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(54) **ELECTRODE FOR ELECTRIC DOUBLE LAYER CAPACITOR, METHOD OF MANUFACTURING THE SAME, AND ELECTRIC DOUBLE LAYER CAPACITOR**

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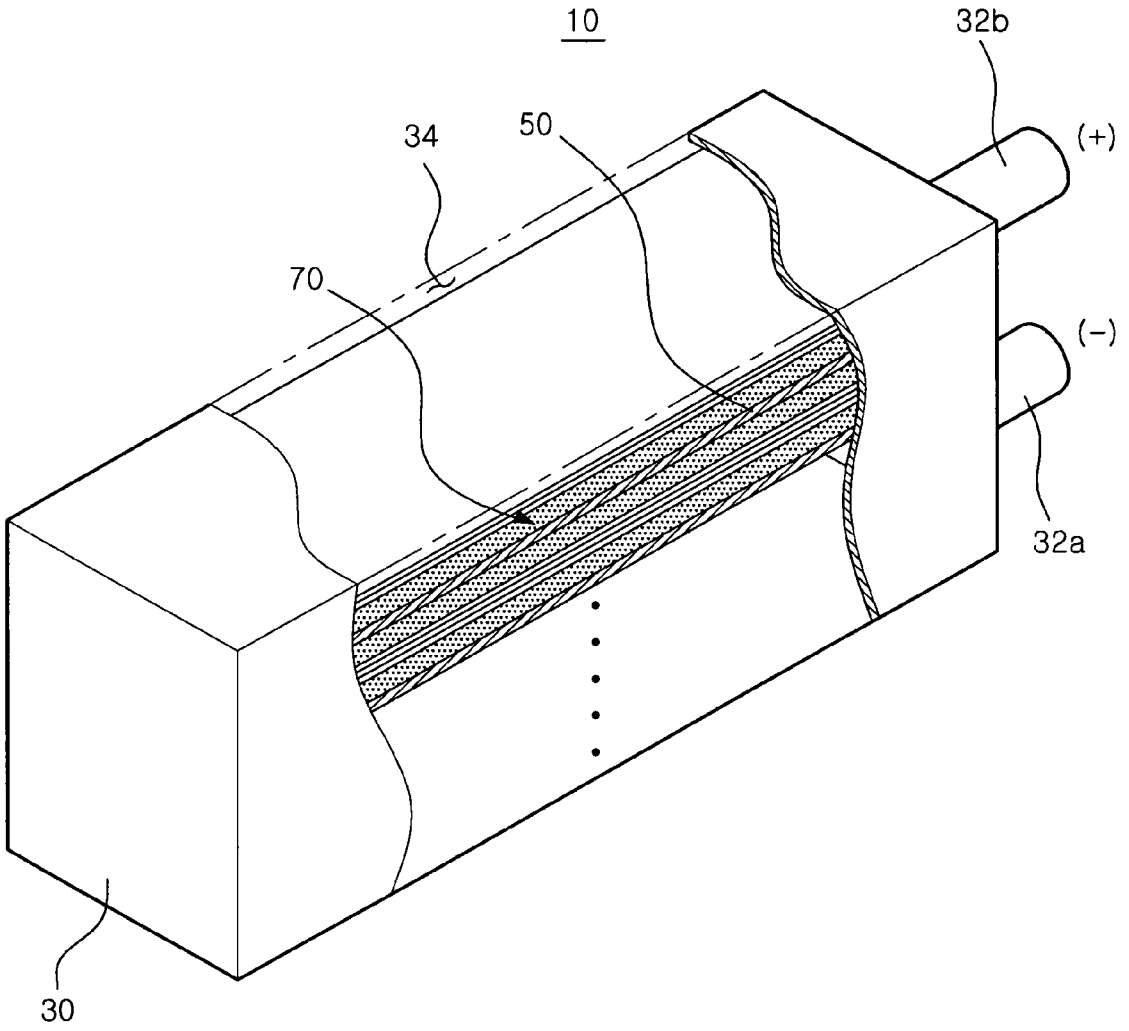
(57) **ABSTRACT**

An electrode for an electric double layer capacitor includes a current collector including an aluminum (Al) foil layer and a highly conductive metal layer having a higher conductivity than Al and laminated on the Al foil layer, a groove formed in the Al foil layer to cause the highly conductive metal layer to contact an electrode material, and an electrode layer formed of the electrode material on the groove and the Al foil layer.



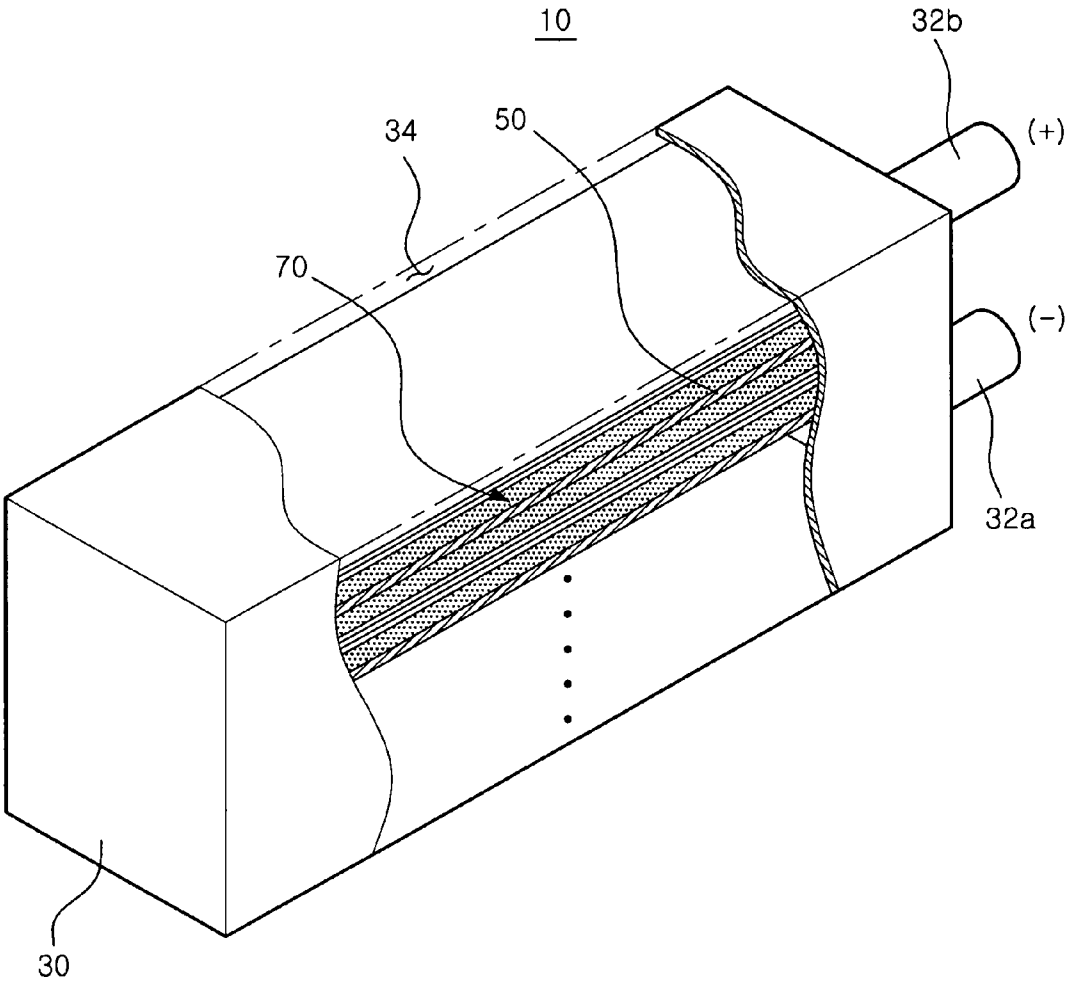


FIG. 1

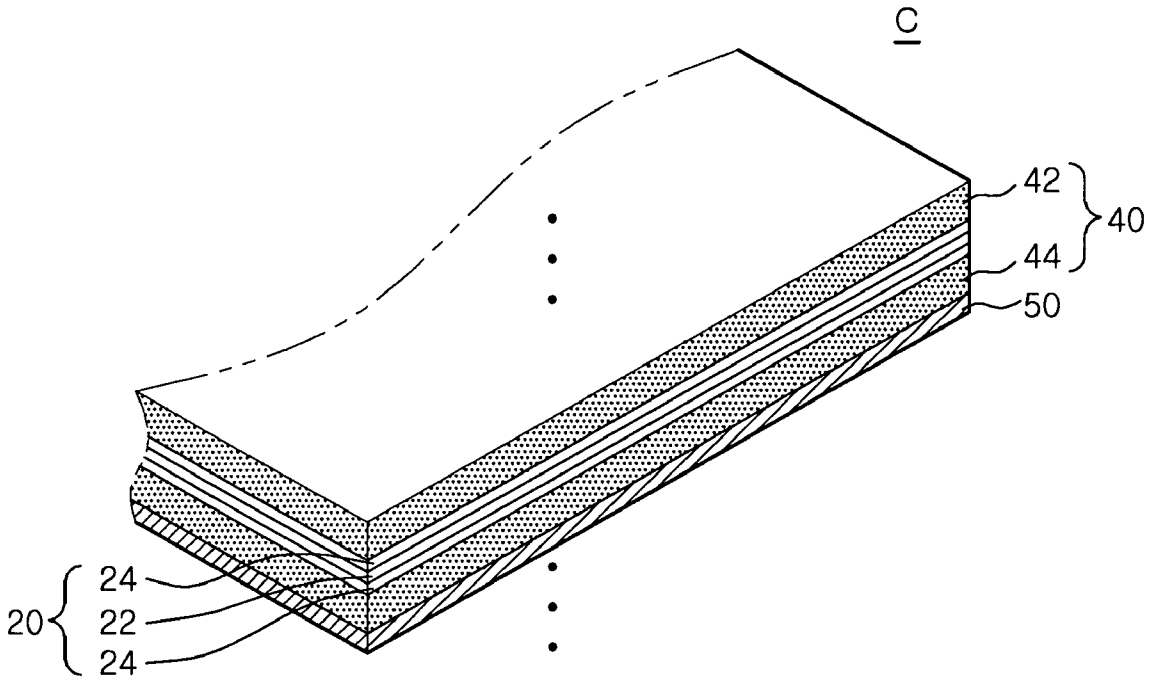


FIG. 2

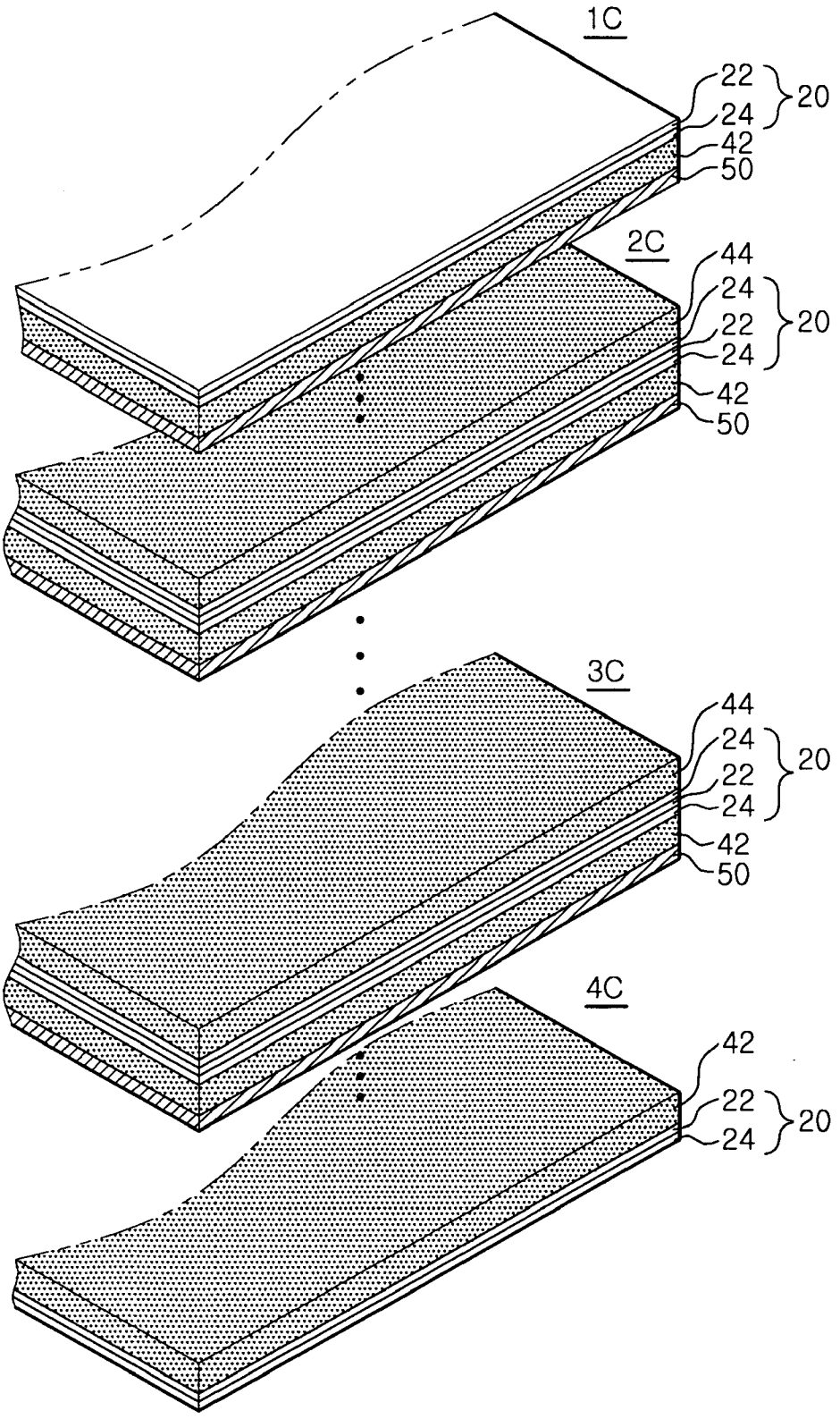

1C
22
24
20
42
50
2C
44
24
22
24
20
42
50
3C
44
24
22
24
20
42
50
4C
42
22
24
20

FIG. 3

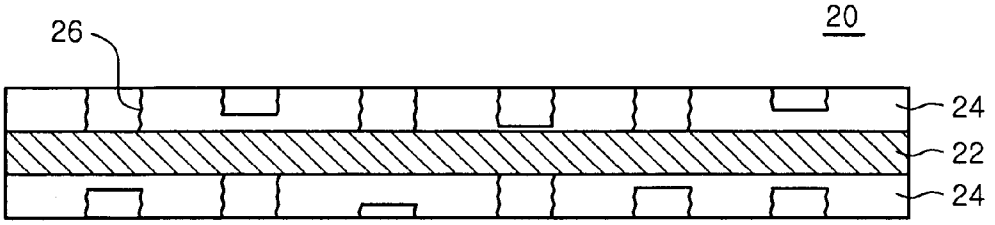


FIG. 4A

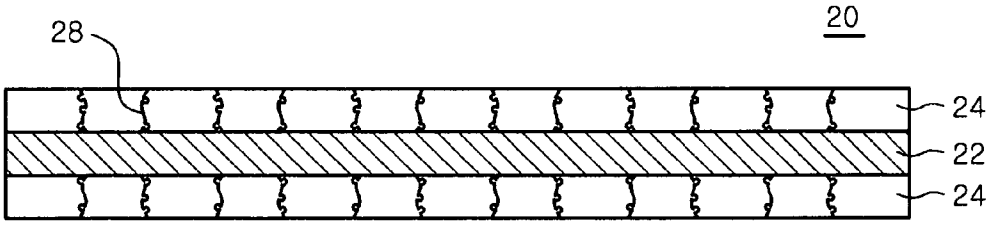


FIG. 4B

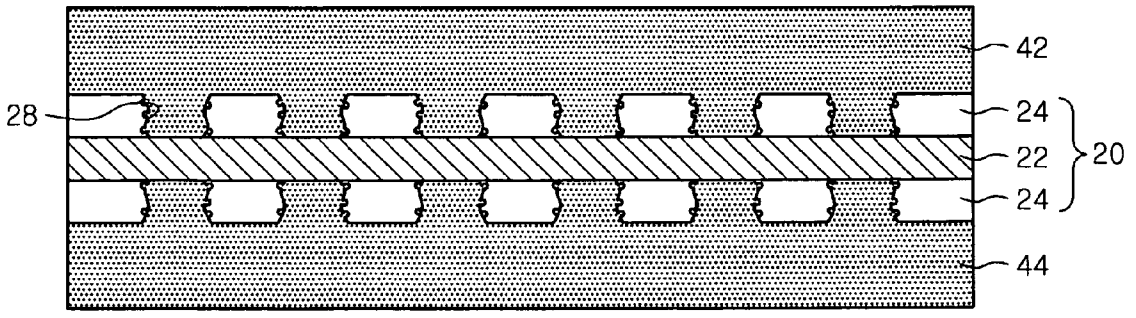


FIG. 4C

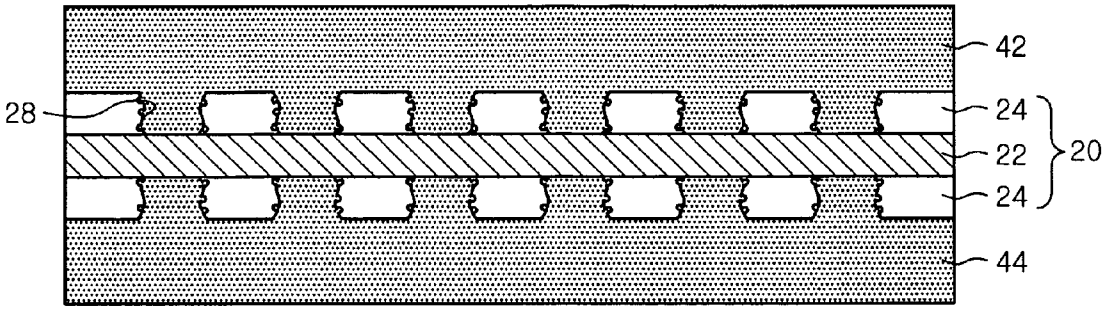


FIG. 5

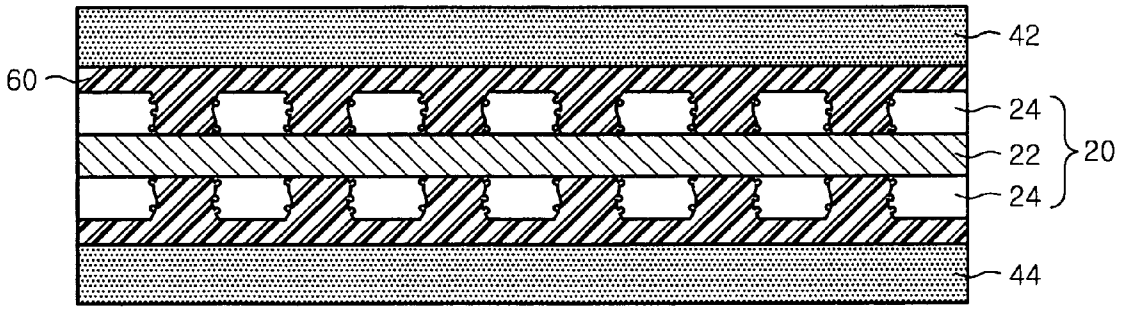


FIG. 6

ELECTRODE FOR ELECTRIC DOUBLE LAYER CAPACITOR, METHOD OF MANUFACTURING THE SAME, AND ELECTRIC DOUBLE LAYER CAPACITOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority of Korean Patent Application No. 10-2009-0057839 filed on Jun. 26, 2009, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to an electrode for an electric double layer capacitor, a method of manufacturing the same and an electric double layer capacitor, and more particularly, to an electrode for an electric double layer capacitor having an improved current-collector structure or including a current collector having a surface coated with a highly conductive material in order to acquire equivalent series resistance (ESR), a method of manufacturing the same and an electric double layer capacitor.

[0004] 2. Description of the Related Art

[0005] An electric double layer capacitor is an energy storage device that uses a pair of electrode layers (charge layers) having opposite polarities. This electric double layer capacitor has characteristics such as quick charge/discharge, high resistance to over-charge/discharge, a long useful life span due to no accompanying chemical reactions, usability in a wide range of temperatures, and the prevention of environmental pollution due to no heavy metal content.

[0006] Recently, the application range of electric double layer capacitors has expanded from systems requiring independent power supply units, control systems for momentary overload and energy storage units to backup power sources which are backup power sources operating at the time of momentary power failure.

[0007] In general, an electric double layer capacitor includes a pair of polarizing electrode layers, a separator interposed between the electrode layers to divide the electrode layers into an anode and a cathode, an aqueous electrolyte solution and a non-aqueous electrolyte solution with which the polarizing electrode layers are respectively impregnated, and a current collector collecting charges.

[0008] Low ESR is necessary in order to enhance the performance of the electric double layer capacitor. To obtain low ESR, structures for increasing the specific surface area of activated carbon used as an electrode material are being proposed.

[0009] In particular, aluminum (Al) foil having a porous surface is used as a current collector, and activated carbon, the electrode material, is provided into the pores of the porous surface, thereby reducing ESR.

[0010] However, acquiring lower ESR than that by the above ESR reduction method needs to be studied so as to diversify the applicability of electric double layer capacitors and ensure high electric capacity thereof.

SUMMARY OF THE INVENTION

[0011] An aspect of the present invention provides an electrode for an electric double layer capacitor, which can realize low ESR by changing the structure of a current collector in a way that reduces charge-transfer resistance, a method of manufacturing the same, and an electric double layer capacitor.

[0012] An aspect of the present invention also provides an electrode for an electric double layer capacitor, which can realize low ESR by placing a material, having a higher conductivity than an electrode material, between a current collector and the electrode material, a method of manufacturing the same, and an electric double layer capacitor.

[0013] According to an aspect of the present invention, there is provided an electrode for an electric double layer capacitor, the electrode including: a current collector including an aluminum (Al) foil layer and a highly conductive metal layer having a higher conductivity than Al and laminated on the Al foil layer; a groove formed in the Al foil layer to cause the highly conductive metal layer to contact an electrode material; and an electrode layer formed of the electrode material on the groove and the Al foil layer.

[0014] The groove of the Al foil layer may have a rough surface.

[0015] The groove may be formed by using etching to expand a contact area of the Al foil layer with the electrode material.

[0016] The current collector may include another Al foil layer laminated on the highly conductive metal layer on the Al foil layer.

[0017] The highly conductive metal layer may be formed of any one selected from the group consisting of Cu, Ag, Au and Pt.

[0018] The electrode material may include: a highly conductive polymer material directly contacting the highly conductive metal layer; and an activated carbon electrode material coated on the polymer material.

[0019] According to another aspect of the present invention, there is provided an electric double layer capacitor including: a plurality of electrode cells, each including a current collector including an Al foil layer and a highly conductive metal layer having a higher conductivity than Al and laminated on the Al foil layer, electrode layers each formed of an electrode material contacting the highly conductive metal layer, and a separator separating the electrode layers; an internal electrode cell formed by successively laminating the plurality of electrode cells; and a metal case filled with an electrolyte solution and receiving the internal electrode cell.

[0020] A groove may be formed in the Al foil layer and have a rough surface.

[0021] The groove may be formed using etching to expand a contact area of the Al foil layer with the electrode material.

[0022] The current collector may include another Al foil layer laminated on the highly conductive metal layer disposed on the Al foil layer.

[0023] The highly conductive metal layer may be formed of any one selected from the group consisting of Cu, Ag, Au and Pt.

[0024] The electrode material may include: a highly conductive polymer material directly contacting the highly conductive metal layer; and an activated carbon electrode material coated on the polymer material.

[0025] According to another aspect of the present invention, there is provided a method of manufacturing an electrode for an electric double layer capacitor, the method including: providing a highly conductive metal layer on an Al foil layer to prepare a current collector; forming a groove in a surface of the Al foil layer, the groove communicating with

the highly conductive metal layer; and injecting an electrode material into the groove to coat the groove and the Al foil layer with the electrode material.

[0026] The forming of the groove in the surface of the Al foil layer may include roughening the surface of the groove of the Al foil layer by using etching.

[0027] The current collector may include another Al foil layer laminated on the highly conductive metal layer disposed on the Al foil layer.

[0028] The highly conductive metal layer may be formed of any one selected from the group consisting of Cu, Ag, Au and Pt.

[0029] The electrode material may include: a highly conductive polymer material directly contacting the highly conductive metal layer; and an activated carbon electrode material coated on the polymer material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The above and other aspects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

[0031] FIG. **1** is a partially cut-away perspective view illustrating an electric double layer capacitor according to an exemplary embodiment of the present invention;

[0032] FIG. **2** is a schematic perspective view illustrating one example of an electrode cell inside an electric double layer capacitor according to an exemplary embodiment of the present invention;

[0033] FIG. **3** is a schematic perspective view illustrating one example of laminated electrode cells inside an electric double layer capacitor according to an exemplary embodiment of the present invention;

[0034] FIGS. **4**A through **4**C are schematic views illustrating a method of manufacturing an electrode for an electric double layer capacitor according to an exemplary embodiment of the present invention;

[0035] FIG. **5** is a schematic view illustrating the flow of charges in an electrode for an electric double layer capacitor, which is manufactured according to an exemplary embodiment of the present invention; and

[0036] FIG. **6** is a schematic view illustrating that a highly conductive polymer material is applied on an Al foil layer before an electrode layer is formed of an activated carbon electrode material in manufacturing an electrode for an electric double layer capacitor according to an exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0037] Exemplary embodiments of the present invention will now be described in detail with reference to the accompanying drawings. The invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

[0038] Like reference numerals in the drawings denote like elements, and thus their description will be omitted.

[0039] FIG. **1** is a partially cut-away perspective view illustrating an electric double layer capacitor according to an exemplary embodiment of the present invention. FIG. **2** is a schematic perspective view illustrating one example of an electrode cell inside an electric double layer capacitor according to an exemplary embodiment of the present invention. FIG. **3** is a schematic perspective view illustrating one example of laminated electrode cells inside an electric double layer capacitor according to an exemplary embodiment of the present invention;

[0040] Referring to FIGS. **1** through **3**, an electric double layer capacitor **10**, according to an exemplary embodiment, includes a plurality of electrode cells **1**C to **4**C, an internal electrode cell **70** formed by successively laminating the plurality of cells **1**C to **4**C, and a metal case **30** filled with an electrolyte solution **34** and receiving the internal electrode cell **70**.

[0041] The electrode cell C is one base unit in the internal electrode cell **70** of the electric double layer capacitor **10**, and includes a current collector **20**, an electrode layer **40** including first and second electrode layers **42** and **44**, and a separator **50** separating the first and second electrode layers **42** and **44** from each other so as to prevent a short-circuit.

[0042] The current collector **20** includes an Al foil layer **24** and a highly conductive metal layer **22** having a higher conductivity than Al and laminated on the Al foil layer **24**. Here, the highly conductive metal layer **22** refers to a metal having a higher conductivity than Al, and may be any one selected from the group consisting of Cu, Ag, Au and Pt in this embodiment.

[0043] Grooves **26** (see FIG. **4**A) are formed in the Al foil layer **24** in order to allow an electrode material to contact the highly conductive metal layer **22**.

[0044] According to the location of the current collector **20** in the metal case **30**, the highly conductive metal layer **22** may be laminated on one surface of the Al foil layer **24** or may be disposed between the Al foil layer **24** and another foil layer **24**.

[0045] The grooves **26** are formed in the surface of the Al foil layer **24** and cause an electrode material to contact the highly conductive metal layer **22**. Here, the grooves **26** are formed by cutting the Al foil layer **24**, and the surfaces of grooves **26** of the Al foil layer **24** are roughened.

[0046] The grooves **26** may be formed by etching in order to expand the contact area of the Al foil layer **24** with the electrode material. The roughened surface of the Al foil layer **24** may increase the amount of electrode material of the first and second electrode layers **42** and **44** laminated on the Al foil layer **24** to a maximum extent. This contributes to a reduction in ESR existing between the Al foil layer **24** and the electrode material.

[0047] Since the electrode material directly contacts the high conductive metal **22** that has a higher conductivity than the Al foil layer **24**, generated charges can move through the highly conductive metal layer **22**, thereby further reducing the ESR.

[0048] By reducing the ESR of an electric double layer capacitor in the above-described manner, a high output power density can be enhanced, which is one of advantages of the electric double layer capacitor.

[0049] The metal case **30** provides a space allowing the internal electrode cell **70** to be received in the electrolyte solution **34**, and includes collector terminals **32***a* and **32***b* exposed to the outside for surface-mounting on a board. Such an electric double layer capacitor **10** may be applied not only to a chip type but also to a coin type.

[0050] In the event that the electric double layer capacitor **10** is surface-mounted, the internal electrode cell **70** needs to be protected from a high temperature of about 260° C. in the surface-mounting, and a liquid electrolyte must be prevented from leaking. In this regard, the case is preferably formed of a metal material rather than resin such as an epoxy.

[0051] The electrode material of the first and second electrode layers **42** and **44** may utilize a polarizable electrode material, such as activated carbon having a relatively high specific surface area. The first and second electrode layers **42** and **44** are impregnated with an electrolyte solution such as an aqueous sulfuric acid solution, thereby serving as charge layers.

[0052] The first and second electrode layers **42** and **44** may be produced by forming an electrode material mainly formed of activated carbon powder into a solid type sheet, or by fixing an electrode material slurry onto the current collector **20**.

[0053] The electrode material may include a highly conductive polymer material directly contacting the highly conductive metal layer **22**, and an activated carbon electrode material coated on the highly conductive polymer material. In detail, the highly conductive polymer material may be laminated first on the grooves **26** in the Al foil layer **24**, and then coated with the activated carbon electrode material (see FIG. **6**).

[0054] The separator **50** may be formed of a porous material in order to enable the transport of ions. The separator **50** may be formed of a material such as polypropylene, polyethylene, glass fiber or the like.

[0055] Hereinafter, a method of manufacturing an electrode for an electric double layer capacitor, according to an exemplary embodiment of the present invention, will be described.

[0056] FIGS. **4**A through **4**C are schematic views illustrating a method of manufacturing an electrode for an electric double layer capacitor, according to an exemplary embodiment of the present invention.

[0057] Referring to FIGS. **4**A through **4**C, a highly conductive metal layer **22** is provided on the Al foil layer **24** to thereby prepare a current collector **20**. Grooves **26** are formed in the surface of the Al foil layer **24** so as to communicate with the highly conductive metal layer **26**.

[0058] After the grooves **26** are formed in the Al foil layer **24**, the Al foil layer **24** may be disposed on the highly conductive metal layer **22**. Thus, the lamination order of the Al foil layer **24** and the highly conductive metal layer **22** and the formation order of the grooves **26** may be changed.

[0059] Here, in the current collector **20**, the highly conductive metal layer **22** may be interposed between the Al foil layers **24**. The description of the kind of highly conductive metal layer **22** is substituted with the above description.

[0060] As shown in FIG. **4**A, the grooves **26** are formed by cutting the surface of the Al foil layer **24**. Then, as shown in FIG. **4**B, the surfaces of the grooves **26** of the Al foil layer **24** are etched be roughened. In FIG. **4**B, reference numeral **28** indicates an etched surface formed by the etching.

[0061] As shown in FIG. **4**C, an electrode material is injected into the grooves **26** of the roughened Al foil layer **24**, thereby coating the grooves **26** and the Al foil layer **24** with the electrode material.

[0062] When the surface of the Al foil layer **24** is roughened in the electric double layer capacitor **10** manufactured in the above-described manner, the amount of electrode material of the first and second electrode layers **42** and **44** laminated on the Al foil layer **24** may increase to a maximum extent, thereby reducing ESR existing between the Al foil layer **24** and the electrode material.

[0063] Since the electrode material directly contacts the highly conductive metal layer **22** which has a higher conductivity than the Al foil layer **24**, generated charges can move through the highly conductive metal layer **22** to thereby further reduce ESR. FIG. **5** is a schematic view illustrating the flow of charges in the capacitor for an electric double layer capacitor manufactured according to an exemplary embodiment of the present invention.

[0064] A reduction in the ESR of an electric double layer capacitor may be contribute to enhancing high output power density, which is one of advantages of the electric double layer capacitor.

[0065] FIG. **6** is a schematic view illustrating that a highly conductive polymer material is applied to the Al foil layers before the electrode layers are formed of an activated carbon electrode material in manufacturing an electrode for an electric double layer capacitor according to an exemplary embodiment of the present invention.

[0066] Referring to FIG. **6**, when the electrode for an electric double layer capacitor is in the state depicted in FIG. **4**B, the highly conductive polymer material **60** is injected before the activated carbon electrode material so that the highly conductive polymer material directly contacts the highly conductive metal layer. This further lowers the ESR of the electric double layer capacitor and increases its high output power density.

[0067] As set forth above, in an electrode for an electric double layer capacitor, a method of manufacturing the same, and an electric double layer capacitor according to exemplary embodiments of the invention, the current collector includes the highly conductive metal layer on the Al foil layer, and the highly conductive metal layer directly contacts the electrode material. Consequently, charge-transfer resistance can be reduced.

[0068] Furthermore, a highly conductive polymer material is interposed between the current collector and the electrode material, thereby implementing low ESR and high output power in an electric double layer capacitor.

[0069] While the present invention has been shown and described in connection with the exemplary embodiments, it will be apparent to those skilled in the art that modifications and variations can be made without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. An electrode for an electric double layer capacitor, the electrode comprising:

a current collector including an aluminum (Al) foil layer and a highly conductive metal layer having a higher conductivity than Al and laminated on the Al foil layer;

a groove formed in the Al foil layer to cause the highly conductive metal layer to contact an electrode material; and

an electrode layer formed of the electrode material on the groove and the Al foil layer.

2. The electrode for an electric double layer capacitor of claim **1**, wherein the groove of the Al foil layer has a rough surface.

3. The electrode of claim **1**, wherein the groove is formed by using etching to expand a contact area of the Al foil layer with the electrode material.

4. The electrode for an electric double layer capacitor of claim **1**, wherein the current collector includes another Al foil layer laminated on the highly conductive metal layer on the Al foil layer.

5. The electrode for an electric double layer capacitor of claim **1**, wherein the highly conductive metal layer is formed of any one selected from the group consisting of Cu, Ag, Au and Pt.

6. The electrode for an electric double layer capacitor of claim **1**, wherein the electrode material includes:

a highly conductive polymer material directly contacting the highly conductive metal layer; and

an activated carbon electrode material coated on the polymer material.

7. An electric double layer capacitor comprising:

a plurality of electrode cells, each including a current collector including an Al foil layer and a highly conductive metal layer having a higher conductivity than the Al and laminated on the Al foil layer, electrode layers each formed of an electrode material contacting the highly conductive metal layer, and a separator separating the electrode layers;

an internal electrode cell formed by successively laminating the plurality of electrode cells; and

a metal case filled with an electrolyte solution and receiving the internal electrode cell.

8. The electric double layer capacitor of claim **7**, wherein a groove is formed in the Al foil layer, and has a rough surface.

9. The electric double layer capacitor of claim **8**, wherein the groove is formed using etching to expand a contact area of the Al foil layer with the electrode material.

10. The electric double layer capacitor of claim **7**, wherein the current collector includes another Al foil layer laminated on the highly conductive metal layer disposed on the Al foil layer.

11. The electric double layer capacitor of claim **7**, wherein the highly conductive metal layer is formed of any one selected from the group consisting of Cu, Ag, Au and Pt.

12. The electric double layer capacitor of claim **7**, wherein the electrode material includes:

a highly conductive polymer material directly contacting the highly conductive metal layer; and

an activated carbon electrode material coated on the polymer material.

13. A method of manufacturing an electrode for an electric double layer capacitor, the method comprising:

providing a highly conductive metal layer on an Al foil layer to prepare a current collector;

forming a groove in a surface of the Al foil layer, the groove communicating with the highly conductive metal layer; and

injecting an electrode material into the groove to coat the groove and the Al foil layer with the electrode material.

14. The method of claim **13**, wherein the forming of the groove in the surface of the Al foil layer includes roughening the surface of the groove of the Al foil layer by using etching.

15. The method of claim **13**, wherein the current collector includes another Al foil layer laminated on the highly conductive metal layer disposed on the Al foil layer.

16. The method of claim **13**, wherein the highly conductive metal layer is formed of any one selected from the group consisting of Cu, Ag, Au and Pt.

17. The method of claim **13**, wherein the electrode material includes:

a highly conductive polymer material directly contacting the highly conductive metal layer; and

an activated carbon electrode material coated on the polymer material.

* * * * *