper punching metal plate so that the negative electrode was formed. The negative electrode was immersed in an acetone-ethylalcohol solution of acetyl cellulose to which azobisisobutyronitril was added, and then it was dried and heated to 110°C. Then, ultraviolet rays were applied so that a film was formed. As a result, the zinc negative electrode 201 was manufactured.

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The positive electrode 203 was manufactured in such a manner that nickel hydroxide was impregnated in a sintered nickel electrode plate and it was covered with an acetylcellulose film similarly to the negative
5 electrode.

The separator 208 was manufactured in such a manner that a hydrophilic unwoven nylon sheet and a nylon film having small apertures were sandwiched.

The electrolyte solution comprised 30 wt% potassium
10 hydroxide water solution to which lithium hydroxide was added.

The battery was assembled similarly to Example 7-1.

Example 7-6

A flat nickel-zinc secondary battery which
15 had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was manufactured.

Under the same conditions as those according to Example 7-5 except that the formed zinc negative
20 electrode was placed in a sputtering apparatus, and the inside pressure was lowered to a degree of vacuum of 1.5×10^{-4} Pascal by lowering and degasifying the inside. Then, argon gas was introduced by 5 sccm, and the internal pressure in the film forming chamber was
25 maintained at 6×10^{-1} Pascal. Then, sputtering was performed while using collagen as a target so that a zinc negative electrode covered with collagen having a thickness of 1000 Å was obtained.

The positive electrode 203 was manufactured by

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impregnating nickel hydroxide into a sintered nickel electrode plate.

Then, similar processes to those according to Example 2-1 were performed so that the nickel-zinc secondary battery was manufactured.

In order to evaluate the performance of the batteries according to the foregoing Examples, batteries according to Comparative Examples were manufactured.

Comparative Example 7-1

A lithium secondary battery was manufactured by a method similar to Example 7-2 except that the surface of the metal lithium foil was not covered.

Comparative Example 7-2

A nickel-zinc secondary battery was manufactured by a method similar to Example 7-6 except that the surface of the zinc negative electrode was not covered.

Evaluation of Performance of Lithium Secondary Battery

The performance of lithium secondary batteries and nickel-zinc secondary batteries according to Examples and Comparative Examples was evaluated. The evaluation was performed by a charge and discharge cycle test under the following conditions with respect to the cycle life of the batteries according to Comparative Examples.

The conditions for the cycle test were made as follows: the charge and discharge was performed by 0.2C (electric current which was 0.2 times capacity/time), pause for 30 minutes and a cut-off voltage of 1.0V was applied. A charging/discharging apparatus HJ-101M6 manufactured by Hokuto Electric was used: The

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charge/discharge test was commenced at discharge, the battery capacity was evaluate the quantity of the third discharge and the cycle life was evaluated by the number of cycles when the battery capacity had deteriorated to 60% or less.

The cycle life of batteries according to Examples of the present invention with respect to the cycle life of the batteries according to Comparative Examples which was made to be 1.0 was as shown in Table 7.

Table 7

Lithium Battery Manufactured		Cycle Life of Example / Cycle Life of Comparative Example
Example	Comparative Example	
Example 7-1	Comparative Example 7-1	3.6
Example 7-2	Comparative Example 7-1	1.7
Example 7-3	Comparative Example 7-1	1.3
Example 7-4	Comparative Example 7-1	1.6
Example 7-5	Comparative Example 7-2	1.8
Example 7-6	Comparative Example 7-2	1.4

10

As can be understood from the results of comparisons made between Examples 7-1 to 7-4 and Comparative Example 7-1 and those between Example 7-5 and Comparative Example 7-2, the cycle life can

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considerably be lengthened due to use of the secondary battery according to the present invention.

Example 8

5 A battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was manufactured.

10 First, an RF (Radio Wave Frequency) discharge plasma processing apparatus having a structure schematically shown in Fig. 6 was used to apply surface treatment to a lithium negative electrode. In an atmosphere of dry argon gas, a nickel mesh collector was pressed against the reverse side of the lithium metal foil. In order to protect the surface of lithium, a polyester film was interposed at the time of coiling
15 them. The coil-shape lithium foil 400 was mounted on a conveyance roll 407 of the plasma processing apparatus, and then the retained gas was exhausted to realize a degree of vacuum of 2×10^{-6} Torr. Then, 20 sccm of nitrogen gas and 10 sccm of argon gas were introduced to
20 a plasma processing chamber 405 through a gas introduction pipe 406. While controlling the internal pressure in the plasma processing chamber to 0.5 Torr, waves having a high frequency of 13.56 MHz were supplied by 200 watts to cause discharge to take place. Then, a
25 winding roll 408 was used to hold and take up the protection film comprising the polyester film so that the surface of lithium was plasma-treated. Then, the lithium foil subjected to the plasma treatment was cut so that a negative electrode was manufactured. The

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protection film to be interposed at the time of the winding operation in the plasma process, a separator for a battery may be used.

The positive electrode active material 203 was prepared in such a manner that a lithium-manganese oxide was prepared by mixing electrolyzed manganese dioxide and lithium carbonate at a ratio of 1:0.4 and by heating the mixture at 850°C. Then, graphite and tetrafluoroethylene polymer powder were mixed to the prepared lithium-manganese oxide. Then, it was pressed against a nickel mesh as to be formed into a desired positive electrode.

The electrolyte solution was prepared by dissolving, by 1 M (mol/l), tetrafluoroborate lithium salt in an equal quantity mixture solvent of propylene carbonate (PC) and dimethoxyethane (DME).

The separator 208 was manufactured in such a manner that a polypropylene separator having small apertures was sandwiched by unwoven polypropylene sheets.

20 Example 9

A battery similar to that according to Example 8 and shown in Fig. 2 was manufactured.

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon similarly to Example 8.

A lithium secondary battery was manufactured by a method similar to that according to Example 8.

First, a microwave discharge plasma processing apparatus having a structure schematically shown in Fig.

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7 was used to apply surface treatment to a lithium negative electrode. In an atmosphere of dry argon gas, a nickel mesh collector was pressed against the reverse side of the lithium metal foil, and then disposed on a sheet processing substrate holder 501 followed by injecting them in a load chamber 508 of the microwave discharge plasma processing apparatus. Then, the retained gas in the load chamber 508 was exhausted to realize a degree of vacuum of 1×10^{-6} Torr. Then, a gate valve 509 was opened, and the substrate holder was conveyed to the plasma processing chamber 502 and the gate valve 509 was closed. Then, 10 sccm of carbon tetrafluoride gas and 5 sccm of hydrogen gas were introduced into the plasma processing chamber 502 through the gas introduction pipe 504. While controlling the internal pressure in the plasma processing chamber to 0.01 Torr, microwaves having a frequency of 2.45 GHz were supplied by 100 watts through a wave guide pipe 506 and a microwave introduction window 505 to cause discharge to take place. As a result, the surface of lithium was plasma-processed. The lithium foil plasma-processed was used as the negative electrode.

Then, similar processes to those according to Example 8 were performed so that the lithium secondary battery was manufactured.

Example 10

Under the same conditions as those according to Example 9 except that 10 sccm of gas of nitrogen trifluoride was, as the lithium surface treatment

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gas, introduced through the gas introduction pipe 504 in place of the 10 sccm of the carbon tetrafluoride gas and the 5 sccm of the hydrogen gas. As a result, the surface of lithium was processed similarly to Example 9. Then, similar processes to those according to Example 8 were performed so that the lithium secondary battery was manufactured.

Example 11

Under the same conditions as those according to Example 8 except that 5 sccm of chlorine trifluoride gas, 2 sccm of oxygen gas and 100 sccm of helium gas were, as the lithium surface treatment gas, introduced through the gas introduction pipe 504 in place of the 5 sccm of chlorine trifluoride gas and 2 sccm of oxygen gas. Then, the surface of lithium was processed while omitting discharge.

Then, similar processes to those according to Example 8 were performed so that the lithium secondary battery was manufactured.

In order to compare and evaluate the performance of the batteries according to the foregoing Examples, the following comparative battery was manufactured.

Comparative Example 8

A lithium secondary battery was manufactured similarly to Example 8 except that the metal lithium foil, to which the nickel mesh was pressed, was, as it is, used as the negative electrode.

Evaluation of Performance of Secondary Battery

The performance of lithium secondary batteries

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according to Examples and Comparative Example was evaluated. The evaluation was performed by a charge and discharge cycle test under the following conditions with respect to the cycle life of the batteries according to Comparative Example.

The conditions for the cycle test were made as follows: the charge and discharge was performed by 0.2C (electric current which was 0.2 times capacity/time), pause for 30 minutes and a cut-off voltage of 1.0V was applied. A charging/discharging apparatus HJ-101M6 manufactured by Hokuto Electric was used. The charge/discharge test was commenced at discharge, the battery capacity was evaluated the quantity of the third discharge and the cycle life was evaluated by the number of cycles when the battery capacity had deteriorated to 60% or less.

The cycle life of batteries according to Examples of the present invention with respect to the cycle life of the battery according to Comparative Example which was made to be 1.0 was as shown in Table 8.

As can be understood from the results of comparisons made between Examples 8 to 11 and Comparative Example 8, the cycle life can considerably be lengthened due to use of the secondary battery according to the present invention.

Table 8

Lithium Battery Manufactured	Cycle Life of Example / Cycle Life of Comparative Example 8
Comparative Example 8	1.0
Example 8	2.5
Example 9	2.0
Example 10	3.0
Example 11	1.7

Example 12

A liquid-rich test cell similar to the apparatus shown in Fig. 1 was used to conduct tests.

5 The preparation of materials and assembly of the battery were performed in an atmosphere of dry Ar. Lithium metal foil, to which a titanium collector was pressed, was inserted into the chamber of an RF plasma CVD apparatus. Then, the retained gas was exhausted to
10 realize a degree of vacuum of 2×10^{-6} Torr. Then, tetrafluoroethylene, ethylene, hydrogen, helium and oxygen were introduced into the chamber, and the internal pressure was maintained at 0.8 Torr. Then, high frequency power of 200 watts was supplied to a parallel
15 and flat electrode so that a plasma polymer film of fluoro-resin was formed on the foregoing sample to have a thickness of 100 Å. Then, acetylene gas was, as raw material gas, introduced into the chamber, and the pressure in the chamber was controlled to 0.1 Torr, and

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then RF discharge was performed so that a carbon film was formed on the surface of lithium to have a thickness of 200 Å so that a sample negative electrode was manufactured (see Fig. 9A) .

5 The positive electrode active material was prepared by heating a mixture of dehydrated and electrolyzed manganese dioxide, lithium carbonate and black lead. The lithium-manganese composite oxide was mixed with tetrafluoroethylene polymer powder, and then it was
10 pressed against titanium mesh to be formed into a desired positive electrode.

The separator was manufactured by sandwiching a polypropylene separator having small apertures and unwoven polypropylene sheets.

15 The electrolyte solution was prepared by dissolving 1 M of arsenate hexafluoride lithium salt in an equal-quantity mixture solvent of propylene carbonate and dimethoxyethane.

20 A lithium secondary battery was manufactured as shown in Fig. 1.

Example 13

25 Under the same conditions as those according to Example 12 except that lithium metal foil covered with a plasma polymer film of fluorine resin was inserted into the chamber of the RF plasma CVD apparatus. Then, the retained gas was exhausted to realize a degree of vacuum of 2×10^{-6} Torr. Monosilane gas was, as the raw material gas, introduced into the chamber, and then the pressure in the chamber was controlled to 0.1 Torr.

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Then, RF discharge was performed so that an amorphous silicon film was formed on the surface of the lithium metal foil to have a thickness of 100 Å as to be used as a sample electrode. A battery similar to that according to Example 12 was manufactured except that the foregoing sample electrode was used as the negative electrode.

Example 14

Petroleum type pitch was spinned by a flow method, and subjected to heat treatment in an atmosphere of inactive gas so that black lead fiber having a specific area of 10 m²/g was obtained. By heating the fiber to completely remove water, and dispersed in toluene dehydrated by molecular sieves as to be applied to the lithium metal foil. Then, the material was dried and pressed by a pressing machine so that a sample was obtained (comprised a fiber layer having a thickness of 50 μm). Then, a titanium mesh collector was pressed against the reverse side of the sample so that a negative electrode was obtained. A battery similar to that according to Example 12 was manufactured except that the foregoing negative electrode was used as the negative electrode.

Example 15

A solution in which Lumifron, which was fluoro-resin paint manufactured by Asahi Glass, and lithium hexafluoride salt were dissolved was applied to the surface of the separator, and then it was pressed. A battery similar to that according to Example 12 was manufactured except that the separator was disposed as

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shown in Fig. 9F.

Example 16

A battery was manufactured under the same conditions as those according to Example 12 except that
5 black lead fiber having a specific area of $10 \text{ m}^2/\text{g}$ or more was paper-made and thus-obtained black lead paper (having a thickness of $200 \text{ }\mu\text{m}$) was disposed between the negative electrode and the separator as shown in Fig. 9B.

10 Example 17

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon. Lithium metal foil, to which a titanium mesh collector was pressed, was inserted into the chamber of an RF
15 plasma CVD apparatus. Then, the retained gas was exhausted to realize a degree of vacuum of 2×10^{-6} Torr. A hexane solution of acetylacetonate complex of nickel was used as the material, and it was bubbled with hydrogen gas as to be introduced into the chamber. The pressure
20 in the chamber was controlled to 1 Torr, and RF discharge was performed so that a nickel film was formed on the surface of the metal foil to have a thickness of 200 \AA as to be served as a sample electrode. A battery was manufactured under the same conditions as those
25 according to Example 12 except that the foregoing sample electrode was used as the negative electrode.

Example 18

RF discharge was performed under the same conditions as those according to Example 17 except that

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oxygen gas was used as the material together with the hexane solution of acetylacetonate complex of nickel. As a result, a nickel oxide film was formed on the surface of the lithium metal foil to have a thickness of 50 Å to
5 serve as a sample electrode. A battery was manufactured under the same conditions as those according to example 12 except that the foregoing sample electrode was used as the negative electrode.

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Example 19

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon. Lithium metal foil, to which a titanium mesh collector was pressed, was inserted into the chamber of the RF plasma CVD apparatus. Then, the retained gas was exhausted to realize a degree of vacuum of 2×10^{-6} Torr. Monosilane gas and ammonia gas were, as raw material gas, introduced into the chamber, and then the pressure in the chamber was controlled to 0.1 Torr to perform RF discharge. As a result, a silicon nitride film was formed on the lithium metal foil to have a thickness of 200 Å as to be serve as a sample electrode. A battery was manufactured under the same conditions as those according to Example 12 except that the foregoing sample electrode was used as a negative electrode.

Example 20

The RF discharge was performed under the same conditions as those according to Example 17 except that methane gas was used as the raw material together with the hexane solution of acetylacetonate complex of titanium. As a result, a composite film of titanium and carbon was formed on the surface of the lithium metal foil to have a thickness of 250 Å to serve as a sample electrode. A battery was manufactured under the same conditions as those according to example 12 except that the foregoing sample electrode was used as the negative electrode.

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Example 21

A polypropylene separator was inserted into the chamber of the RF plasma CVD apparatus. Then, the retained gas was exhausted to realize a degree of vacuum of 2×10^{-6} Torr. Acetylene gas was introduced into the chamber, and then the pressure in the chamber was controlled to 0.1 Torr and RF discharge was performed. As a result, a carbon film was formed on the surface of the separator to have a thickness of 200 Å. A battery was manufactured under the same conditions as those according to example 12 except that the foregoing separator was used and disposed as shown in Fig. 9F.

Example 22

Under the same conditions as those according to Example 21 except that monosilane gas was used as the raw material gas to cover the separator with an atmosphere silicon film. A battery was manufactured under the same conditions as those according to example 12 except that the separator was used and disposed as shown in Fig. 9F.

Example 23

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon. A polypropylene separator was inserted into the chamber of the RF plasma CVD apparatus. Then, the retained gas was exhausted to realize a degree of vacuum of 10^{-5} Torr. Then, tetrafluoroethylene ethylene, H_2 , helium and oxygen were introduced into the chamber, and the internal pressure was maintained at 0.8 Torr. High frequency

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power was, by 200 watts, supplied to a parallel and flat electrode so that a plasma polymer film of fluororesin was formed on the separator. Then, acetylene gas was, as the raw material gas, introduced into the chamber, and
5 the internal pressure in the chamber was controlled to 0.1 Torr to perform RF discharge. As a result, a carbon film was formed to have a thickness of 200 Å. A battery was manufactured under the same conditions as those according to example 12 except that the foregoing
10 separator was used and disposed as shown in Fig. 9G.

Example 24

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon. A fluororesin film having micropores was inserted into the
15 chamber of the RF plasma CVD apparatus. Then, the retained gas was exhausted to realize a degree of vacuum of 2×10^{-6} Torr. A hexane solution of acetylacetonate complex of nickel was, as the raw material, used as to be bubbled with hydrogen gas as to be introduced into
20 the chamber. The pressure in the chamber was controlled to 1 Torr to perform RF discharge so that a nickel film was formed on the surface of the separator to have a thickness of 300 Å. A battery was manufactured under the same conditions as those according to example 12 except
25 that the foregoing film was used and disposed as shown in Fig. 19C.

Example 25

Under the same conditions as those according to Example 24 except that monosilane gas was used as the

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raw material gas to form an amorphous silicon film on the fluoro-resin film having micropores. A battery was manufactured under the same conditions as those according to example 12 except that the foregoing film was used and disposed as shown in Fig. 9C.

Example 26

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon. Lithium metal foil, to which a titanium mesh collector was pressed, was inserted into the chamber of the RF plasma CVD apparatus. Then, the retained gas was exhausted to realize a degree of vacuum of 2×10^{-6} Torr. Monosilane gas and acetylene gas were, as the raw material gas, introduced into the chamber, and then the pressure in the chamber was controlled to 0.1 Torr to perform RF discharge. As a result, the surface of the lithium metal foil was covered with silicon carbide film having a thickness of 300 Å to serve as a sample electrode. A battery was manufactured under the same conditions as those according to example 12 except that the foregoing sample electrode was used as the negative electrode.

Example 27

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon. Lithium metal foil, to which a titanium mesh collector was pressed, was inserted into the chamber of the RF plasma CVD apparatus. Then, the retained gas was exhausted to realize a degree of vacuum of 5×10^{-6} Torr.

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Then, Ar gas was allowed to flow to make the inside of the chamber to be an inactive atmosphere. Then, the pressure in the chamber was lowered to 3×10^{-3} Torr, and black lead and Si were used as the target for use in the RF discharge. Sputtering of Si was commenced at the initial stage of the discharge and the proportion of black lead sputtering was gradually raised so that a composite layer of carbon and Si was formed on the surface of the lithium metal foil to have a thickness of 300 Å to serve as a sample electrode. A battery was manufactured under the same conditions as those according to example 12 except that the foregoing sample electrode was used as the negative electrode.

Example 28

A battery was manufactured under the same conditions as those according to example 27 except that black lead, Si and polytetrafluoroethylene were used as target and the thus-formed composite film was stacked on the surface of the lithium metal foil.

Example 29

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon. The sample according to Example 12 was inserted into the chamber of the RF plasma CVD apparatus. Then, the retained gas was exhausted to realize a degree of vacuum of 10^{-5} Torr. Then, tetrafluoroethylene ethylene, hydrogen, helium and oxygen were introduced into the chamber, and the internal pressure was maintained at 0.8 Torr. Then, high frequency power was, by 200 watts,

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supplied to a parallel and flat electrode to form a plasma polymer film of fluoro-resin on the foregoing sample so that a sample electrode was obtained. A battery was manufactured under the same conditions as those according to example 12 except that the foregoing sample electrode was used as the negative electrode.

Example 30

The preparation of materials and assembling of the battery were performed in an atmosphere of dry argon. Lithium metal foil, to which a titanium mesh collector was pressed, was inserted into the chamber of sputtering apparatus. Then, the retained gas was exhausted to realize a degree of vacuum of 5×10^{-6} Torr. Ar gas was allowed to flow to make the inside of the chamber to be an inactive atmosphere. Then, pressure in the chamber was lowered to 3×10^{-3} Torr, and black lead and LiAsF_6 were used as the targets to perform RF discharge. As a result, carbon and LiAsF_6 were formed on the surface of the lithium metal foil to have a thickness of 300 Å so that a sample electrode was obtained. A battery was manufactured under the same conditions as those according to example 12 except that the foregoing sample electrode was used as the negative electrode.

Example 31

The separator according to Example 21 and covered with carbon was used, and a fluoro-resin film having micropores was stacked on the coated carbon as shown in Fig. 9H. A battery was manufactured under the same conditions as those according to example 12 except that

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the foregoing film was used.

Example 32

The spiral and cylindrical battery shown in Fig. 3 was used in the test, the battery being KR-A type
5 battery having a contour of 17.0 mm and 50.5 mm high.

Paste obtained by, together with ethylene glycol, kneading zinc oxide and metal zinc serving as the main active material and polyvinyl alcohol serving as the bonding material was applied to an iron plate applied
10 with nickel plating having apertures. Then, drying and pressing were performed so that a zinc electrode plate was obtained.

The zinc electrode plate was inserted into the chamber of the RF plasma CVD apparatus to perform RF
15 discharge in such a manner that the proportion of tetrafluoroethylene was high in the initial stage of the discharge process and the proportions of acetylene and oxygen were raised in the following stage of the discharge process. As a result, a fluororesin film
20 having a thickness of 200 Å was formed on the surface of the zinc electrode plate so that a sample electrode was obtained.

The positive electrode plate was manufactured in such a manner that paste was obtained by kneading a
25 solution in which nickel and cobalt were added to nickel hydroxide and carboxydimethyl cellulose serving as a bonding material, and water was added to the kneaded solution. The paste was injected into foamed metal (Celmet manufactured by Sumitomo Denko), and it was

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dried and pressed.

A separator (Cell Guard manufactured by Cellanese) was used which was manufactured by integrating a film having small apertures and unwoven polypropylene sheet.

5 The electrolyte solution comprised 30 wt% potassium solution.

Assembly was performed in such a manner that a wound group in which a separator was interposed between the negative electrode and the positive electrode was
10 inserted into a battery case made of titanium clad stainless steel. Then, the electrolyte solution was injected, and the negative electrode cap made of titanium stainless steel and an insulating packing made of fluorine rubber were inserted and they were caulked
15 so that a nickel-zinc secondary battery was manufactured.

Example 33

The flat type battery shown in Fig. 2 was used to conduct the test.

20 Tetrafluoroethylene polymer powder was mixed to zinc oxide and metal zinc, and then was pressed against a nickel mesh as to be formed into a zinc electrode plate. The zinc negative electrode was inserted into chamber of the RF plasma CVD apparatus, and then
25 fluororesin having a thickness of 50 Å and carbon having a thickness of 200 Å were formed on the surface of the zinc electrode plate so that a negative electrode was formed.

A positive electrode catalyzer layer was formed by

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adding manganese dioxide to active carbon. Then, a water
repellant film made of polytetrafluoroethylene and
dispersed paper made of cellulose were stacked on the
positive electrode catalyzer layer so that a positive
5 electrode was formed. A separator made of cellophane and
30 wt% potassium hydroxide serving as the electrolyte
solution were employed.

Assembly was performed in such a manner that a
separator was interposed between the negative electrode
10 and the positive electrode and they were inserted into a
battery case made of stainless steel and having small
apertures. Then, the electrolyte solution was injected,
and then a negative electrode cap made of titanium clad
stainless steel and an insulating packing made of
15 fluorine rubber were used to perform sealing. As a
result, an air-zinc secondary battery was manufactured.

Comparative Example 12

A battery was manufactured under the same
conditions as those according to example 12 except that
20 a negative electrode, which comprised lithium metal foil
having no carbon film, was used.

Comparative Example 13

A battery was manufactured under the same
conditions as those according to example 31 except that
25 a negative electrode, which comprised a zinc electrode
plate which was not covered with the composite film of
the fluororesin and carbon, was used.

Comparative Example 14

A battery was manufactured under the same

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conditions as those according to example 33 except that a negative electrode, which comprised a zinc electrode plate which was not covered with the composite film of the fluoro-resin and carbon, was used.

5 The batteries respectively according to Examples 12 to 31 and Comparative Example 12 were charged with a current of 0.2 C to a level of 4.0 V, then paused for 30 minutes, and then discharged with a current of 0.2 C to a level of 2.8 V. The foregoing test was repeated,
10 resulting in as shown in Table 9.

 The batteries respectively according to Examples 32 and 33 and Comparative Examples 13 and 14 were charged with a current of 0.2 C to 150 %, then paused for 30 minutes, and then discharged with a current of 0.2 C to
15 1.0 V.

 The results of the cycle life tests of the respective Examples with respect to Comparative Examples are shown in Table 9 while making the cycle life of the batteries according to Comparative Examples 12 to 14 to
20 be 1. As can be understood from the results shown in Table 9, the charge/discharge cycle life can significantly be lengthened as compared with Comparative Examples when a single layer, a multi-layer or a composite layer is disposed between the negative
25 electrode and the separator, the single layer, the multi-layer or the composite layer being the conductor layer made of carbon or nickel or titanium, the semiconductor layer made of silicon or the metal oxide, and the insulating layer made of the halide, nitride,

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carbide or the organic polymer (according to respective Examples).

Table 9

Manufactured Secondary Battery		Cycle Life of Example
Examples	Comparative Examples	Cycle Life of Comparative Example
Example 12	Comparative Example 12	2.5
Example 13	Comparative Example 12	2.1
Example 14	Comparative Example 12	1.5
Example 15	Comparative Example 12	1.3
Example 16	Comparative Example 12	1.3
Example 17	Comparative Example 12	2.2
Example 18	Comparative Example 12	2.3
Example 19	Comparative Example 12	2.0
Example 20	Comparative Example 12	2.1
Example 21	Comparative Example 12	1.6
Example 22	Comparative Example 12	1.5
Example 23	Comparative Example 12	1.7
Example 24	Comparative Example 12	1.5
Example 25	Comparative Example 12	1.5
Example 26	Comparative Example 12	2.2
Example 27	Comparative Example 12	2.1
Example 28	Comparative Example 12	2.2
Example 29	Comparative Example 12	2.0
Example 30	Comparative Example 12	2.6
Example 31	Comparative Example 12	1.6
Example 32	Comparative Example 13	2.2
Example 33	Comparative Example 14	2.2

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Example 34

A polysiloxane film was formed by the following method.

As the film forming compound, 0.05 M (mol/l) an
5 amphipathic compound N-[b-(trimethylammonio)
ethyloxybenzoyl]-didodecyl-L-glutamic acid bromide and
0.15 M of trimethoxymethyl silane were processed with
supersonic waves for 3 minutes as to be dispersed in
water. The dispersion solution was developed on a
10 tetrafluoroethylene polymer sheet (Goatex manufactured
by Japan Goa Tex) and allowed to stand at 25°C and 60%
relative humidity for 3 days so that a multi-layer
bimolecular film was obtained. The film was treated with
ammonia gas in a sealed glass container to hydrolyze and
15 condense the methoxysilane group. Ethyl alcohol was used
to extract and remove the amphipathic compound so that a
polysiloxane film was obtained on the Goa Tex sheet.

Manufacturing of Secondary Battery

A lithium secondary battery which had a simple
20 structure, which could be assembled simply and which had
a cross sectional shape schematically shown in Fig. 2
was manufactured.

The positive electrode active material 203 was
prepared in such a manner that electrolyzed manganese
25 dioxide and lithium carbonate were mixed at a ratio of
1:0.4, and then heated at 800°C so that a lithium-
manganese oxide was prepared. Then, graphite and
tetrafluoroethylene polymer powder were mixed to the
prepared lithium-manganese oxide, and then pressed

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against a nickel mesh as to be formed into the positive electrode.

Then, silica sol dispersion ethyl alcohol (manufactured by Shokubai Kasei) was mixed in water in which N-[β -(trimethylammonio)ethyloxybenzoyl]-didodecyl-L-glutamic acid bromide, which was the film forming compound, was dispersed. The positive electrode was dipped in the foregoing dispersion solution, dried at room temperature, further dried at 80°C, and cleaned with hexane to remove the film forming compound. Then, it was dried at 250°C in a vacuum atmosphere so that the positive electrode 203 covered with the multi-layer silica film was manufactured.

In an atmosphere of dry argon gas, titanium mesh collector 200 was pressed against the reverse side of the lithium metal foil, and then the lithium metal foil was immersed in a solution of Lumiflon, which was a copolymer of ethylene tetrafluoride and vinyl ether and which was manufactured by Asahi Glass, and then dried as to be hardened. As a result, the lithium negative electrode 201 covered with fluororesin was manufactured.

The electrolyte solution was prepared by dissolving, by 1 M (mol/l), boron tetrafluoride lithium salt in an equal quantity mixture solvent of propylene carbonate (PC) and dimethoxyethane (DME).

The separator 208 comprised a composite member of the polysiloxane film prepared as described above and the Goa Tex sheet.

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Assembly was performed in such a manner that the separator 208 was interposed between the negative electrode 201 and the positive electrode 203 as to be inserted into the positive electrode case 207 made of titanium clad stainless steel. Then, the electrolyte solution was injected, and then the negative electrode cap 206 made of titanium clad stainless steel and the insulating packing 210 made of fluorine rubber were used to seal so that a lithium secondary battery was manufactured.

Example 35

Preparation of Multi-Layer Metal Oxide

A titanium oxide was prepared by the following method.

A film forming compound, that is, dihexadecylphosphate was mixed to a sol dispersed solution of very small particles of titanium oxide (manufactured by Idemitsu), and dispersed with ultrasonic waves similarly to Example 34. Then, it was developed on a tetrafluoroethylene polymer membrane filter. Then, it was dried at room temperature, resulting in a cast film to be obtained which was then cleaned with ethyl alcohol. Then, it was baked at 300°C so that a titanium oxide film was formed.

The separator 208 was manufactured in such a manner that the thus-formed titanium oxide, unwoven polypropylene sheets and a polypropylene separator having small apertures were sandwiched.

A battery was manufactured under the same

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conditions as those according to example 34 except the foregoing arrangements.

Example 36

5 A lithium secondary battery was manufactured under the same conditions as those according to example 35 except that the titanium oxide film was immersed in 0.1% ethylalcohol solution of silane coupling SH6020 (manufactured by Toray Dowconing).

Example 37

10 Preparation of Multi-Layer Metal Oxide

A cast film obtained similarly to Example 35 was based at 800°C so that an alumina film was manufactured, the cast film being obtained from a film forming compound brought into class four from N-(11-
15 bromoundecanoyl)-L-glutamic acid didodecylester with triethylamine and amorphous alumina super fine particle sol.

The N-X11-bromoundecanoyl)-L-glutamic acid didodecylester was prepared in such a manner that L-
20 glutamic acid didodecylester hydrochloride salt was synthesized from L-glutamic acid and dodecylalcohol, and then the L-glutamic acid didodecylester hydrochloride salt, triethylamine, cyanophosphoric acid diethyl and 11-bromoundecan acid were used.

25 Assembly of Secondary Battery

A nickel-zinc secondary battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was manufactured.

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The positive electrode was manufactured by impregnating nickel hydroxide into a sintered nickel electrode plate.

5 The negative electrode was formed in such a manner that tetrafluoride ethylene polymer powder serving as the bonding material was added to a mixture of zinc powder and zinc oxide powder and they were pressed against the two sides of a copper punching metal to be formed into the desired shape. Then, alumina trichloride
10 and phosphoric acid were, in ethyl alcohol, caused to react with each other at 0°C as to dip the negative electrode. Then, it was gradually heated up to 100°C so that glass-type aluminum phosphate film was formed on the negative electrode.

15 The electrolyte solution comprised 30 wt% potassium hydroxide containing lithium hydroxide added thereto.

The battery was assembled similarly to Example 34.

Example 38

20 A nickel-zinc secondary battery was manufactured under the same conditions as those according to Example 37 except that the surface of the negative electrode was not covered with the aluminum phosphate.

Example 39

25 A nickel-zinc secondary battery was manufactured under the same conditions as those according to Example 37 except that a positive electrode manufactured as follows was used.

A dispersion solution in which was mixed a film forming compound obtained by bringing N-(11-

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bromoundecanoyl)-L-glutamic acid didodecylester into class four with triethylamine, amorphous alumina very small particles sol and polyvinyl alcohol water solution containing crosslinking material added thereto was developed on the surface of the positive electrode formed by causing a sintered nickel plate to impregnate nickel hydroxide, followed by drying the developed solution. Then, crosslinking reactions were caused to take place at 120°C, and cleared with ethyl alcohol. Then, the material was dried in a vacuum atmosphere so that a positive electrode covered with a composite film of alumina and polyvinyl alcohol was manufactured.

In order to compare and evaluate the foregoing batteries, the following comparative batteries were manufactured.

Comparative Example 34

A lithium secondary battery was manufactured under the same conditions as those according to example 35 except that no titanium oxide was used and the lithium of the negative electrode was not covered.

Comparative Example 35

A nickel-zinc secondary battery was manufactured under the same conditions as those according to example 37 except that no alumina was used and zinc of the negative electrode was not covered.

Evaluation of Performance of Secondary Battery

The performance of lithium secondary batteries according to Examples and Comparative Examples was

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evaluated. The evaluation was performed by a charge and discharge cycle test under the following conditions with respect to the cycle life of the batteries according to Comparative Examples.

5 The conditions for the cycle test were made as follows: the charge and discharge was performed by 0.2C (electric current which was 0.2 times capacity/time), pause for 30 minutes and a cut-off voltage of 1.0V was applied. A charging/discharging apparatus HJ-101M6
10 manufactured by Hokuto Electric was used. The charge/discharge test was commenced at discharge, the battery capacity was evaluated by the quantity of the third discharge and the cycle life was evaluated by the number of cycles when the battery capacity had
15 deteriorated to 60% or less.

 The cycle life of each battery with respect to the cycle life of the battery according to Comparative Examples which was made to be 1 was as shown in Table 2.

 As can be understood from the results of
20 comparisons made between Examples 34 to 36 and Comparative Example 34 and those between Examples 37 to 39 and Comparative Example 35, the cycle life can be lengthened due to use of the secondary battery having the structure according to the present invention.
25

Table 10

Secondary Battery Manufactured		Cycle Life of Example
Example	Comparative Example	Cycle Life of Comparative Example
Example 34	Comparative Example 34	5.4
Example 35	Comparative Example 34	2.1
Example 36	Comparative Example 34	2.3
Example 37	Comparative Example 35	2.6
Example 38	Comparative Example 35	1.9
Example 39	Comparative Example 35	2.2

Example 40

A lithium secondary battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was manufactured.

The positive electrode active material 203 was manufactured in such a manner that electrolyzed manganese dioxide and lithium carbonate were mixed at a ratio of 1:0.4. Then, the mixture was heated to 800°C so that a lithium-manganese oxide was prepared. Graphite and tetrafluoroethylene polymer powder were added to the prepared lithium-manganese oxide, and pressed against a nickel mesh as to be formed into the positive electrode.

Then, the positive electrode was immersed in a solution of Teflon AF which was a copolymer of

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tetrafluoroethylene and 2, 2-bistrifluoromethyl-4,5-difluoro-1, 3-dioxol and which was manufactured by Dupont, and then it was dried. As a result, the positive electrode 203 covered with the fluororesin was
5 manufactured.

In an atmosphere of dry argon gas, the titanium mesh collector 200 was pressed against the reverse side of the lithium metal foil, and then the lithium metal foil was immersed in a solution which was a copolymer of
10 ethylene tetrafluoride and vinyl ether and which was manufactured by Asahi Glass. Then, it was dried as to be hardened so that the lithium negative electrode 201 covered with the fluororesin was manufactured.

The electrolyte solution was prepared by
15 dissolving, by 1 M (mol/l), boric acid tetrafluoride lithium salt in an equal quantity mixture solvent of propylene carbonate (PC) and dimethoxyethane (DME).

The separator 208 was manufactured in such a manner that a polypropylene separator having small apertures
20 was sandwiched by unwoven polypropylene sheets.

The assembly was performed in such a manner that the separator 208 was held between the negative electrode 201 and the positive electrode 203 as to be inserted into the positive case 207 made of titanium
25 clad stainless steel. Then, the electrolyte solution was injected, and then the negative electrode cap made of titanium clad stainless steel and the insulating packing 210 made of fluorine rubber were used for sealing so that a lithium secondary battery was manufactured.

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Example 41

A lithium battery was manufactured under the same conditions as those according to example 40 except the process for covering the positive electrode.

5 The positive electrode was manufactured similarly to Example 40. Then, the positive electrode was immersed in an acetonitril solution, in which were dissolved 0.1 M of monomer of benzo-15-crown-5 and 2.0 M of electrolytic boronic acid tetrafluoride tetrabutyl ammonium salt. Then, the platinum electrode was used as
10 the cathode electrode, and voltage of 3 V was applied to perform electrolysis and polymerization so that a large ring compound polymer covering film was formed on the surface of the positive electrode.

15 In an atmosphere of dry argon gas, the titanium mesh collector 200 was pressed against the lithium metal foil so that the negative electrode was manufactured.

 Then, similar processes to those according to Example 40 were performed so that the lithium secondary
20 battery was manufactured.

Example 42

A lithium secondary battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2
25 was manufactured.

 The positive electrode was manufactured by a similar process according to Example 40. Then, peroxide benzoyl and boronic acid tetrafluoride lithium were dissolved in a tetrahydrofuran solution of poly (2-vinyl

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naphthalene) manufactured by Aldrich Chemical Company, Inc. Then, the positive electrode was immersed in it, and then heated to 100°C so that the positive electrode 203 covered with poly (2-vinyl naphthalene) was
5 manufactured.

Then, similar processes to those according to Example 41 were performed so that the lithium secondary battery was manufactured.

Example 43

10 The positive electrode was manufactured by a process similar to that according to Example 40. Then, boronic acid tetrafluoride lithium salt was added and dissolved in a toluene solution PPZ-U1001 manufactured by Idemitsu. Then, the positive electrode was immersed,
15 and previously dried, and then ultraviolet rays were applied so that the positive electrode 203 covered with polyphosphazene was manufactured.

Then, similar processes to those according to Example 41 were performed so that the lithium secondary
20 battery was manufactured.

Example 44

The positive electrode was manufactured by a process similar to that according to Example 40. The thus-manufactured positive electrode was injected into a
25 sputtering apparatus. Then, the retained gas was exhausted to realize a degree of vacuum of 2×10^{-6} Torr. Then, argon gas, which was a mixture of 10% nitrogen gas and 5% acetylene gas, was allowed to flow. The internal pressure was controlled to 3×10^{-3} Torr, and lithium

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fluoride was made to be a target of sputtering. As a result, the positive electrode covered with carbon and a film made of lithium nitride containing fluorine were formed.

5 Then, similar processes to those according to Example 41 were performed so that the lithium secondary battery was manufactured.

Example 45

10 A nickel-zinc secondary battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was manufactured.

15 The positive electrode was manufactured in such a manner that zinc hydroxide was impregnated in a sintered nickel electrode plate. Then, acetic acid and water were added to an ethyl alcohol solution of tetraethoxy silane to be dehydrated. Then, diethylamine was added so that colloidal silica was formed. Then, the positive electrode was immersed in the colloidal solution of the silica, and dried at 100°C. As a result, a silica film was formed on the surface of the positive electrode.

20 The negative electrode was manufactured in such a manner that ethylene tetrafluoride polymer powder serving as a bonding material was added to a mixture of zinc powder and zinc oxide powder, then they were pressed to the two sides of a copper punching metal as to be formed into the negative electrode.

 The electrolyte solution comprised 30 wt% potassium hydroxide water solution to which lithium hydroxide was

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added.

The battery was assembled similarly to Example 40.

In order to compare and evaluate the performance of the batteries according to Examples, the following comparative batteries were manufactured.

Comparative Example 40

A lithium secondary battery was manufactured under the same conditions as those according to example 40 except that the positive electrode and the negative electrode were not covered.

Comparative Example 41

A nickel-zinc secondary battery was manufactured under the same conditions as those according to example 45 except that the surface coating was omitted.

Evaluation of Performance of Secondary Battery

The performance of the secondary batteries according to Examples and Comparative Examples was evaluated. The evaluation was performed by a charge and discharge cycle test under the following conditions with respect to the cycle life of the batteries according to Comparative Examples. The conditions for the cycle test were made as follows: the charge and discharge was performed by 0.2C (electric current which was 0.2 times capacity/time), pause for 30 minutes and a cut-off voltage of 1.0V was applied. A charging/discharging apparatus HJ-101M6 manufactured by Hokuto Electric was used.

The charge/discharge test was commenced at discharge, the battery capacity was evaluate the

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quantity of the third discharge and the cycle life was evaluate by the number of cycles when the battery capacity had deteriorated to 60% or less.

5 The cycle life of each battery with respect to the cycle life of the battery according to Comparative Examples which was made to be 1 was as shown in Table 11.

10 As can be understood from the results of comparisons made between Examples 40 to 44 and Comparative Example 11 and those between Example 45 and Comparative Example 41, the cycle life can be lengthened due to use of the secondary battery having the structure according to the present invention.

Table 11

Secondary Battery Manufactured		Cycle Life of Example
Example	Comparative Example	Cycle Life of Comparative Example
Example 40	Comparative Example 40	5.1
Example 41	Comparative Example 40	2.0
Example 42	Comparative Example 40	1.4
Example 43	Comparative Example 40	1.6
Example 44	Comparative Example 40	1.8
Example 45	Comparative Example 41	1.7

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Preparation of Positive Electrode Active Material

Methods of preparing the positive electrode active material according to the present invention are exemplified in Preparation Methods 46 to 55 and the conventional preparation methods are exemplified by Comparative Preparation Methods.

Preparation Method 46

A lithium-manganese oxide was prepared as follows.

Manganese acetate was dissolved in water, and then super fine nickel powder ENP-005 manufactured by Sumitomo Denko was suspended in a water solution of manganese nitrate. Then, a water solution of lithium hydroxide was dripped until the pH was 8 or higher while vibrating the suspension solution with supersonic vibrations of 20 kHz so that sedimentation was generated. Then, ethyl alcohol was added, and supernatant liquid of the solution including the sediment was removed by decantation. The ethylalcohol cleaning and the decantation were repeated. Then, it was dissolved in 0.1% methyl alcohol solution of Sila Ace S210 (vinylmethoxysilane) which was a silane coupling material manufactured by Chisso. Then, the solvent was removed by a centrifugal separator. The obtained sedimentation was dried at 120°C, and dried at 200°C in a vacuum drier so that grains of manganese oxide were prepared.

The size of crystal grains was measured from the half value width of the X-ray analysis curve with respect to a manganese oxide and the angle of

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diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 60 Å or larger.

The RHEED pattern resulted in a ring pattern like a halo pattern.

5 The X-ray radial distribution function resulted in a continuous and moderate peak curve.

The scattering angle and the scattering intensity obtainable from the X-ray small angle scattering method resulted in non-uniform density fluctuation to be
10 observed.

The specific area was measured by the BET method, resulting in that the specific area was 123 m²/g.

Preparation Method 47

Vanadium oxide was prepared as follows.

15 Vanadium pentoxide was gradually added to a water solution of lithium hydroxide as to be dissolved. While applying supersonic vibrations, the water solution was sprayed into liquid nitrogen as to be frozen. Then, the temperature was raised to -20°C, and the pressure was
20 lowered so that freezing and drying were performed to dehydrate and dry the material. Obtained grains were dried at 150°C, and further dried in a vacuum drier at 250°C so that grains of vanadium oxide were obtained. Then, the sample was immersed in 0.1% isopropylalcohol
25 solution of tetra-iso-propoxytitanium, and then the solvent was removed by a centrifugal separator. The obtained sedimentation was dried at 120°C, and then dried at 200°C in a vacuum state so that grains of manganese oxide were prepared.

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Although the size of crystal grains was intended to measure from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation, it could not be measured because the diffraction curve resulted in a broad form.

The RHEED pattern resulted in a halo pattern.

The X-ray radial distribution function resulted in a continuous and moderate peak curve.

The scattering angle and the scattering intensity obtainable from the X-ray small angle scattering method resulted in non-uniform density fluctuation to be observed.

The specific area was measured by the BET method, resulting in that the specific area was 105 m²/g.

15 Preparation Method 48

A lithium-nickel oxide was prepared as follows.

Nickel acetate was dissolved in a mixture solvent of acetic acid, ethyl alcohol and water. While vibrating the solution with supersonic vibrations of 20 kHz, an ethyl alcohol solution of ethoxylithium, which was alkoxide, was dripped as to be mixed. Then, the solution was heated to 80°C to enhance the hydrolysis decomposition reactions so that sol was generated. The supernatant liquid of the solution including the sol-
shape sedimentation was removed by decantation, cleaned with ethyl alcohol, the decantation was repeated and the solvent was removed by a centrifugal separator. The obtained sedimentation was dried at 150°C, and then suspended in a non-electrolyzed nickel plating solution

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Ni-701 manufactured by Kojundo Kagaku. Then, it was heated to 70°C, nickel coating was performed, and water cleaning and decantation were repeated. Then, ethyl alcohol cleaning was performed, and decantation was repeated, and then the solvent was removed by a centrifugal separator. The sample was dried at 230°C in a vacuum state so that grains of nickel oxide were obtained.

Although the size of crystal grains was intended to measure from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation, it could not be measured because the diffraction curve with respect to an oxide resulted in a broad form.

The RHEED pattern resulted in a ring pattern considered due to nickel plating. The pattern before the nickel plating process resulted in a halo pattern.

The X-ray radial distribution function resulted in a continuous and moderate peak curve. The scattering angle and the scattering intensity obtainable from the X-ray small angle scattering method resulted in non-uniform density fluctuation to be observed.

The specific area was measured by the BET method, resulting in that the specific area was 210 m²/g.

25 Preparation Method 49

A lithium-nickel-cobalt oxide was prepared by the following method.

Nickel nitrate and cobalt nitrate were dissolved in water, and then a water solution of lithium hydroxide

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was dripped to a solution of the nickel nitrate and cobalt nitrate while vibrating with supersonic vibrations of 20 kHz until the pH was 8 or higher so that sedimentation was generated. Then, ethyl alcohol was added so that the supernatant liquid of the solution including the sedimentation was removed by decantation. the ethyl alcohol cleaning and the decantation were repeated and the solvent was removed by a centrifugal separator. The obtained sedimentation was dried at 120°C, dried at 200°C in a vacuum state so that grains of a nickel cobalt oxide were prepared.

The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 140 Å.

The RHEED pattern resulted in a ring pattern like a halo pattern.

The X-ray radial distribution function resulted in a continuous and moderate peak curve.

The scattering angle and the scattering intensity obtainable from the X-ray small angle scattering method resulted in non-uniform density fluctuation to be observed.

The specific area was measured by the BET method, resulting in that the specific area was 160 m²/g.

Preparation Method 50

Vanadium-molybdenum oxide was prepared as follows.

Vandyl sulfate and molybdenum sulfate were added to water as to be suspended, and acetic acid was gradually

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added as to be dissolved. Then, a water solution of lithium hydroxide was dripped to a solution of the vanadium oxide and acetic acid while vibrating with supersonic vibrations of 20 kHz until the pH was 8 or higher so that sedimentation was generated. Then, ethyl alcohol was added so that the supernatant liquid of the solution including the sedimentation was removed by decantation. The ethyl alcohol cleaning and the decantation were repeated and the solvent was removed by a centrifugal separator. The obtained sedimentation was dried at 120°C, dried at 200°C in a vacuum state so that grains of a vanadium oxide were prepared.

The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 80 Å.

The RHEED pattern resulted in a ring pattern like a halo pattern.

The X-ray radial distribution function resulted in a continuous and moderate peak curve.

The scattering angle and the scattering intensity obtainable from the X-ray small angle scattering method resulted in non-uniform density fluctuation to be observed.

The specific area was measured by the BET method, resulting in that the specific area was 100 m²/g.

Preparation Method 51

Vanadium-molybdenum oxide was prepared by the following method.

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The vanadium oxide and the molybdenum oxide were mixed at a ratio of 7:3, and heated up to 800°C as to be melted and mixed so that a molten bath was made. Then, the molten bath was dispersed by jet gas which was a mixture of 20% oxygen and 2% hydrogen with argon gas. It was sprayed at high speed to a cooled and retaining metal disc so that grains of vanadium oxide and molybdenum oxide were prepared.

The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 110 Å.

The RHEED pattern resulted in a ring pattern having weak intensity.

The X-ray radial distribution function resulted in a continuous and moderate peak curve.

The scattering angle and the scattering intensity obtainable from the X-ray small angle scattering method resulted in non-uniform density fluctuation to be observed.

The specific area was measured by the BET method, resulting in that the specific area was 60 m²/g.

Preparation Method 52

Titanium sulfide was prepared by the following method.

Hydrogen gas was allowed to flow by 500 sccm into a reaction chamber of a plasma CVD apparatus degasified as to be vacuum state. The pressure was maintained at 10 Torr and discharge was caused to take place at a high

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frequency wave of 13.56 MHz. Then, 200 sccm of helium gas was, as a carrier gas, bubbled in a hexane solution of tetrabutoxytitanium, and injected by 200 sccm through a nozzle into the reaction chamber of the plasma CVD apparatus. Simultaneously, 250 sccm of hydrogen sulfide was introduced as to be reacted in a gas phase to capture grains of titanium sulfide by a capturing machine.

The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 200 Å.

The RHEED pattern resulted in a ring pattern having weak intensity.

The X-ray radial distribution function resulted in a continuous and moderate peak curve.

The scattering angle and the scattering intensity obtainable from the X-ray small angle scattering method resulted in non-uniform density fluctuation to be observed.

The specific area was measured by the BET method, resulting in that the specific area was 175 m²/g.

Preparation Method 53

Lithium-iron-cobalt oxide was prepared by the following method.

A mixture solution of 0.5 mol/l cobalt chloride and 1 mol ferric chloride mixed at a ratio of 1:1 was gradually added to a 5 mol/l water solution of lithium hydroxide while stirring and bubbling argon gas. Then,

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reaction chamber was set to 100°C to be matured. After the maturation, it was injected into cooled water, and cleaning was performed with water cooled by water by means of decantation until the pH of the solution was 8. 5 It was dried at 200°C in a vacuum state, and crushed by a ball mill in an atmosphere of argon gas.

The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's 10 Equation. The size of the crystal grain was 150 Å.

The RHEED pattern resulted in a ring pattern having weak intensity to be observed.

The X-ray radial distribution function resulted in a continuous and moderate peak curve.

15 The scattering angle and the scattering intensity obtainable from the X-ray small angle scattering method resulted in non-uniform density fluctuation to be observed.

The specific area was measured by the BET method, 20 resulting in that the specific area was 2100 m²/g.

Example 54

Manganese Acetate, magnesium chloride and urea were added to a solution in which 300 g of vanadium pentoxide was dissolved in 2 liters of hydrochloric acid, 25 followed by heating the solution to 95 to 95°C for 10 minutes to generate ammonia. Lithium hydride solution was dripped to make the pH to generate sediment. Then, decantation and water cleaning were repeated, and then cleaning with ethyl alcohol was performed, and the

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material was dried by a spray drier. Then, the sample was dried at 200°C in a vacuum state.

The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 90 Å.

The RHEED pattern resulted in a ring pattern like a halo pattern.

The X-ray radial distribution function resulted in a continuous and moderate peak curve.

The scattering angle and the scattering intensity obtainable from the X-ray small angle scattering method resulted in non-uniform density fluctuation to be observed.

The specific area was measured by the BET method, resulting in that the specific area was 80 m²/g.

Preparation Method 55

A lithium-copper-cobalt oxide was prepared by the following method.

An oxalic acid was added to a water solution in which a copper sulfate and a cobalt nitrate were dissolved. Then, supersonic vibrations were applied, and lithium hydroxide was dripped until the pH was 7 so that sedimentation was generated. Water cleaning and decantation were repeated, and then, a water solution of lithium hydroxide was added, supersonic vibrations were applied, and an ethyl alcohol was added. Decantation and cleaning with ethyl alcohol were repeated, and the material was dried by using a spray drier. Further, the

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material was dried at 200°C in a vacuum state.

The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 160 Å.

The RHEED pattern resulted in a ring pattern having weak intensity.

The X-ray radial distribution function resulted a continuous and moderate peak curve.

The scattering angle and the scattering intensity obtainable from the X-ray small angle scattering method resulted in non-uniform density fluctuation to be observed.

The specific area was measured by the BET method, resulting in that the specific area was 50 m²/g.

Other Analyses

The SIMS analysis resulted that the positive electrode active materials according to Preparation Methods 46 to 55 contained hydrogen and lithium. Also the dehydration peak of each TG (Thermogravimetric analysis), DTA (Differential Thermal Analysis) and DSC (Differential Scan Thermal Heating Value Measurement) and the absorption spectrum of FTIR (Fourier Transform Infrared) resulted that a hydroxyl group was present.

Comparative Preparation Method 46

A lithium-manganese oxide was prepared by the following method.

Powder of electrolyzed manganese dioxide manufactured by Mitsui Kinzoku and lithium carbonate

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were mixed with each other at a ratio of 1:0.4 and they were heated at 800°C so that lithium manganese oxide was prepared.

5 The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 600 Å or larger.

10 The RHEED pattern resulted in a ring pattern in which a spot pattern could be confirmed.

The X-ray radial distribution function resulted in discontinuous peak curve.

The specific area was measured by the BET method, resulting in that the specific area was 40 m²/g.

15 Comparative Preparation Method 47

A reagent manufactured by Wako was dried at 400°C in a vacuum state.

20 The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 800 Å.

The RHEED pattern resulted in a ring pattern in which a spot pattern could be confirmed.

25 The X-ray radial distribution function resulted in discontinuous peak curve.

The specific area was measured by the BET method, resulting in that the specific area was 4 m²/g.

Comparative Preparation Method 48

A lithium-nickel oxide was prepared by the

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following method.

A lithium carbonate and nickel nitrate were mixed at an equal mol ratio of 1:1 and the mixture was heated to 800°C so that a lithium-nickel oxide was prepared.

5 The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 2000 Å or larger.

10 The RHEED pattern resulted in a ring pattern in which a spot pattern could be confirmed.

The X-ray radial distribution function resulted in discontinuous peak curve.

The specific area was measured by the BET method, resulting in that the specific area was 50 m²/g.

Comparative Preparation Method 49

A lithium-nickel-cobalt oxide was prepared by the following method.

20 A lithium carbonate, nickel carbonate and cobalt carbonate were mixed at a mol ratio of 10:3:7 and the mixture was heated to 900°C for 20 hours as to be decomposed so that a nickel-cobalt oxide was prepared.

25 The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 1100 Å or larger.

The RHEED pattern resulted in a ring pattern in which a spot pattern could be confirmed.

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The X-ray radial distribution function resulted in discontinuous peak curve.

The specific area was measured by the BET method, resulting in that the specific area was 40 m²/g.

5 Comparative Preparation Method 50

A vanadium-molybdenum oxide was prepared by the following method.

10 A vanadium oxide and a molybdenum oxide were mixed at a ratio of 7:3, and the mixture was heated to 800°C in a platinum crucible as to be melted and mixed. Then, the mixture was cooled gradually so that the block-shape vanadium oxide and molybdenum oxide were prepared. They were crushed by a roller mill so that grains of vanadium oxide-molybdenum oxide were prepared.

15 The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 700 Å or larger.

20 The RHEED pattern resulted in a ring pattern in which a spot pattern could be confirmed.

The X-ray radial distribution function resulted in discontinuous peak curve.

25 The specific area was measured by the BET method, resulting in that the specific area was 10 m²/g.

Comparative Preparation Method 51

A titanium sulfide was prepared by the following method.

A titanium disulfide powder manufactured by Kojundo

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Kagaku was dried at 400°C in a vacuum state.

The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 900 Å or larger.

The RHEED pattern resulted in a ring pattern in which a spot pattern could be confirmed.

The X-ray radial distribution function resulted in discontinuous peak curve.

The specific area was measured by the BET method, resulting in that the specific area was 50 m²/g.

Comparative Preparation Method 52

A lithium-iron-cobalt oxide was prepared by the following method.

Lithium carbonate, iron acetate and cobalt carbonate were mixed at the same mole ratio, and decomposed at 600°C in air so that an iron cobalt oxide was prepared. Then, it was crushed by a ball mill so that grains were obtained.

The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 1000 Å or larger.

The RHEED pattern resulted in a ring pattern in which a spot pattern could be confirmed.

The X-ray radial distribution function resulted in discontinuous peak curve.

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The specific area was measured by the BET method, resulting in that the specific area was 40 m²/g.

Comparative Preparation Method 53

5 A manganese containing magnesium added thereto-vanadium oxide was prepared by the following method.

A manganese dioxide, vanadium pentoxide and magnesium hydroxide were mixed at a mol ratio of 10:10:1, and then they were decomposed at 700°C in air. As a result, the manganese containing magnesium added thereto-vanadium oxide was prepared. Then, they were 10 crushed by a ball mill so that grains were obtained.

The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 1300 Å or 15 larger.

The RHEED pattern resulted in a ring pattern in which a spot pattern could be confirmed.

20 The X-ray radial distribution function resulted in discontinuous peak curve.

The specific area was measured by the BET method, resulting in that the specific area was 27 m²/g.

Comparative Preparation Method 54

25 A lithium-copper-cobalt oxide was prepared by the following method.

A lithium carbonate, cobalt carbonate and copper carbonate were mixed at the same mol ratio, and then they were decomposed at 600°C in air. As a result, the manganese containing magnesium added thereto-vanadium

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oxide was prepared. Then, they were crushed by a ball mill so that grains were obtained.

The size of crystal grains was measured from the half value width of the X-ray analysis curve and the angle of diffraction in accordance with the Scherrer's Equation. The size of the crystal grain was 1100 Å or larger.

The RHEED pattern resulted in a ring pattern in which a spot pattern could be confirmed.

The X-ray radial distribution function resulted in discontinuous peak curve.

The specific area was measured by the BET method, resulting in that the specific area was 10 m²/g.

Analyzing Apparatus

The positive electrode active material prepared by Preparation Methods 46 to 55 and Comparative Preparation Methods 46 to 54 were analyzed by using the following apparatuses. The X-ray diffraction measurement was performed by using MXP3VA manufactured by MacScience.

The RHEED measurement was performed by using JEM-100SX manufactured by Nihon Denshi.

The specific area measurement by the BET method was performed by using GEMIN12300 manufactured by Micromeritex.

As a result of the comparisons between the transition metal and the group 6A element according to Preparation Methods according to the present invention and those according to Comparative Preparation Methods, the compounds according to the present invention

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exhibited smaller particle grain size as compared with the results of Comparative Preparation Method while having an amorphous or microcrystal structure.

Manufacturing of Lithium Secondary Battery

5 Lithium secondary batteries were manufactured by using the positive electrode active materials prepared by the foregoing preparation methods.

Example 46

10 The positive electrode active material prepared by the foregoing Preparation Method 46 was used to manufacture a battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2.

15 In an atmosphere of dry argon gas, the negative electrode active material 201 was used in such a manner that the titanium mesh collector 200 was pressed against the reverse side of the lithium metal foil. Then, the surface of lithium was covered with a fluoro-resin thin film by using thin solution of Lumiflon, which was a
20 fluoro-resin paint manufactured by Asahi Glass, so that the negative electrode was manufactured.

 Acetylene black powder and xylene solution of the Lumiflon, which was a fluoro-resin paint manufactured by Asahi Glass, were mixed with the positive electrode
25 active material which was prepared by Preparation Method 46 and which was lithium-manganese oxide. The mixture was applied to the titanium mesh, and it was hardened at 80°C, and then heated with microwaves. As a result, the positive electrode 203 was formed.

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The electrolyte solution was prepared by dissolving, by 1 M (mol/l), boronic acid tetrafluoride lithium salt in an equal quantity mixture solvent of propylene carbonate (PC) and dimethoxyethane (DME).

5 The separator 208 was manufactured in such a manner that a polypropylene separator having small apertures was sandwiched by unwoven polypropylene sheets.

The assembly was performed in such a manner that the separator 208 was sandwiched between the negative
10 electrode 201 and the positive electrode 203, followed by inserting them into a positive electrode case 207 made of titanium clad stainless steel. Then, the electrolyte solution was injected. Then, the negative electrode cap 206 made of the titanium clad stainless
15 steel and the insulating packing 210 made of fluorine rubber were used for sealing so that the lithium secondary battery was manufactured.

Example 47

The vanadium oxide prepared by Preparation Method
20 47 was used as the positive electrode active material, a battery having a cross sectional shape schematically shown in Fig. 2 was manufactured.

First, the nickel mesh collector was pressed against the reverse side of the lithium metal foil in an
25 atmosphere of dry argon gas so that the negative electrode was manufactured.

Acetylene black powder and Super Konak F which was a fluoro-resin paint manufactured by Nihon Yushi were mixed with the vanadium oxide serving as the positive

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electrode active material and prepared by Preparation Method 2, followed by adding xylene by a small quantity. The mixture was applied to the nickel mesh, and it was hardened at 150°C. As a result, the positive electrode
5 was manufactured.

Then, similar processes to those according to Example 46 were performed so that the lithium secondary battery shown in Fig. 2 was assembled.

Example 48

10 By using the positive electrode active material prepared by Preparation Method 48, a battery which had a simple structure, which could be assembled simply and which had a cross sectional shape schematically shown in Fig. 2 was assembled.

15 First, the nickel mesh collector was pressed against the reverse side of the lithium metal foil in an atmosphere of dry argon gas so that the negative electrode was manufactured.

20 Acethylene black powder and tetrafluoroethylene polymer powder were mixed with the lithium-nickel oxide prepared by Preparation Method 48 and serving as the positive electrode active material. The mixture was pressed against the nickel mesh with heat as to be formed into the positive electrode 203.

25 Then, similar processes to those according to Example 46 were performed so that the lithium secondary battery shown in Fig. 2 was assembled.

Example 49

The lithium-nickel-cobalt oxide prepared by

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Preparation Method 49 was used as the positive electrode active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to Example 48.

5 Example 50

The vanadium-molybdenum oxide prepared by Preparation Method 50 was used as the positive electrode active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to
10 Example 48.

Example 51

The vanadium-molybdenum oxide prepared by Preparation Method 51 was used as the positive electrode active material so that the battery shown in Fig. 2 was
15 manufactured by the process similar to that according to Example 48.

Example 52

The titanium sulfide prepared by Preparation Method 52 was used as the positive electrode active material so
20 that the battery shown in Fig. 2 was manufactured by the process similar to that according to Example 48.

Example 53

The lithium-iron-cobalt oxide prepared by Preparation Method 53 was used as the positive electrode
25 active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to Example 48.

Example 54

The manganese containing magnesium added thereto-

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vanadium oxide prepared by Preparation Method 54 was used as the positive electrode active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to Example 48.

5 Example 55

The lithium-copper-cobalt oxide prepared by Preparation Method 55 was used as the positive electrode active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to
10 Example 48.

Comparative Example 46

By using the positive electrode active material prepared by Comparative Preparation Method 46, the battery having a cross sectional shape schematically
15 shown in Fig. 2 was manufactured.

First, the titanium mesh collector 200 was pressed against the reverse side of the lithium metal foil in an atmosphere of dry argon so that the negative electrode was manufactured.

20 Acetylene black powder and tetrafluoroethylene polymer powder were mixed to the lithium-manganese oxide prepared by Comparative Preparation Method 46 and serving as the positive electrode active material as to be, with heat, pressed and formed into the positive
25 electrode 203.

Then, similar processes to those according to Example 46 were performed so that the lithium secondary battery was assembled.

Comparative Example 47

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The vanadium oxide prepared by Comparative Preparation Method 47 was used as the positive electrode active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to Example 48.

Comparative Example 48

The lithium-nickel oxide prepared by Comparative Preparation Method 48 was used as the positive electrode active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to Example 48.

Comparative Example 49

The lithium-nickel-cobalt oxide prepared by Comparative Preparation Method 49 was used as the positive electrode active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to Example 48.

Comparative Example 50

The vanadium-molybdenum oxide prepared by Comparative Preparation Method 50 was used as the positive electrode active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to Example 48.

Comparative Example 51

The titanium sulfide prepared by Comparative Preparation Method 51 was used as the positive electrode active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to Example 48.

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Comparative Example 52

The lithium-iron-cobalt oxide prepared by Comparative Preparation Method 52 was used as the positive electrode active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to Example 48.

Comparative Example 53

The manganese containing magnesium added thereto-vanadium oxide prepared by Comparative Preparation Method 53 was used as the positive electrode active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to Example 48.

Comparative Example 54

The lithium-copper-cobalt oxide prepared by Comparative Preparation Method 54 was used as the positive electrode active material so that the battery shown in Fig. 2 was manufactured by the process similar to that according to Example 48.

20 Evaluation of Performance of Lithium Secondary Battery

The performance of lithium secondary batteries according to Examples and Comparative Examples was evaluated. The evaluation was performed by a charge and discharge cycle test under the following conditions with respect to the cycle life of the batteries according to Comparative Examples.

The conditions for the cycle test were made as follows: the charge and discharge was performed by 0.2C (electric current which was 0.2 times capacity/time),

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pause for 30 minutes and a cut-off voltage of 1.0V was applied. A charging/discharging apparatus HJ-101M6 manufactured by Hokuto Electric was used. The charge/discharge test was commenced at discharge, the battery capacity was evaluated by the quantity of the third discharge and the cycle life was evaluated by the number of cycles when the battery capacity had deteriorated to 60% or less.

The lithium batteries using the positive electrode active materials respectively according to the present invention and the comparative examples, that is, the battery capacities and cycle life of the examples of the present invention and the comparative examples were evaluated as shown in Table 12 while making the performance of the battery according to the comparative example to be a reference value of 1.

As can be understood from Table 12, the comparisons made between Examples 46 to 55 and Comparative Examples 46 to 54 resulted that the use of the batteries according to the present invention enabled the capacity of the battery to be enlarged and the cycle life to be lengthened.

Table 12

Lithium Battery Manufactured		Capacity of Battery (Present Invention/ Comparative Example)	Cycle life (Present Invention/ Comparative Example)
Examples	Comparative Examples		
Example 46	Comparative Example 46	2.3	4.8
Example 47	Comparative Example 47	3.1	3.2
Example 48	Comparative Example 48	2.1	1.7
Example 49	Comparative Example 49	2.0	1.4
Example 50	Comparative Example 50	4.1	2.9
Example 51	Comparative Example 50	3.2	2.1
Example 52	Comparative Example 51	2.4	1.4
Example 53	Comparative Example 52	2.3	1.5
Example 54	Comparative Example 53	1.7	2.0
Example 55	Comparative Example 54	2.2	1.8

Further, combinations of the embodiments of the present invention will enable further improved secondary battery to be obtained.

5 According to the present invention, if dendrite of lithium or zinc grows at the time of charge, short circuits between the negative electrode and the positive electrode can be prevented. Therefore, a lithium

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secondary battery, a nickel zinc secondary battery and
an air zinc secondary battery exhibiting a long
charge/discharge cycle life can be manufactured.
Further, the metal lithium can be used as the negative
5 electrode active material. Therefore, a secondary
battery exhibiting a high energy density can be
manufactured while improving safety.

Although the invention has been described in its
preferred form with a certain degree of particularity, it
10 is understood that the present disclosure of the
preferred form can be changed in the details of
construction and the combination and arrangement of
parts may be resorted to without departing from the
spirit and the scope of the invention as hereinafter
15 claimed.

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THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A secondary battery comprising:
 - 5 a negative electrode having a negative electrode active material,
 - a positive electrode substantially made of a positive electrode active material;
 - 10 a separator arranged between the negative electrode and the positive electrode;
 - an electrolyte provided between said positive and negative electrodes; and
 - 15 a film with a thickness of 50 Å to 100 μm and of a molecular structure of large voids and fine holes covering at least separator side of said negative electrode for protecting said negative electrode from contact with said electrolyte, while permitting passage of ions which contribute to battery reactions.
- 20 2. A secondary battery according to claim 1, wherein said film has a molecular structure or apertures having gaps larger than the ions relating to said battery reaction.
- 25 3. A secondary battery according to claim 1, wherein said film has a molecular structure or apertures through which the ions relating to said battery reactions are able to pass but through which deposited negative active material during charging is hard to pass.

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4. A secondary battery according to claim 1, wherein said film is stable such that said film does not react with said electrolyte or an electrolyte solution and said film cannot be dissolved by the same.

5

5. A secondary battery according to claim 1, wherein the material of said film has an electron donative element or a group.

10

6. A secondary battery according to claim 5, wherein said electron donative element of the material of said film has an unpaired electron, a paired electron or electron d.

15

7. A secondary battery according to claim 5, wherein said electron donative group of the material of said film has electron n.

20

8. A secondary battery according to claim 5 or 6, wherein said electron donative element of the material of said film has one or more types of elements selected from a group consisting of oxygen, nitrogen and sulfur.

25

9. A secondary battery according to claim 1, wherein the material of said film is in the form of a macrocyclic compound.

10. A secondary battery according to claim 1, wherein the material of said film is in the form of an aromatic

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ring structure.

11. A secondary battery according to claim 1, wherein the material of said film is fluoro-resin.

5

12. A secondary battery according to claim 1, wherein the material of said film is in the form of an ether bond structure.

10 13. A secondary battery according to claim 1, wherein the material of said film has a carbonyl group.

14. A secondary battery according to claim 1, wherein the material of said film is in the form of a structure
15 in which phosphorus atoms and nitrogen atoms are alternately double-bonded in a phosphorus-nitrogen manner.

15. A secondary battery according to claim 1, wherein
20 the material of said film is made of a glass-type metal oxide.

16. A secondary battery according to claim 1, wherein the material of said film has a polymer structure.

25

17. A secondary battery according to claim 1, wherein the material of said film has a crosslinked polymer structure.

18. A secondary battery according to claim 1, wherein

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said film includes conductor powder dispersed therein.

19. A secondary battery according to claim 1, wherein
said negative electrode active material is lithium or
5 lithium alloy.

20. A secondary battery according to claim 1, wherein
said negative electrode active material is zinc or zinc
alloy.
10

21. A secondary battery according to claim 19, wherein
said surface of said negative electrode covered with
said film is subjected to lipophilic treatment.

15 22. A secondary battery according to claim 20, wherein
said surface of said negative electrode covered with
said film is subjected to hydrophilic treatment.

23. A secondary battery according to claim 1, wherein
20 at least the surface of said separator opposing said
negative electrode is covered with the same material
which forms said film.

24. A secondary battery having a negative electrode
25 substantially made of a negative electrode active
material, a positive electrode substantially made of a
positive electrode active material disposed while
interposing a separator from said negative electrode and
an electrolyte or an electrolyte solution held between

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said negative electrode and said positive electrode,
said secondary battery comprising:

at least a surface of said negative electrode
opposing said positive electrode is treated with a
5 reactive and gaseous material containing a nitrogen
element or a halogen element; and

the concentration of nitrogen atoms or halogen
atoms are gradually lowered from the surface to an
inside portion of said negative electrode.

10

25. A secondary battery according to claim 24, wherein
said reactive and gaseous material is a plasma-type
material.

15

26. A secondary battery according to claim 24, wherein
said material containing nitrogen is one or more types
of materials selected from a group consisting of
nitrogen, ammonia and nitrogen trifluoride.

20

27. A secondary battery according to claim 24, wherein
said material containing said halogen element is one or
more types of materials selected from a group consisting
of fluorine, chlorine, hydrogen fluoride, hydrogen
chloride, nitrogen trifluoride and a carbon

25

tetrafluoride.

28. A secondary battery according to claim 24, wherein
one or more types of gases selected from a group
consisting of oxygen gas, hydrogen gas, argon gas,

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helium gas and xenon gas are added to said reactive and gaseous raw material gas containing the nitrogen element or halogen element to treat the surface of said negative electrode.

5

29. A secondary battery according to claim 24, wherein said reactive and gaseous material is a material in a plasma state which treats the surface of said negative electrode.

10

30. A secondary battery according to claim 24, wherein said negative electrode active material is lithium or lithium alloy.

15

31. A secondary battery having a negative electrode substantially made of a negative electrode active material, a positive electrode substantially made of a positive electrode active material disposed while interposing a separator from said negative electrode and an electrolyte or an electrolyte solution held between said negative electrode and said positive electrode, said secondary battery comprising: an insulating layer and a layer selected from a group consisting of a conductor layer and a semiconductor layer disposed between said negative electrode and said separator.

20

25

32. A secondary battery according to claim 31, wherein said negative electrode is made of lithium, lithium alloy, zinc or zinc alloy.

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33. A secondary battery according to claim 31, wherein
said conductor layer or said semiconductor layer is made
of one or more types of elements selected from a group
5 consisting of carbon, Ni, Ti, Pt and Si.

34. A secondary battery according to claim 31, wherein
said insulating layer is one or more types of insulators
selected from a group consisting of halide, nitride and
10 carbide.

35. A secondary battery according to claim 31, wherein
a layer selected from a group consisting of said
conductor layer, said semiconductor layer and said
15 insulating layer is in contact with said negative
electrode active material.

36. A secondary battery according to claim 31, wherein
a layer selected from a group consisting of said
20 conductor layer, said semiconductor layer and said
insulating layer is in contact with said separator.

37. A secondary battery according to claim 31, wherein
a layer selected from a group consisting of said
25 conductor layer, said semiconductor layer and said
insulating layer covers at least the surface of said
negative electrode active material adjacent to said
separator.

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38. A secondary battery according to claim 31, wherein
a layer selected from a group consisting of said
conductor layer, said semiconductor layer and said
insulating layer is pressed and secured to the surface
5 of said negative electrode active material.

39. A secondary battery according to claim 31, wherein
a layer selected from a group consisting of said
conductor layer, said semiconductor layer and said
10 insulating layer covers at least the surface of said
separator adjacent to said negative electrode.

40. A secondary battery according to claim 36, wherein
a layer selected from a group consisting of said
15 conductor layer, said semiconductor layer and said
insulating layer is pressed and secured to said
separator.

41. A secondary battery according to claim 31, wherein
20 said conductor layer is made of carbon fiber having a
specific area of $10 \text{ m}^2/\text{g}$ and a void ratio of 50% or more.

42. A secondary battery having a negative electrode
made of a negative electrode active material and a
25 positive electrode made of a positive electrode active
material and arranged in such a manner that said
negative electrode active material and said positive
electrode active material are separated from each other
by a separator, said secondary battery comprising:

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at least a multi-layer metal oxide formed between said positive electrode and said negative electrode.

5 43. A secondary battery according to claim 42, wherein
said multi-layer metal oxide contains one or more types
of materials selected from a group consisting of
alumina, titanium oxide, silica, selenium oxide, zirconia
oxide, magnesium oxide, chrome oxide, calcium oxide, tin
10 oxide, indium oxide and germanium oxide.

44. A secondary battery according to claim 42, wherein
said multi-layer metal oxide is formed by a mold made of
bimolecular film.

15 45. A secondary battery according to claim 44, wherein
said bimolecular film is a compound (a amphipathic
materials having both hydrophobic group and a
hydrophilic group).

20 46. A secondary battery according to claim 44, wherein
said bimolecular film is formed in a film shape
combining an amphipathic material and a polymer
compound.

25 47. A secondary battery according to claim 44, wherein
said bimolecular film is a reactant (polyion complex) of
an ionic amphipathic material and a polymer electrolyte.

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48. A secondary battery according to claim 42, wherein said multi-layer metal oxide is a composite of an organic polymer.

5 49. A secondary battery according to claim 42, wherein said multi-layer metal oxide is a portion of said separator.

10 50. A secondary battery according to claim 42, wherein the surface of said positive electrode made of said positive electrode active material, opposing said negative electrode, is covered with at least a film through which ions relating to battery reactions are able to pass.

15 51. A secondary battery according to claim 42, wherein the surface of said negative electrode made of said negative electrode active material and opposing said positive electrode is covered with at least a film
20 through which ions relating to battery reactions are able to pass.

25 52. A secondary battery according to claim 42, wherein said film through which the ions relating to the battery reactions are able to pass is made of a multilayer metal oxide prepared in a mold made of a bimolecular film.

53. A secondary battery according to claim 42, wherein said negative electrode active material is lithium or

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lithium alloy.

54. A secondary battery according to claim 42, wherein said negative electrode active material is zinc or zinc alloy.

5

55. A secondary battery according to claim 42, wherein said multi-layer metal oxide is subjected to lipophilic treatment.

10

56. A secondary battery according to claim 42, wherein said multi-layer metal oxide has a conductor member on the surface thereof which opposes said negative electrode.

15

57. A secondary battery comprising:

a negative electrode having a negative electrode active material;

a positive electrode having a positive electrode active material;

20

an insulating layer, through which an ion contributing to the battery reaction passes, arranged at a plane of the positive electrode opposite to the negative electrode;

25

a film layer with a thickness of 10 Å to 100µm formed by a film selected from a semiconductor layer, made of a composite of an insulating layer and the semiconductor layer for covering at least a separator side of said positive electrode, thereby precluding substantially a contact between said positive electrode

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and an electrolyte or an electrolyte solution;

a separator arranged between the negative electrode and the positive electrode; and

said electrolyte or electrolyte solution
5 arranged between the negative electrode and the positive electrode.

58. A secondary battery according to claim 57,
wherein said insulating member through which the ions
10 are able to pass is a macrocyclic compound through which the ions relating to the battery reactions are able to pass.

59. A secondary battery according to claim 58, wherein
15 said large ring compound is a ring compound having one or more types of structures selected from a group consisting of a ring polyether, a ring polyamine, ring polythioether, azacrown ether, ring thioether, thiocrown ether, cryptand, cyclam, cyclodextrin, cyclofan,
20 phthalocyanin and porphyrin compound.

60. A secondary battery according to claim 57, wherein
said insulating member through which the ions are able
to pass is a polymer of a derivative of an aromatic
25 hydrocarbon.

61. A secondary battery according to claim 60, wherein
said derivative of the aromatic hydrocarbon is one or
more types of derivatives selected from a group

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consisting of naphthalene, anthracene, phenanthlene, naphthacene, pyrene, triphenylene, perillene, picene, benzopyrene, coronene and ovalene.

5 62. A secondary battery according to claim 57, wherein said insulating member through which the ions are able to pass is fluororesin.

10 63. A secondary battery according to claim 62, wherein said fluororesin has an ether bond.

15 64. A secondary battery according to claim 57, wherein said insulating member through which the ions are able to pass is silicone resin which is an organic silicon compound.

20 65. A secondary battery according to claim 57, wherein said insulating member through which the ions are able to pass is a titanium polymer which is an organic titanium compound.

25 66. A secondary battery according to claim 57, wherein said insulating member through which the ions are able to pass is a polymer in which phosphorus atoms and nitrogen atoms alternately form phosphorus-nitrogen double bonds.

67. A secondary battery according to claim 57, wherein said insulating member through which the ions are able

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to pass is inorganic glass comprised of an inorganic oxide.

5 68. A secondary battery according to claim 67, wherein said inorganic glass is combined with an organic polymer.

10 69. A secondary battery according to claim 67, wherein said inorganic oxide contains oxides of one or more elements selected from a group consisting of silicon, titanium, aluminum, magnesium, zirconium, lead and calcium.

15 70. A secondary battery according to claim 57, wherein said insulating member through which the ions are able to pass is a carbide.

20 71. A secondary battery according to claim 57, wherein said insulating member through which the ions are able to pass is a nitride.

25 72. A secondary battery according to claim 57, wherein said insulating member through which the ions are able to pass is a halide.

73. A secondary battery according to claim 72, wherein said halide is a fluoride.

74. A secondary battery according to claim 57, wherein

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said insulating member through which the ions are able to pass contains one or more elements selected from a group consisting of carbon and silicon.

5 75. A secondary battery according to claim 57, wherein the surface of said negative electrode is covered with a film through which ions relating to battery reactions are able to pass.

10 76. A secondary battery according to claim 57, wherein said negative electrode is made of lithium or lithium alloy and said ions relating to the reactions are lithium ions.

15 77. A secondary battery according to claim 57, wherein said negative electrode is made of zinc or zinc alloy and said ions relating to the reactions are hydroxide ions.

20 78. A secondary battery comprising:
a negative electrode substantially made of a negative electrode active material;
a positive electrode substantially made of a positive electrode active material disposed while
25 interposing a separator from said negative electrode;
and
an electrolyte or an electrolyte solution held between said negative electrode and said positive electrode, wherein

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said positive electrode active material is
comprised of a compound of one or more types of
transition metal having a crystal grain size of 500 Å or
less and a group 6A element, and wherein said positive
5 electrode active material contains hydrogen.

79. A secondary battery according to claim 78, wherein
said positive electrode active material is an aggregate
selected from a group consisting of amorphous,
10 microcrystal, a mixture of amorphous and microcrystal
and a mixture of amorphous, microcrystal and multi-
crystal.

80. A secondary battery according to claim 78, wherein
15 said positive electrode active material has a hydroxide.

81. A secondary battery according to claim 78, wherein
said positive electrode active material contains one or
more types of elements selected from a group consisting
20 of lithium, carbon, magnesium, sodium, potassium,
nitrogen, aluminum, calcium, barium, lead, indium,
boron, silicon, tin, phosphorus, arsenic, antimony,
bismuth, fluorine and chlorine.

25 82. A secondary battery according to claim 78, wherein
said group 6A element which is the main component of
said positive electrode active material is oxygen.

83. A secondary battery according to claim 78, wherein

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said group 6A element which is the main component of said positive electrode active material is sulfur.

84. A secondary battery according to claim 78, wherein
5 said positive electrode active material is applied with coating treatment with a conductor.

85. A secondary battery according to claim 78, wherein
10 a positive electrode active material of a type in which conductor powder serving as the core is covered with a compound of said transition metal and said group 6A element is used.

86. A secondary battery according to claim 78, wherein
15 said positive electrode active material is mixed with one or more materials selected from a group consisting of carbon material, a resin material and a metal material mixed thereto to form a positive electrode.

20 87. A secondary battery according to claim 78, wherein said positive electrode active material is subjected to lipophilic treatment.

88. A secondary battery according to claim 87, wherein
25 said lipophilic treatment is treatment using an organometal compound.

89. A secondary battery according to claim 86, wherein said resin material contains one or more types of resins

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selected from a group consisting of fluororesin,
polyethylene, polypropylene and silicon resin.

5 90. A secondary battery according to claim 89, wherein
said resin material is a resin in the form of liquid or
molten liquid or a resin having a low melting point.

10 91. A secondary battery according to claim 90, wherein
said resin is fluororesin having an ether bond.

15 92. A secondary battery according to claim 78, wherein
said negative electrode active material is composed of
one or more types of materials selected from a group
consisting of lithium, lithium alloy and carbon.

20 93. A secondary battery according to claim 78, wherein
the surface of said negative electrode active material
of said secondary battery is covered with a film through
which lithium ions are able to pass.

25 94. A secondary battery according to claim 78, wherein
said electrolyte is composed of at least an alkali metal
compound.

95. A secondary battery according to claim 78, wherein
said electrolyte is in a state selected from a group
consisting of a solid state, a solution state dissolved
in a non-aqueous solvent and a solid-liquid state.

FIG. 1

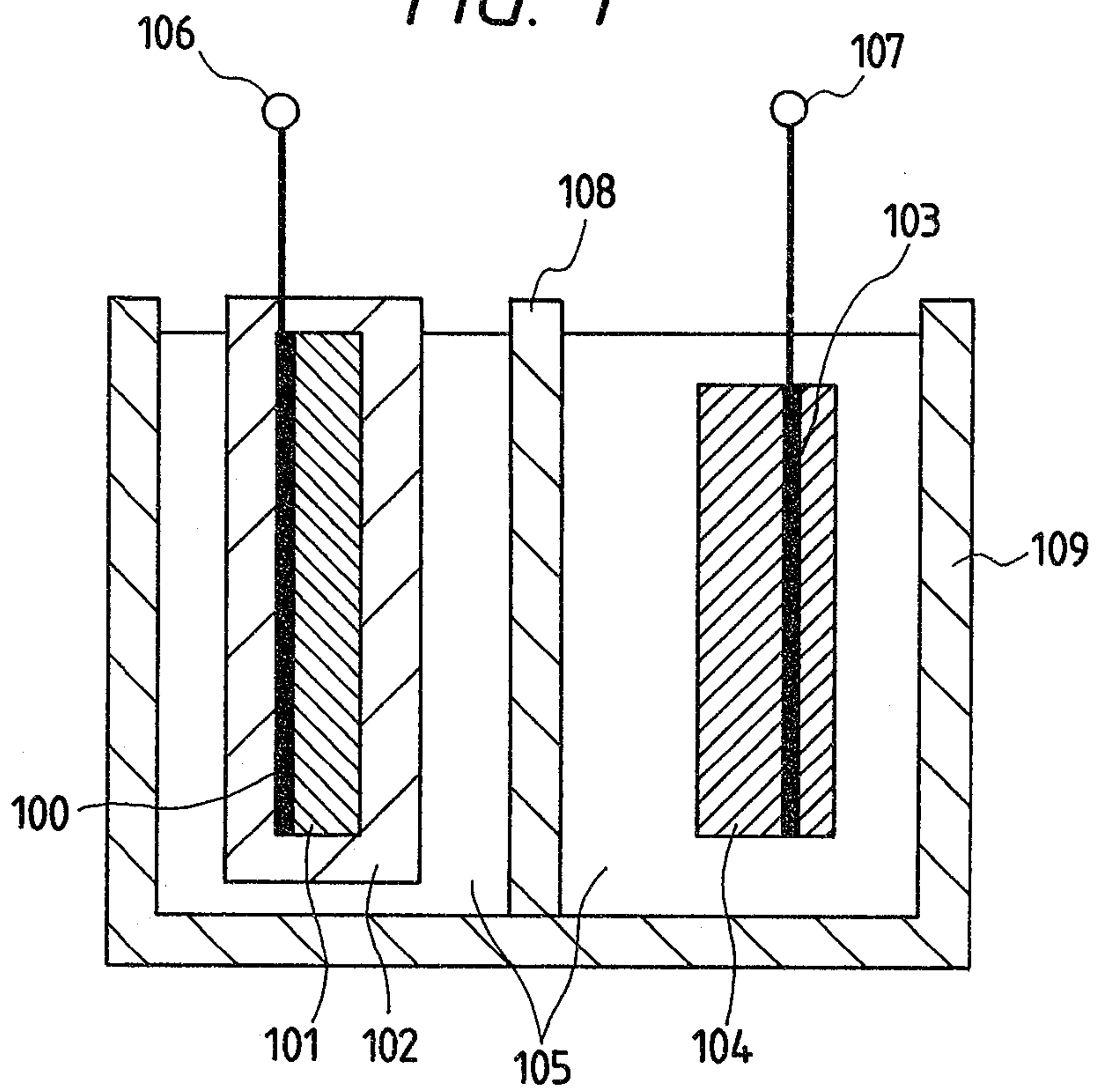


FIG. 2

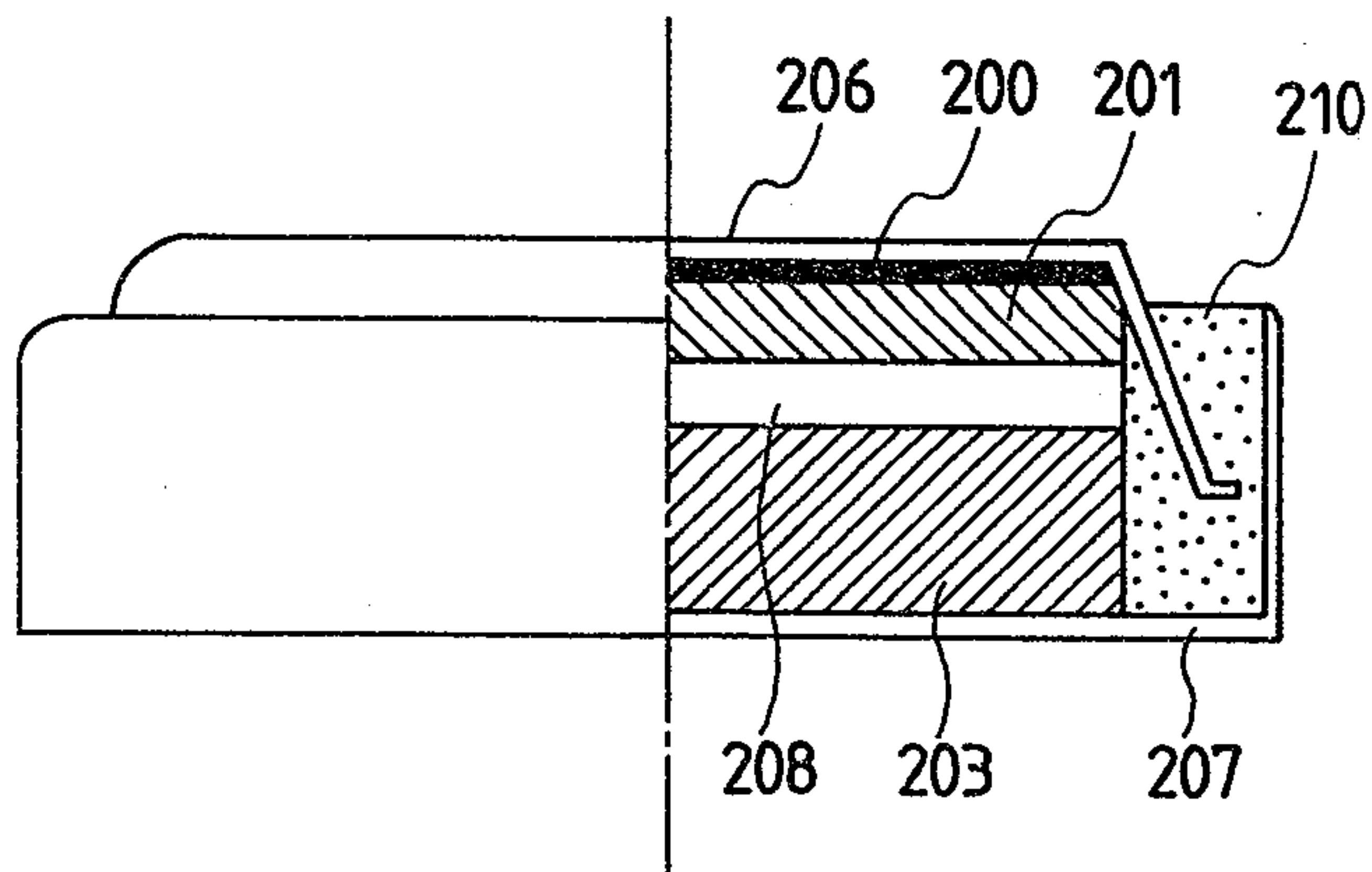


FIG. 3

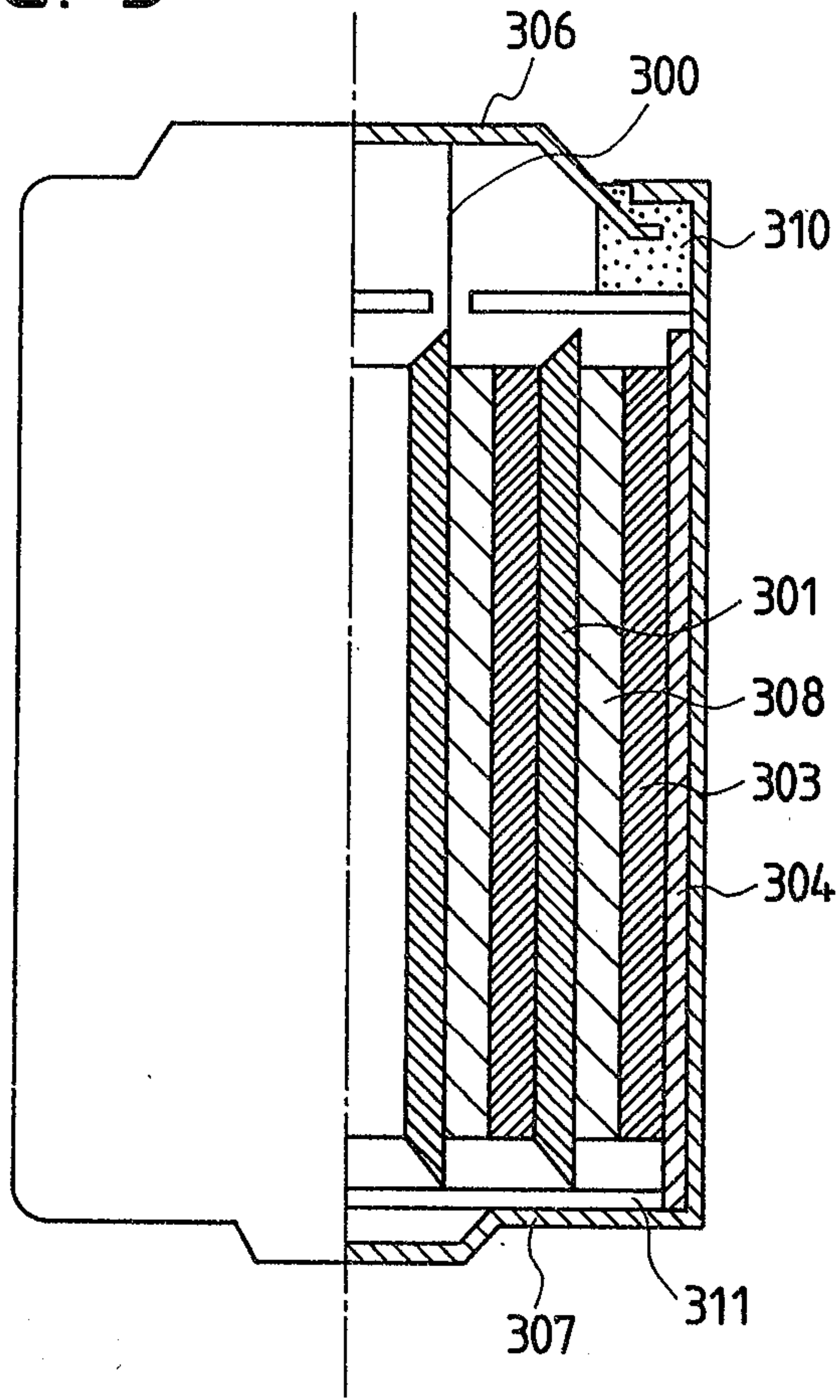
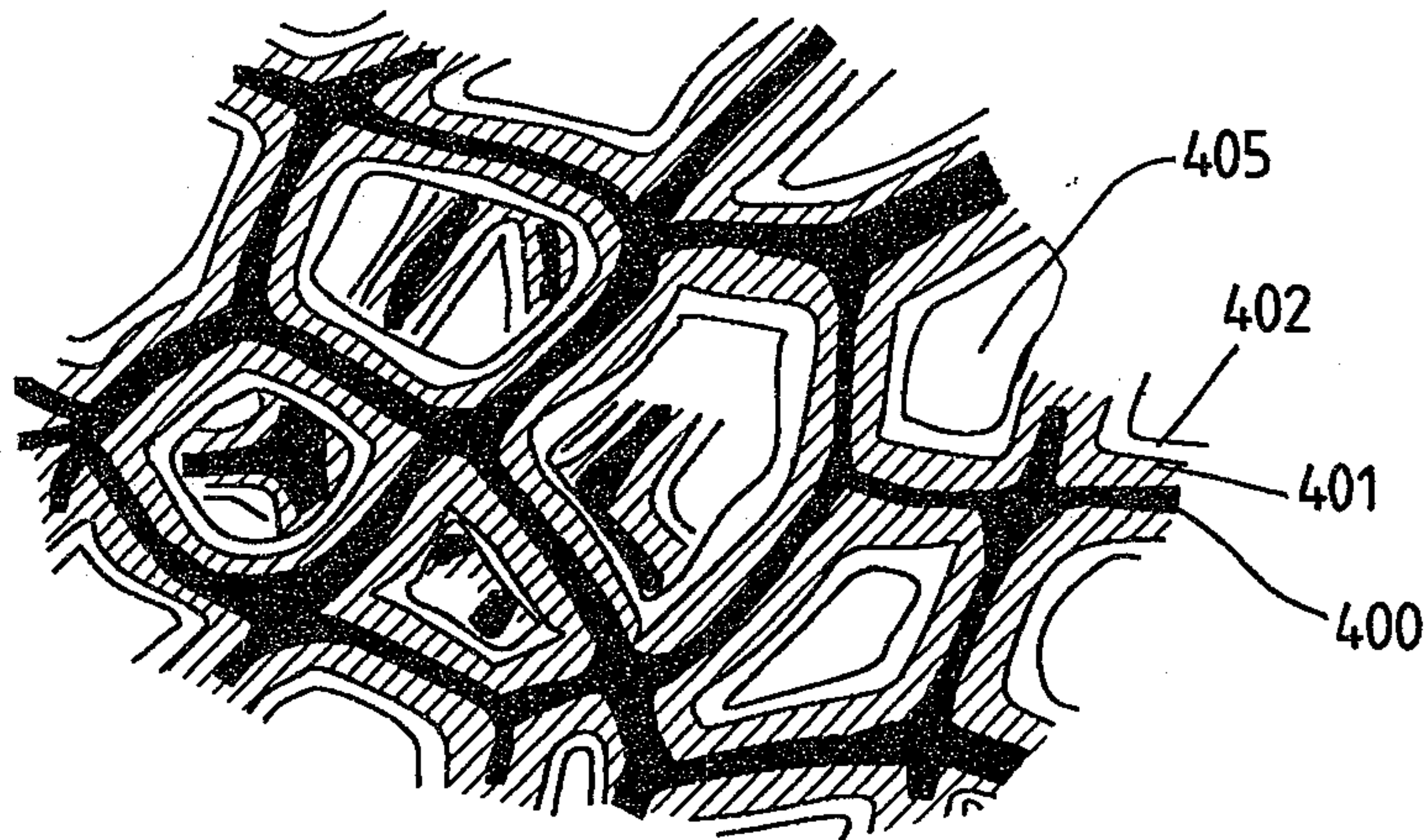


FIG. 4



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FIG. 5

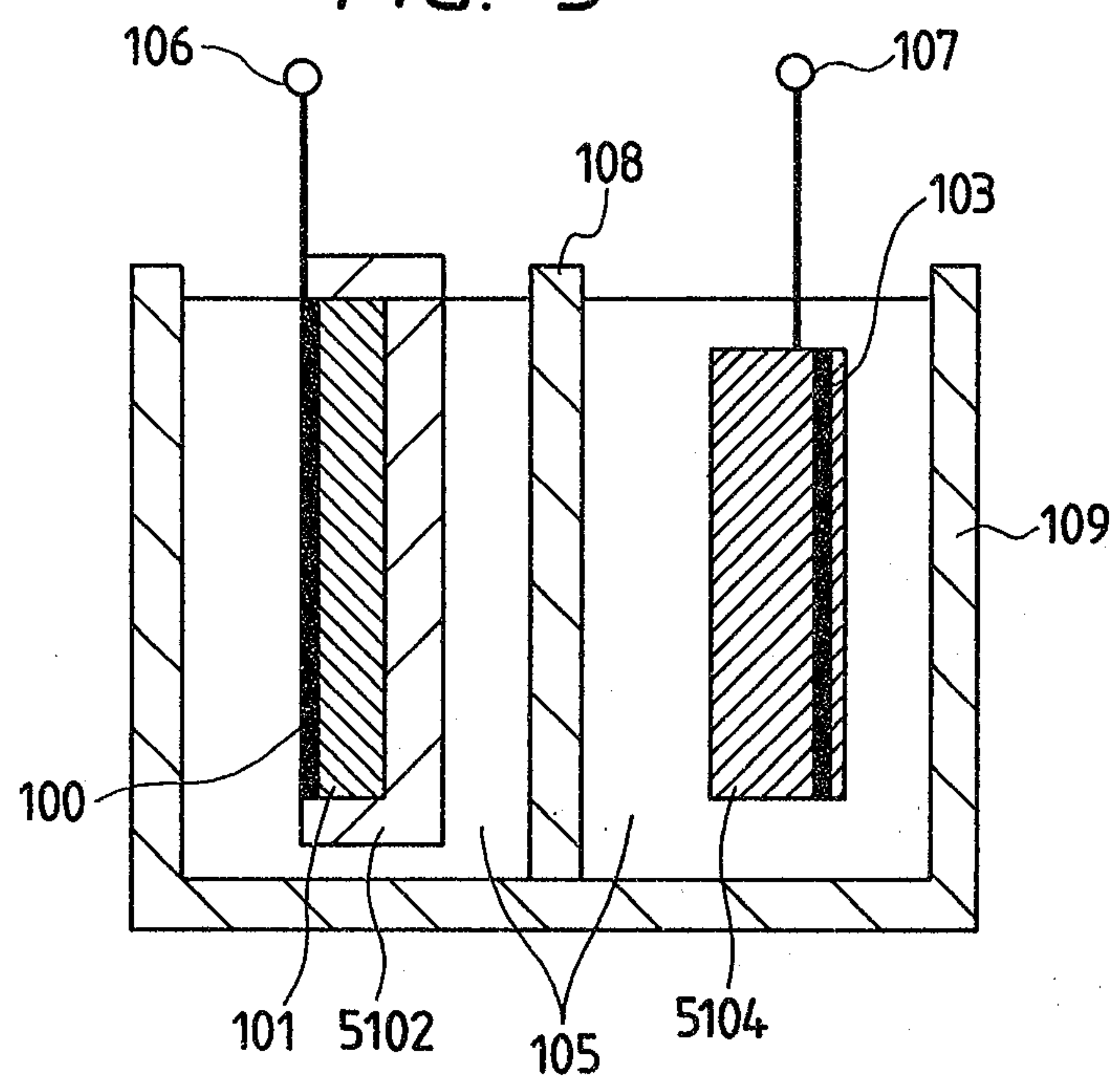
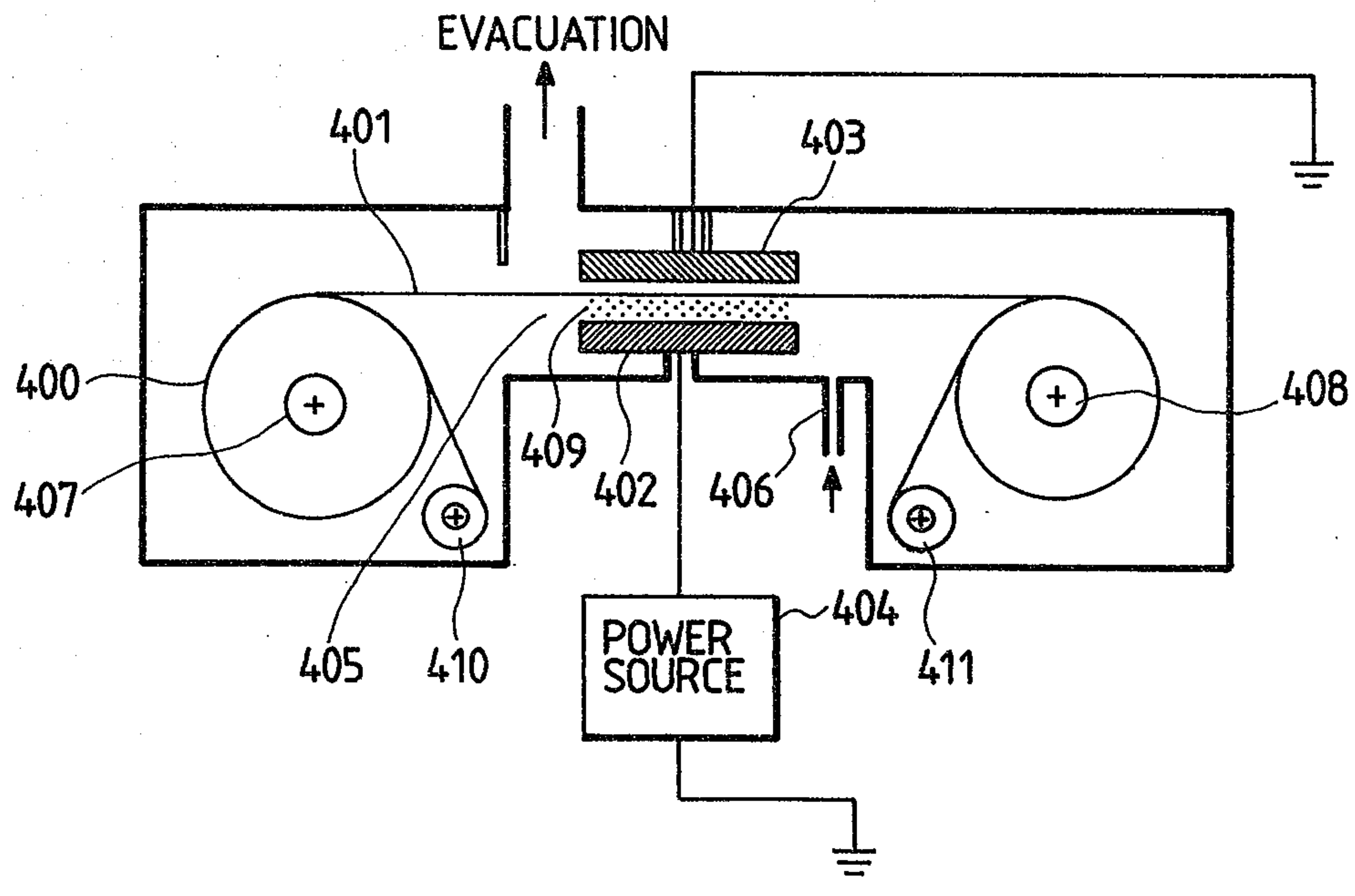


FIG. 6



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FIG. 7

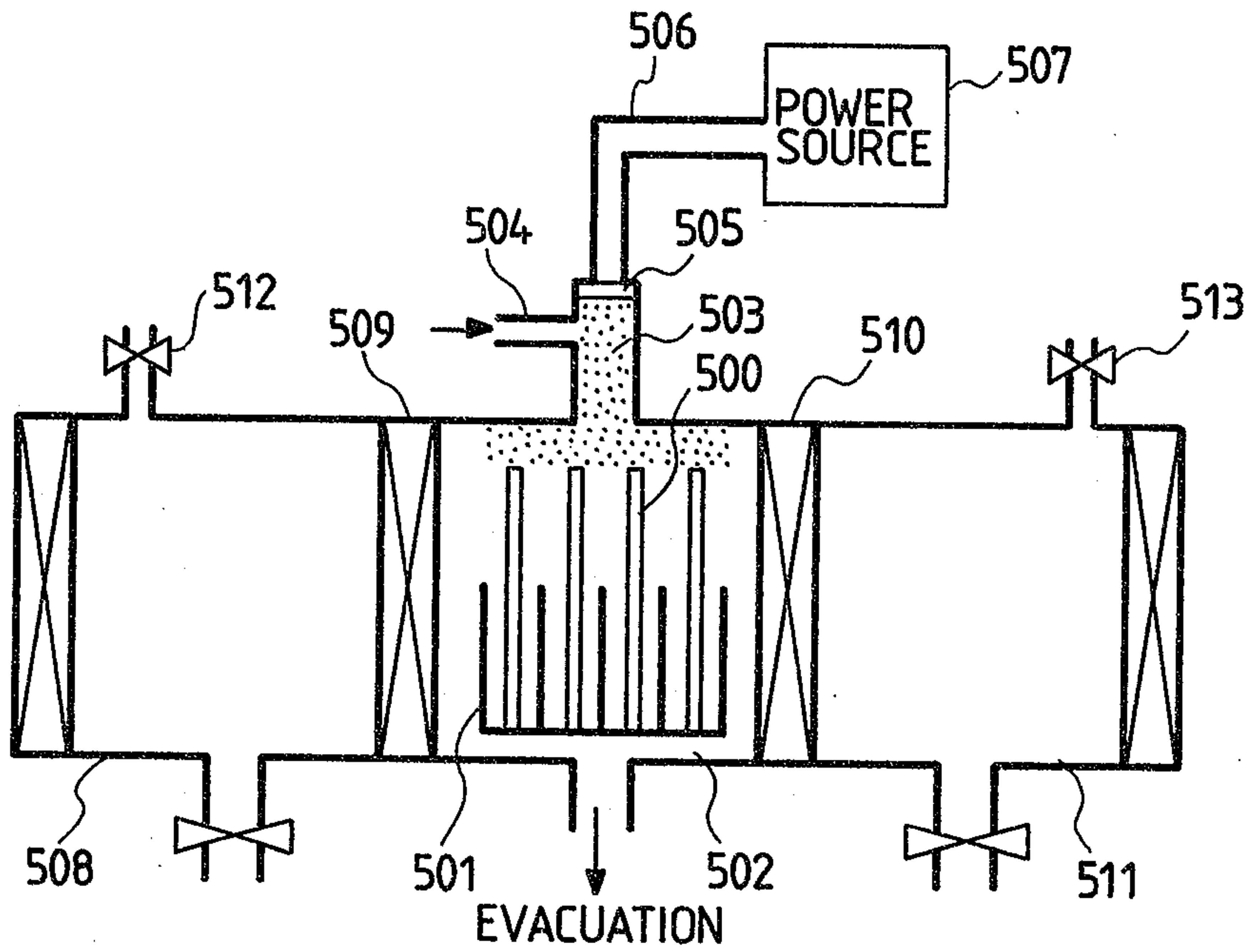
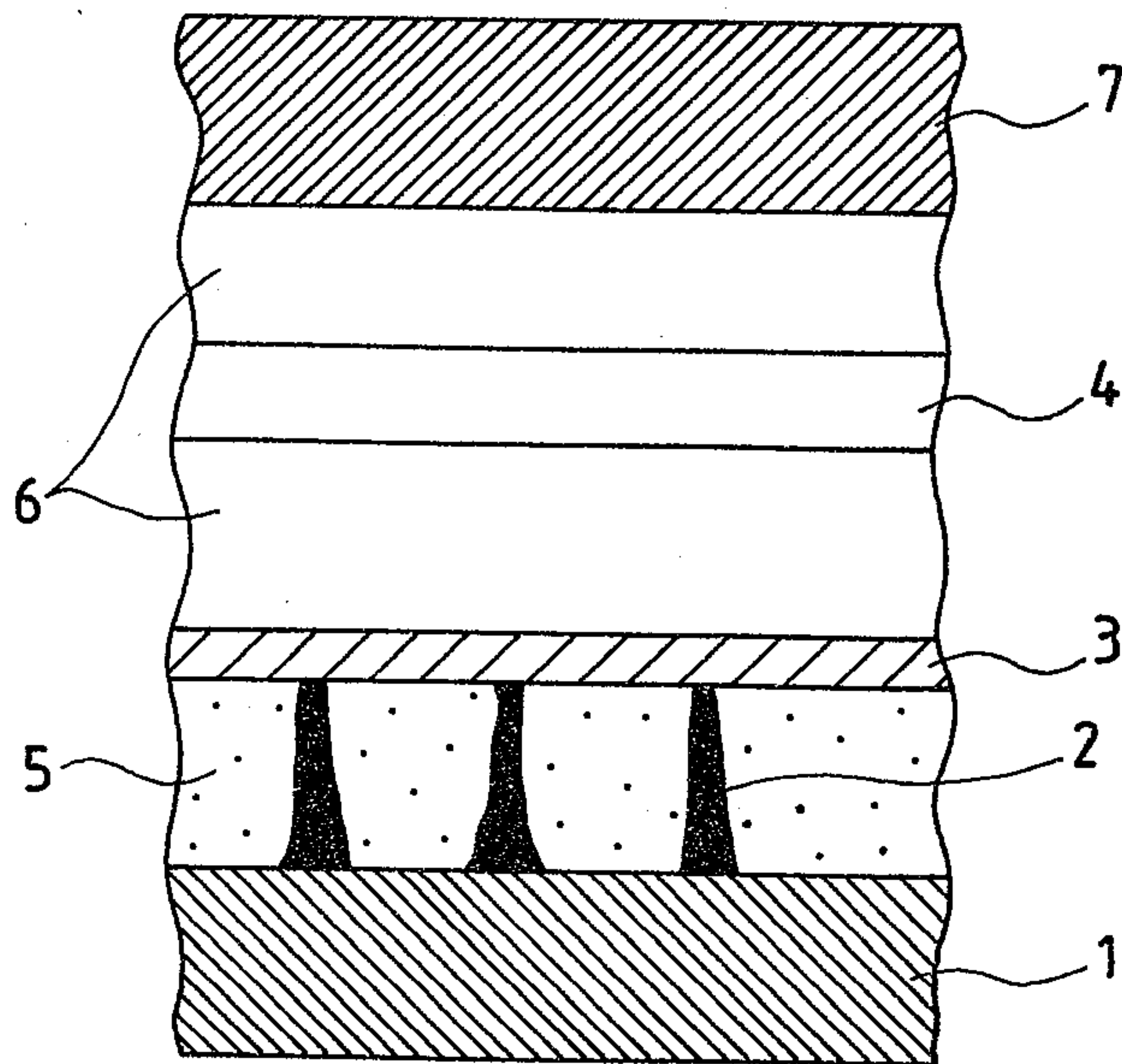


FIG. 8



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FIG. 9A

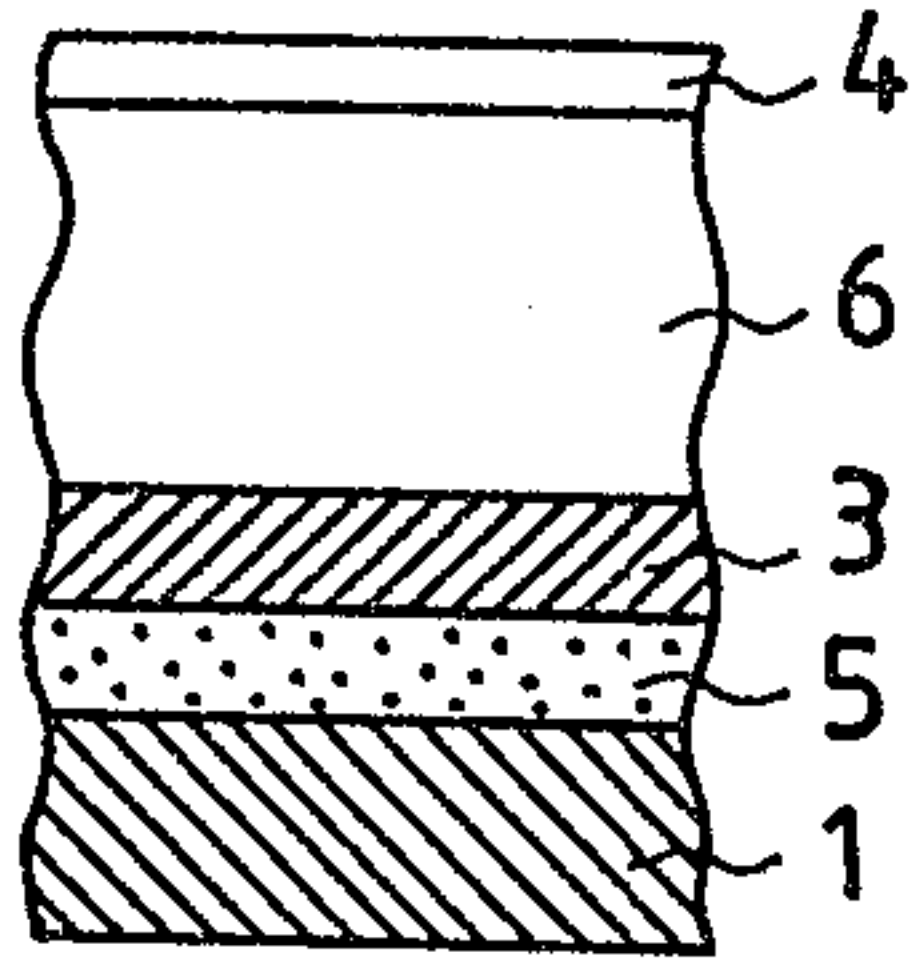


FIG. 9B

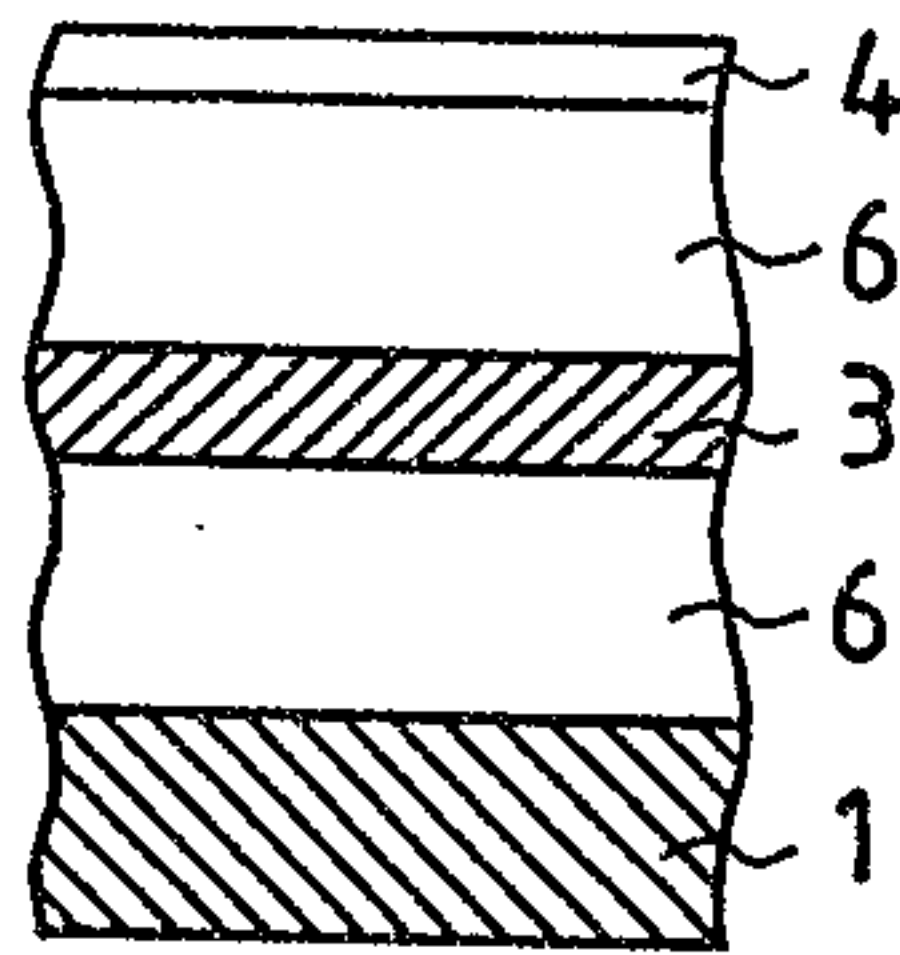


FIG. 9C

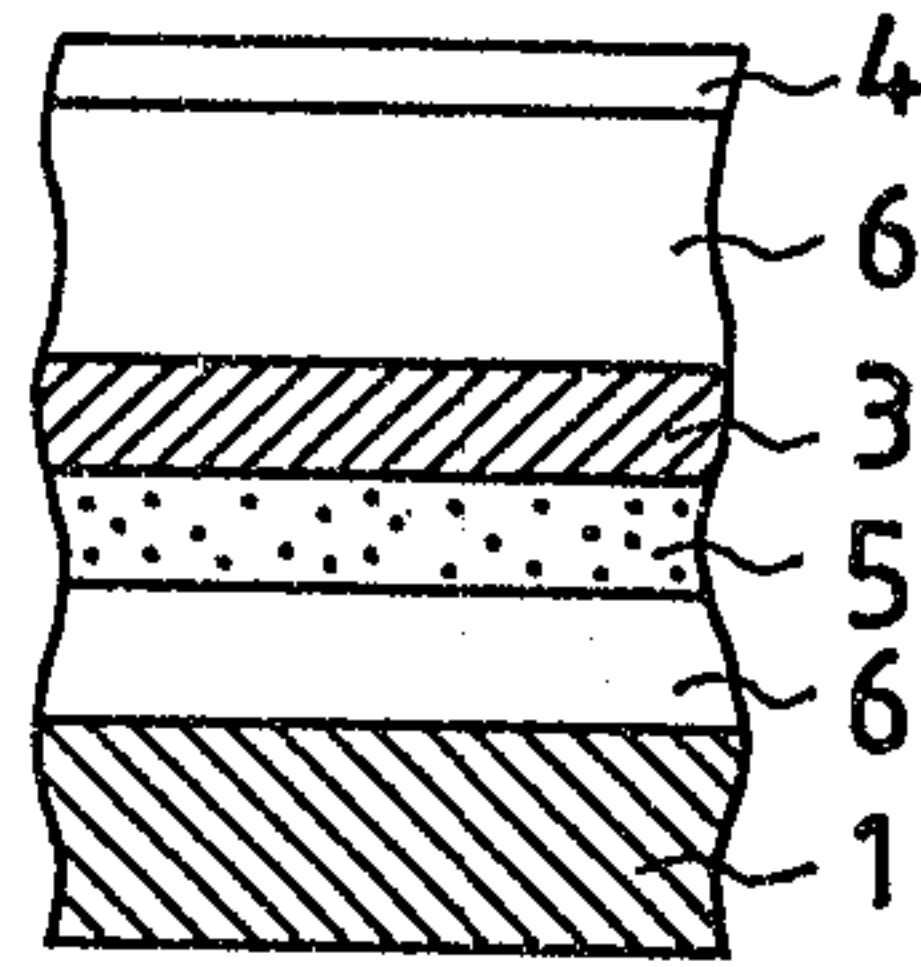


FIG. 9D

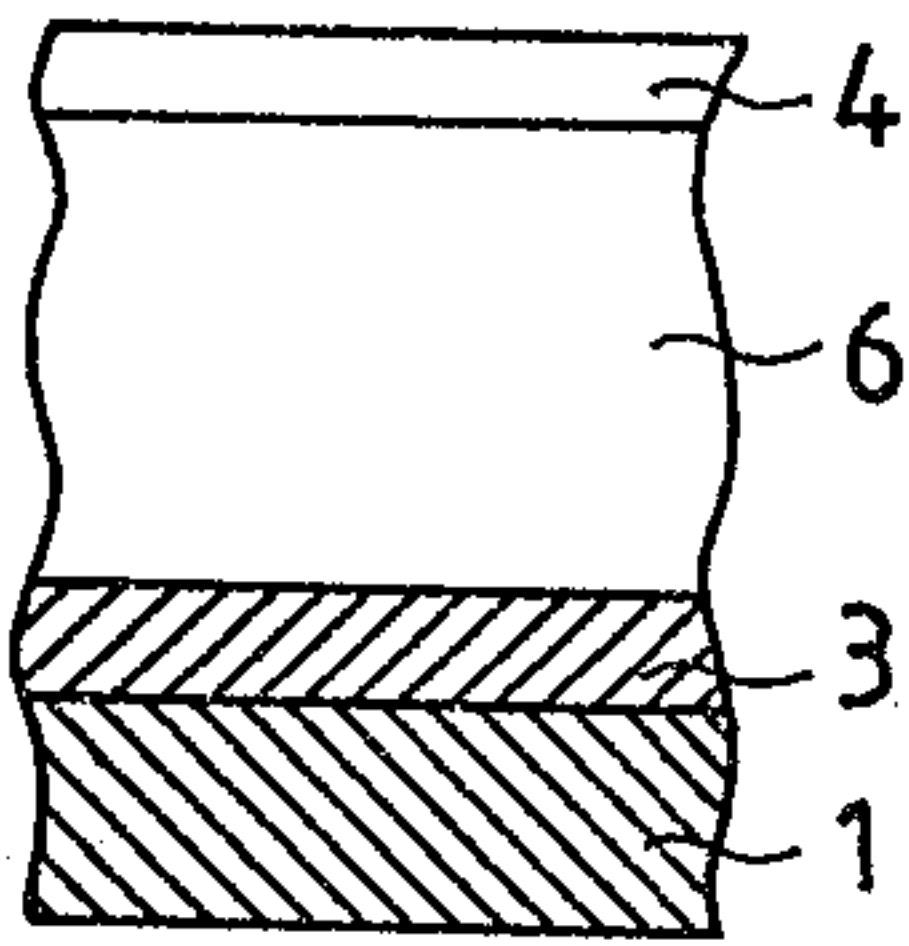


FIG. 9E

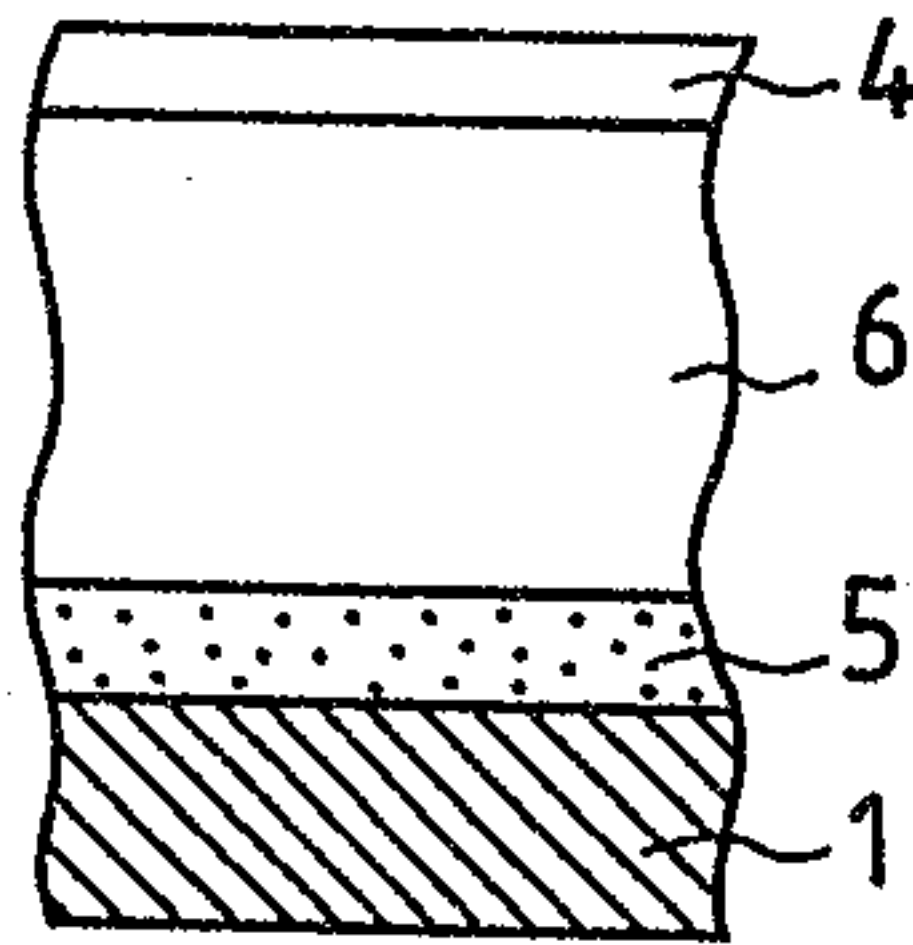


FIG. 9F

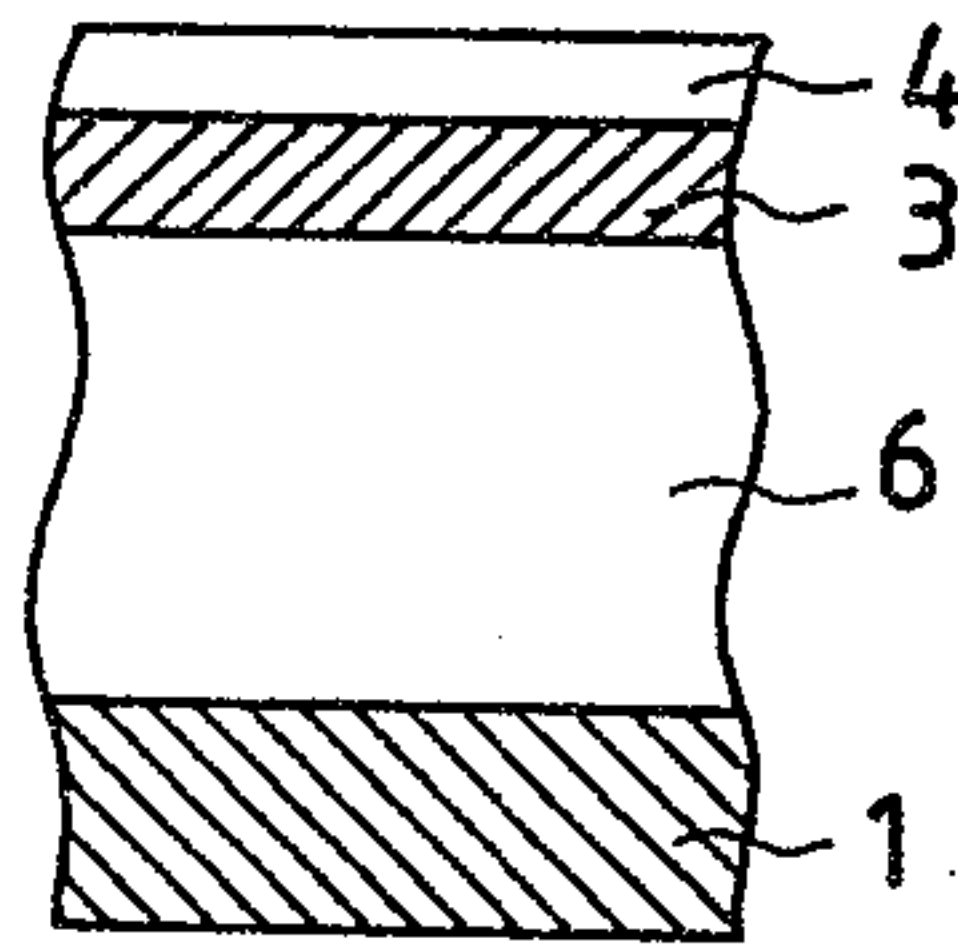


FIG. 9G

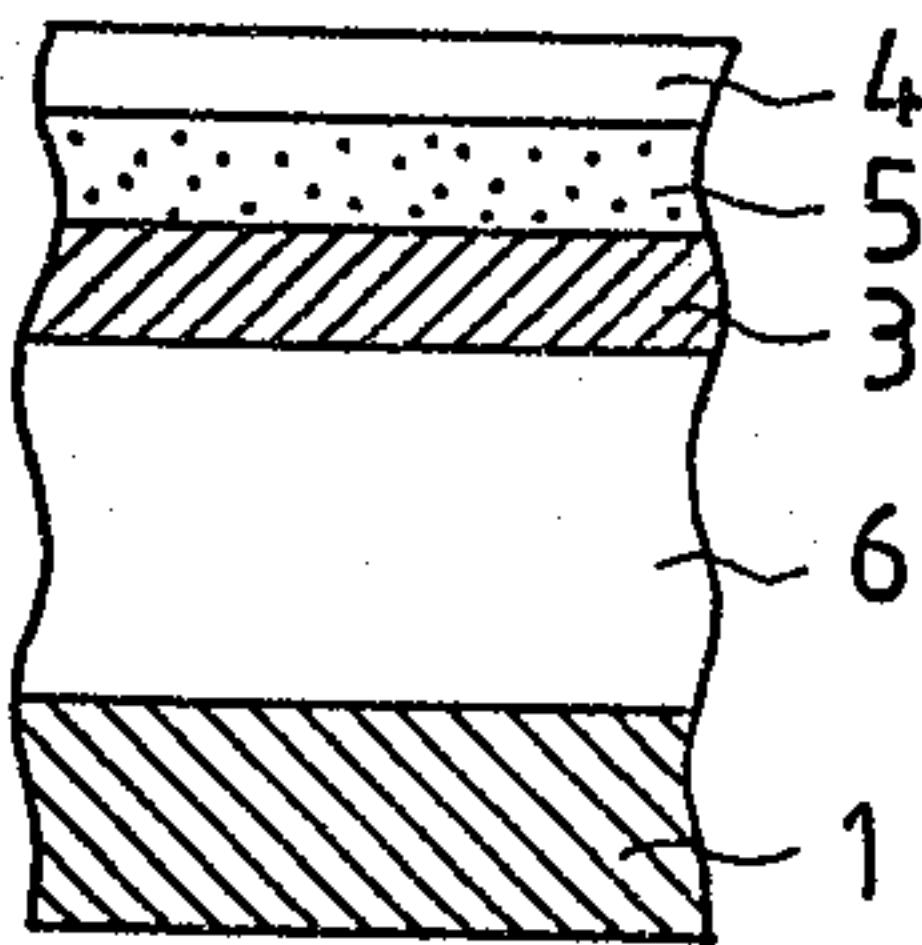


FIG. 9H

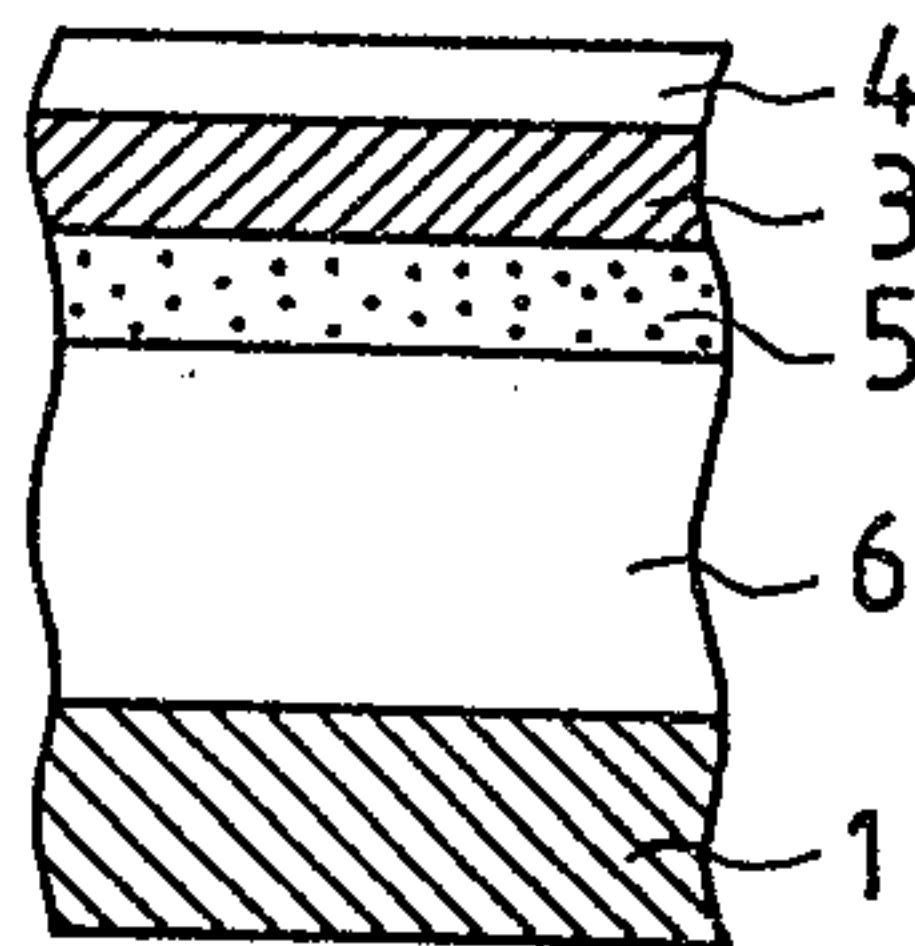


FIG. 10

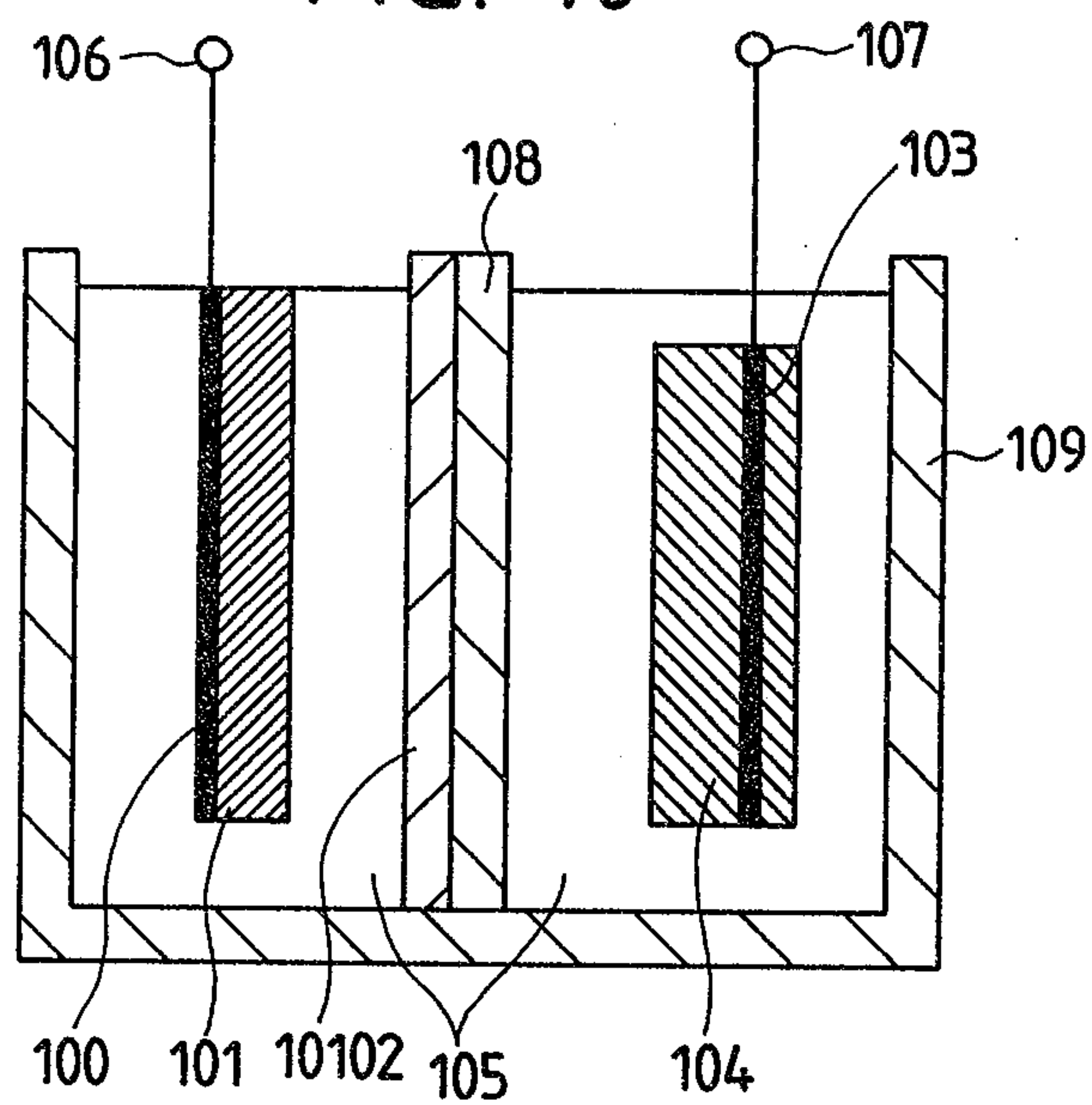
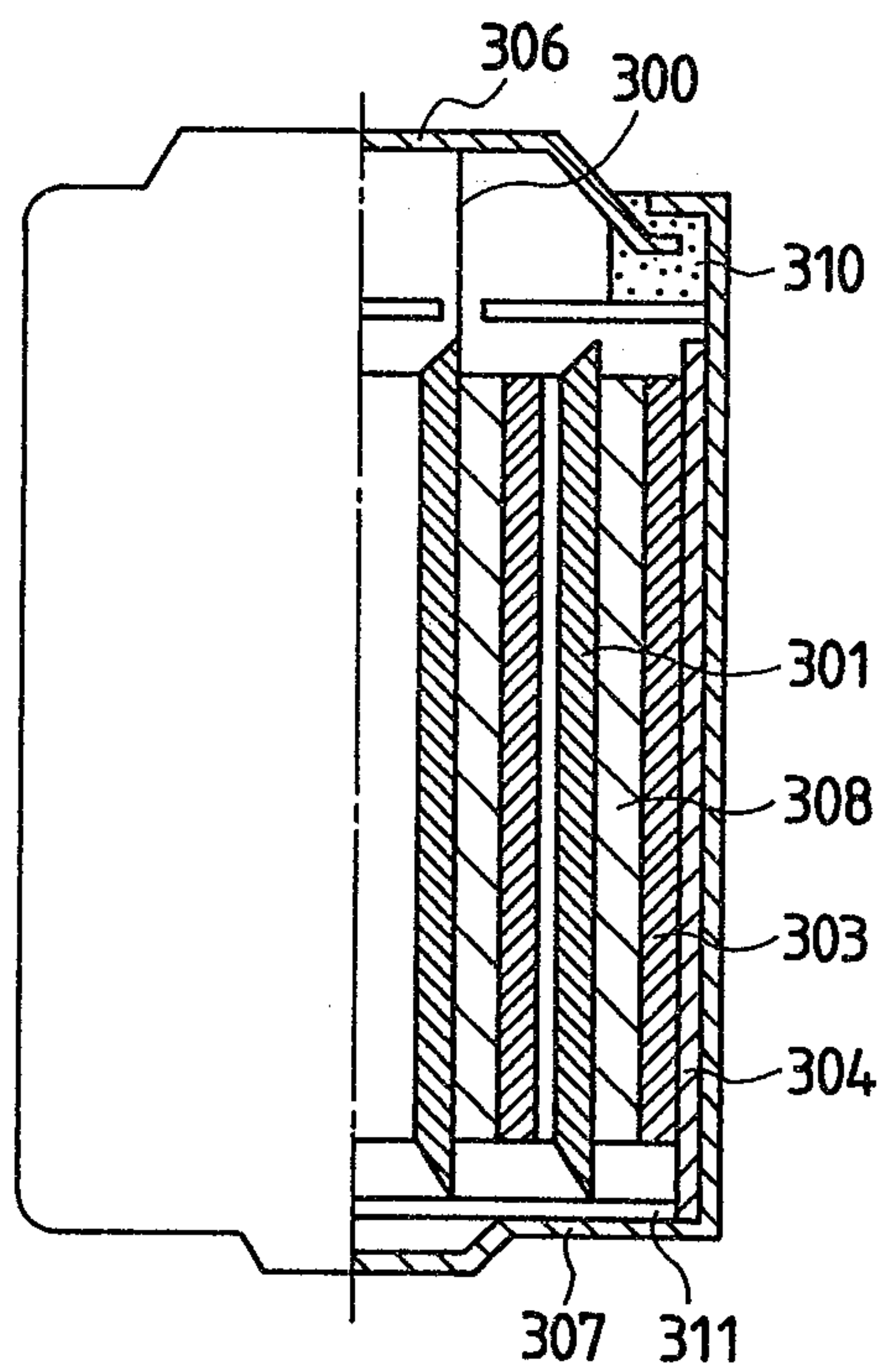


FIG. 11



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FIG. 12

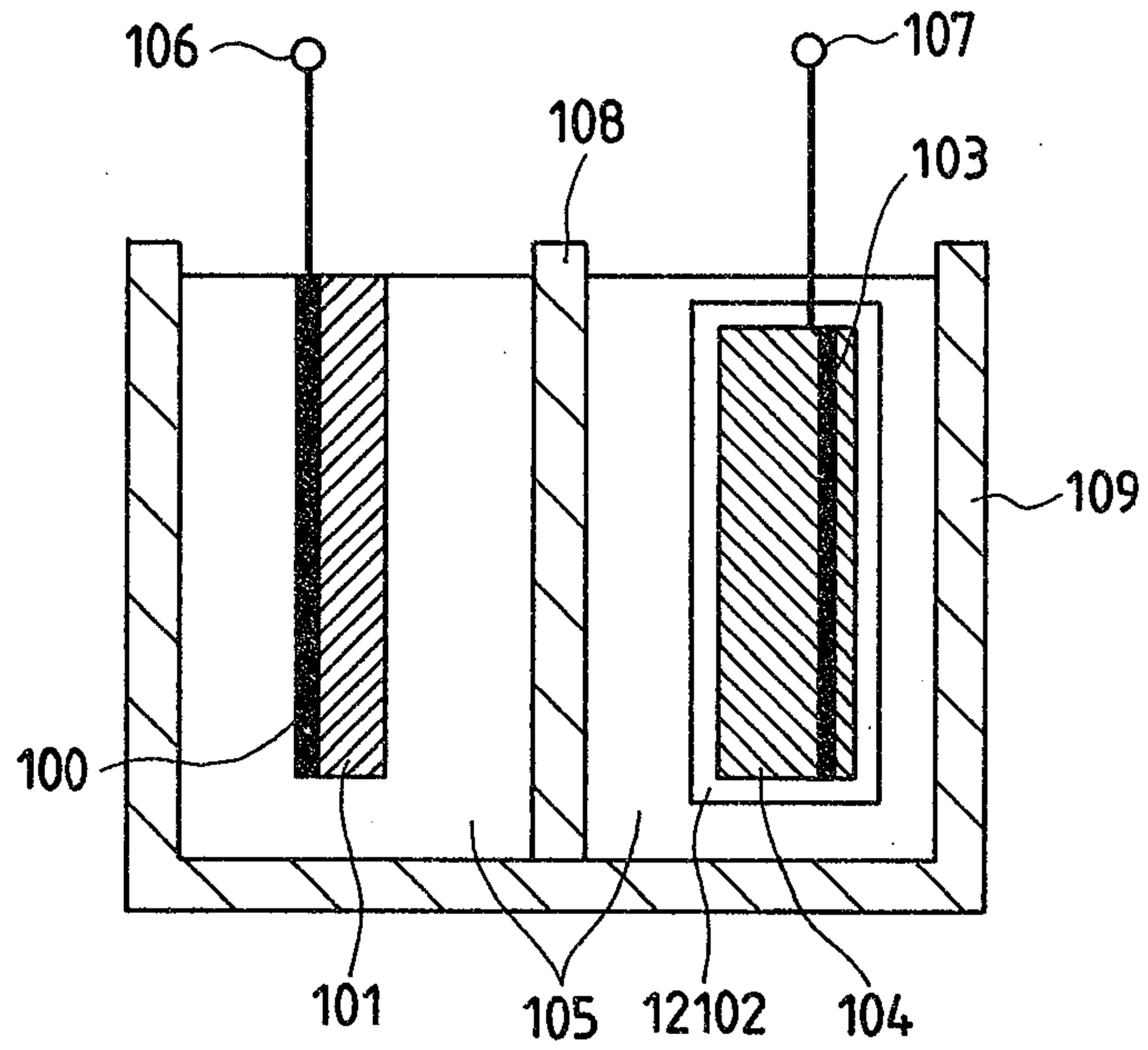


FIG. 13

