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(54) Title: MULTI ELECTRODE SERIES CONNECTED ARRANGEMENT SUPERCAPACITOR

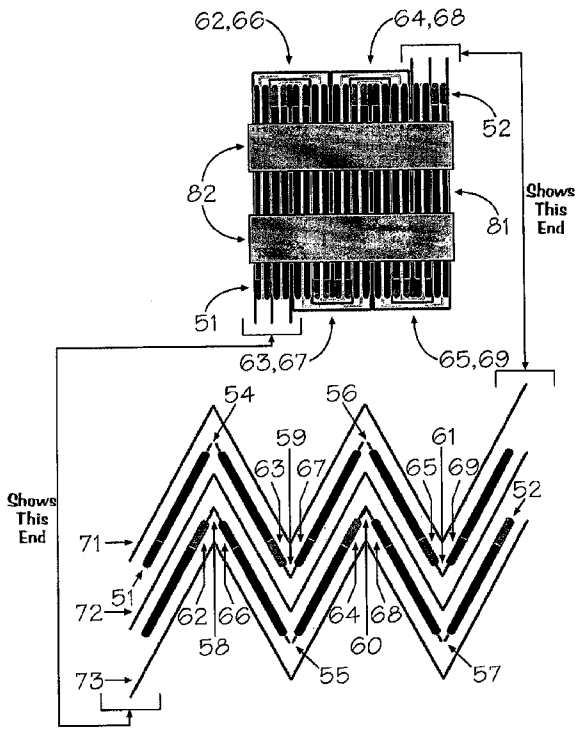


Figure 5

(57) Abstract: The present invention is an electrochemical double layer capacitor (EDLC) series stack formed into a single electrolyte cell structure. The concatenated multiple electrode assembly stack has electrode assemblies electrically connected in series. The electrode assemblies have a double-sided activated carbon electrode formed on a current collector. Power tabs are connected to the end electrode assemblies. An electrolyte is also provided. A poly bag contains the electrolyte and the electrode assemblies. The electrode assemblies form a double-sided activated-carbon electrode on a current collector. The EDLC stack has a number of segments and mass free zones separating them. The segments are folded so that mass free zones are disposed at the apex of each fold.

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MULTI ELECTRODE SERIES CONNECTED ARRANGEMENT SUPERCAPACITOR

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to and is a continuation of U.S. Nonprovisional Patent Application Serial No. 11/903,929, entitled "Multi Electrode Series Connected Arrangement Supercapacitor," filed September 25, 2007, which is hereby incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The invention pertains to electrochemical double layer capacitor devices and, more particularly, to a device fabricated using multiple series connected electrode assemblies within a single cell to form a predetermined voltage standoff.

BACKGROUND OF THE INVENTION

Direct current electronic circuits and devices that are manufactured today have specific voltage requirements for proper operation. Nominal voltages can range from 1.2 volts to hundreds of volts. The power supply, or source, must match the load requirements.

Until recently only chemical batteries with specific voltage windows were suitable for certain applications. The most common battery is the 1.5-volt single cell. In order to obtain larger voltage limits, individual battery cells

must be stacked, or concatenated in series, plus to minus to plus to minus etc. Combining individual cells into battery packs has therefore been the conventional solution to overcoming the voltage limitation of single cells. Larger batteries are merely a collection of smaller, in-series, single battery cells placed in one container with single input and output terminals.

Symmetrical, bipolar electrochemical double layer capacitors, or EDLCs, are constructed by alternately layering electrode material and separators, forming the electrode assembly a stacked structure. The electrode material is generally made, starting with capacitor grade aluminum. An activated carbon mixture is deposited or laminated on top and bottom, forming a double-sided electrode. Two of these electrodes are used, one being the positive and the other being the negative side of a simple cell. The separator is used to electrically isolate the two electrodes and also as the conductor for electrically charged protons. Typically, the completed electrode assembly is then placed in a canister with an electrolyte and then sealed becoming a one-cell structure.

Until now, as with chemical batteries, individual EDLC cells must operate within specific voltage ranges dictated by the choice of electrolyte. Electrolytes used today are available in two different forms: aqueous and aprotic. Aqueous electrolytes generally have a working window of 1.0 to 1.2 volts, per cell. Aprotic, or dampened-wetted,

electrolytes, however, have a range of 2.2 to 4.6 working volts, per cell. In this disclosure, an Acetonitrile solvent is used with a quanterry salt of 1.0M TEABF4.

It is well known to electrochemists that charged ionic transfer occurs primarily in one region, namely the Helmholtz layer. This layer is only several angstroms thick and is formed between the current collector and activated carbon. It is in this region that charged particles, negative or positive, transfer their charge to the current collector. In a neutral solution state, or a non-charged state, the electrolyte has an evenly distributed zero charge. As the electrode assembly structure gains or loses charge, the movement of charge separates individually to its own polarity terminal. The charge concentration penetrates the activated carbon material composite into the Helmholtz region to varying degrees. The level of electrolyte charge concentration is minimum at the separator and maximum at the Helmholtz region.

SUMMARY OF THE INVENTION

In accordance with the present invention there is provided an electrochemical double layer capacitor (EDLC) single cell, with electrolyte, incorporating series electrode assemblies to provide an increased voltage stack. The series voltage stack has essentially individual electrode assemblies electrically concatenated together in series. The electrodes have a double-sided activated carbon

composition formed on a capacitor grade aluminum current collector.

The EDLC stack has a number of segments and mass free zones separating them. The segments are folded so that mass free zones are disposed at the apex of each fold. Power tabs, plus and minus, are connected to the end extensions of the electrode assemblies. Monitor/control tabs are operatively attached and extended from the series connected segments. In one embodiment, a poly bag, as a single cell, contains the electrolyte and the electrode assemblies. Power and monitor/control tabs are operatively extended from the electrode assemblies. The EDLC stack has a number of segments and mass free zones separating them. The segments are folded so that mass free zones are disposed at the apex of each fold.

BRIEF DESCRIPTION OF THE DRAWINGS

Various objects, features, and attendant advantages of the present invention will become more fully appreciated as the same becomes better understood when considered in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the several views, and wherein:

FIGURE 1a is a front view of the components of a single EDLC device of the prior art;

FIGURE 1b is a side view of the single EDLC device of FIGURE 1a assembled;

FIGURE 2 is an illustration of 12-volt EDLC unit with external monitor/control leads;

FIGURE 3 is an illustration of the front side, top and bottom side of two electrodes specifically manufactured for an integrated assembly of a 12 volt stacked arrangement;

FIGURE 4 is an illustration of the backside, top and bottom side of two electrodes specifically manufactured for an integrated assembly of a 12 volt stacked arrangement;

FIGURE 5 is an illustration of a complete 12 volt series electrode assembly showing power and monitor/control voltage taps incorporated into the folding scheme; and

FIGURE 6 is an illustration of a completed single cell series connected 12-volt device packaged within a poly bag container with power and monitor/control lead extensions.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention is a symmetrical bipolar electrochemical double layer capacitor device. A series multiple voltage stack has electrode assemblies electrically connected in series. The electrode assemblies have a double-sided activated carbon electrode formed on a current collector. A poly bag is used to contain the electrolyte and the

electrode assemblies.

Two embodiments have been developed for increasing the voltage standoff of a single cell device typically rated at 2.7-volts. Although a 12-volt cell is described herein, it should be understood that any other voltage can be obtained including, but not limited to 12-volt cells.

Individual EDLC electrodes and required separator 10 is shown in Figures 1 and the completed assembly 20 in Figure 1b. A typical electrolyte window of 2.7-volts (1M $TEABF_4$/ACN) of the EDLC electrode assembly 20 is divided into the required voltage needed by the application. The primary consideration is that the electrolyte depends only on the first electrode assembly and its electrolyte voltage window when considering a series string of EDLCs.

Two double sided activated carbon electrodes 11 and 12 are disposed parallel to each other, as shown. Separators 13 and 14 extend between and beneath the two electrodes 11, 12. A negative bare aluminum foil tab 16 and a positive bare aluminum foil tab 15 extend from the respective electrodes 12, 11. Although the electrodes 11, 12 and separators 13, 14 are shown offset from each other in Figure 1a, this depiction is only illustrative. Electrodes 11, 12 are rolled from bottom to top, leaving terminal tabs 15, 16, respectively, exposed 180° from each other.

Referring now also to Figure 1b, top view of EDLC electrodes 10 shows negative and positive tabs 16, 15,

respectively. Separators 14, 13 electrically isolate electrodes 12, 11. Kapton tape 21 binds the package of electrodes 12, 11 and separators 14, 13, like a sandwich. The amount of activated carbon and composite material used in fabricating the single EDLC 10, 20 is dependent on the required capacitance of the total cell.

Referring now to Figure 2, there is shown a single EDLC device 10 using only one electrolyte 43, not shown, for an entire structure comprising five concatenated electrode assemblies, 34-38. The voltage monitor/control tabs 39-42 are extended external to the pouch bag 31. The power tabs 32, 33 and voltage control\monitor tabs 39-42 provide the complete electrical interface. Figure 2 shows a complete 12-volt EDLC in a poly bag package.

Using an electrolyte with 1.0 M of $TEABF_4$ in Acetonitrile limits the voltage to 2.7 volts. This now becomes the determining factor for the total number of electrode assemblies required for the entire stack 30. For example, a 12-volt cell requires five assemblies, as shown. The current collector interface tabs between electrode assemblies are sonically welded 32 to minimize electrical lead resistance.

It is difficult to manufacture individual electrodes to contain the exact amount of capacitance so that all assemblies in the stack are identical. It is for this reason monitor/control terminal tabs 39-42 are available

externally.

Poly bag 31 is constructed with multiple layers, not shown. Poly bag 31 provides a lightweight, puncture resistant, airtight seal having a long service factor and being chemically indifferent to the electrolyte used within this embodiment. Poly bag 31 also has a small form factor since all gas can be replaced with nitrogen, then purged and supplemented with electrolyte to form a vacuum tight seal. The sealant material is a linear, low-density polyethylene that reforms below 120°C. A low-density polyethylene layer is then applied and used as a tie layer. Tie layers are very thin layers binding and holding two different materials together. Copper is used as the chemically non-reactive foil layer to moisture-proof the assembly. The copper is sandwiched between another low-density polyethylene tie layer. The outermost, puncture resistant material is a layer of polyethylene terephthalate.

A specific voltage standoff EDLC need not necessarily have individual electrode assemblies separately made and connected by welding, such as shown in the preferred embodiment (Figure 2). The two electrodes required for each electrode assembly encompassed into a single cell EDLC can be manufactured to accommodate separate activated carbon partitions, this being the individual electrode assemblies in series on the current collector capacitor grade aluminum.

Figure 3 illustrates the front, top and bottom views of

two electrodes on one side of a complete EDLC unit, Figure 5, whereas Figure 4 illustrates the backside, top and bottom views thereof. A fold line 53 (Figure 3) indicates where the top and bottom portions of the electrode arrangement are folded. Similarly, in Figure 4, folded line 53 indicates the location at which the top and bottom electrodes 50a are folded and overlap.

The 12-volt manufactured electrode of Figures 3 and 4 has a total of ten activated carbon pads on each side of the electrode that are carbon isolated from each other. The tabs of Figures 3 and 4 can be color coded to indicate the specific voltage polarity segments. Figures 3 and 4 show both the front and back of the device, activated carbon pads segmented areas being imprinted onto two aluminum current collectors of which a two-electrode structure can be configured for a 12-volt stack. Other electrode arrangements can also be configured for larger and smaller voltage stack arrangements as desired.

The capacitance of each pad and its arrangement on the current collector determines the total cell capacitance. The activated carbon mix has a specific capacitance associated with its inherent physical properties, such as pore size and pore size distribution. The carbon loading and specific capacitance yields the desired capacitance in farads per cubic centimeter, F/cm^3. Since the application voltage standoff dictates the volumetric pad size, the volume of the pad must be calculated, LxWxH. An individual

pad is designed and duplicated to populate the entire current collector interface.

Referring to Figures 3 and 4, pad areas of the carbon composite on the current collector must be identified to ensure voltage isolation between the individual electrode terminals. Areas 54-57 are clean cut or foil free relative the rest of the assembly.

Referring now to Figures 5 and 6, the single electrode aluminum current collector structure as depicted in Figures 3 and 4 is first made by layering a thin coating of specially formulated activated carbons and binder combination, not shown, onto an aluminum current collector. The capacitance is designed into electrodes 50, 50a by the physical area of carbon applied, LxWxH. Mass-free zones 58-61 are carbonless and are used as the folding points, along with the clean cut areas 54-57 for the series electrode voltage stages. Two separate and physically different electrodes are provided, one being the positive and one being a negative electrode. The unique folding scheme creates five segments in series for a single cell double layer capacitor. Since each electrode has carbon composites on both sides, the bipolar carbon composite layout for each electrode (Figure 3) matches the alternate electrical pole (Figure 4) precisely.

The material for poly bag 92 (Figure 6) is cut into the desired shape of the electrode assembly 81 with provisions made for extension of the poly bag material to extend beyond

the electrode assembly edge, providing a better seal around the tabbed leads 94 (62,66), 95 (63,67), 96 (64,68), and 97 (65,69). The total number of extensions in the 12 volt assembly 80 protruding to the outside of the poly bag 92 includes power 71 and ground 52 with four tabs 94-97 for the individual connections to the series stack.. The individual series cell aluminum tabs are sonically welded to copper or aluminum flat stock materials, which are brought out through the poly bag 92.

Since other modifications and changes varied to fit particular operating requirements and environments will be apparent to those skilled in the art, the invention is not considered limited to the example chosen for purposes of disclosure, and covers all changes and modifications which do not constitute departures from the true spirit and scope of this invention.

Having thus described the invention, what is desired to be protected by Letters Patent is presented in the subsequently appended claims.

What is claimed is:

1. An electrochemical double layer capacitor (EDLC) stack comprising:

a) a series multiple voltage stack comprising a plurality of electrode assemblies electrically connected in series, said electrode assemblies comprising a double-sided activated carbon electrode formed on a current collector;

b) an electrolyte; and

c) a poly bag for containing said electrolyte and said plurality of electrode assemblies.

2. The EDLC stack in accordance with claim 1, further comprising power tabs operatively connected to said plurality of electrode assemblies.

3. The EDLC stack in accordance with claim 1, wherein said poly bag provides an external interface for said cell stack.

4. The EDLC stack in accordance with claim 1, wherein said electrode assemblies comprise a double-sided activated carbon electrode formed on a current collector.

5. The EDLC stack in accordance with claim 1, wherein said EDLC stack comprises a plurality of segments and further

comprising a plurality of mass free zones separating said plurality of segments.

6. The EDLC stack in accordance with claim 5, wherein said plurality of segments is folded so that said mass free zones are disposed at the apex of said folds.

7. The EDLC stack in accordance with claim 1, wherein said poly bag is shaped to conform to said EDLC stack.

8. The EDLC stack in accordance with claim 1, wherein said poly bag comprises a one cell structure having one electrolyte source for accommodating a plurality of variant voltage stacks, thereby yielding a variant of different terminal voltage limits.

9. An electrochemical double layer capacitor (EDLC) stack comprising:

a) a series multiple voltage stack comprising a plurality of electrode assemblies electrically connected in series;

b) an electrolyte; and

c) a poly bag for containing said plurality of electrode assemblies.

10. The EDLC stack in accordance with claim 9, further comprising power tabs operatively connected to said plurality of electrode assemblies.

11. The EDLC stack in accordance with claim 9, wherein said poly bag provides an external interface for said cell stack.

12. The EDLC stack in accordance with claim 9, wherein said electrode assemblies comprise a double-sided activated carbon electrode formed on a current collector.

13. The EDLC stack in accordance with claim 9, wherein said EDLC stack comprises a plurality of segments and further comprising a plurality of mass free zones separating said plurality of segments.

14. The EDLC stack in accordance with claim 13, wherein said plurality of segments is folded so that said mass free zones are disposed at the apex of said folds.

15. The EDLC stack in accordance with claim 9, wherein said poly bag is shaped to conform to said EDLC stack.

16. The EDLC stack in accordance with claim 9, wherein said poly bag is a one cell structure containing one electrolyte source which can accommodate a multitude of variant voltage stacks thereby yielding a variant of different terminal voltage limits.

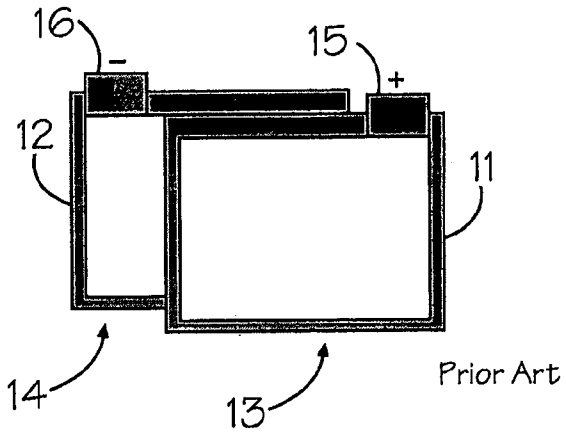


Figure 1a

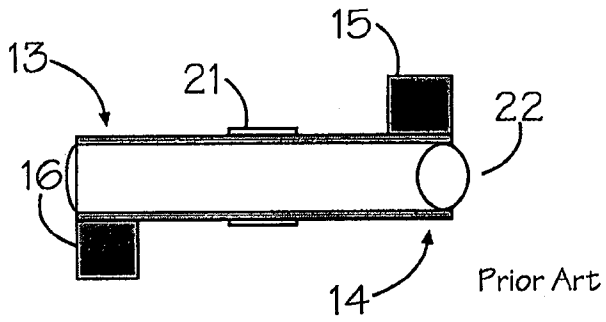


Figure 1b

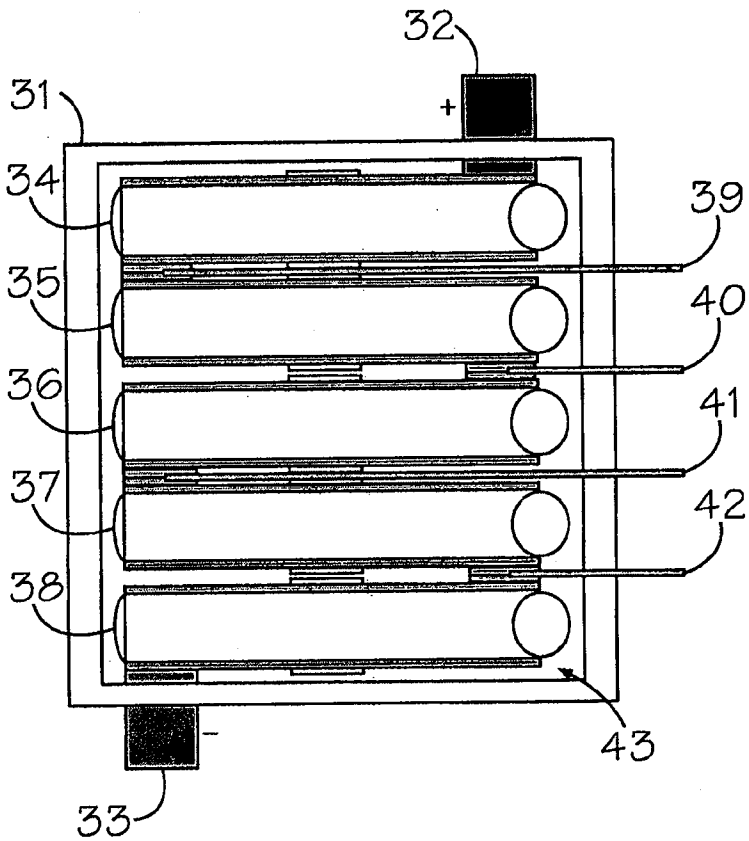


Figure 2

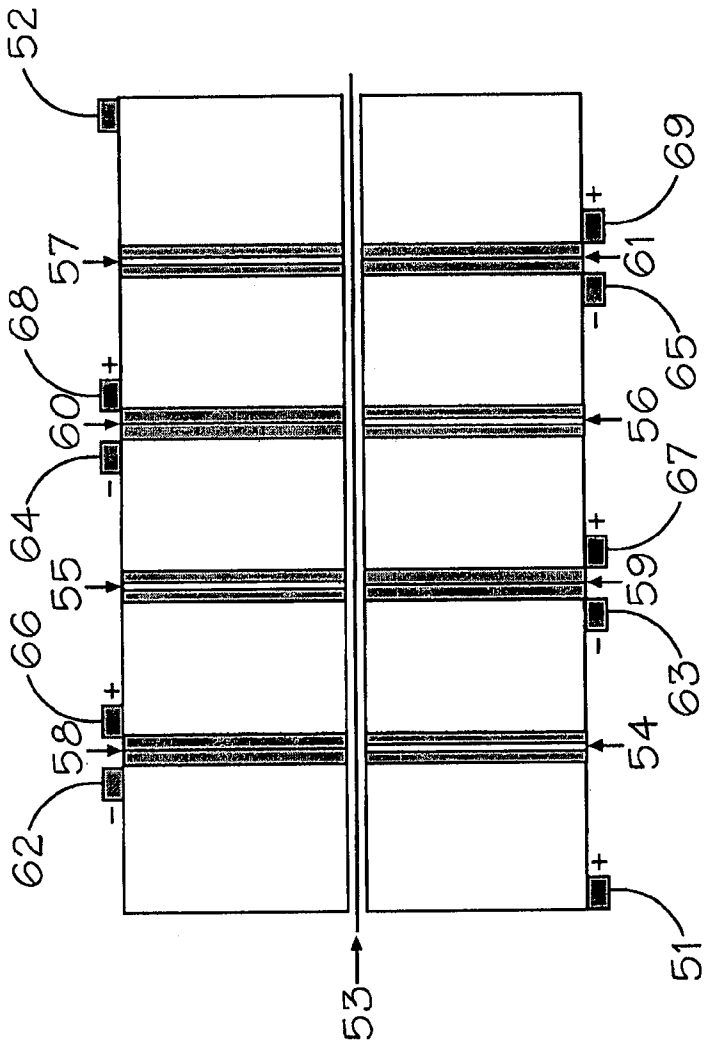


Figure 3

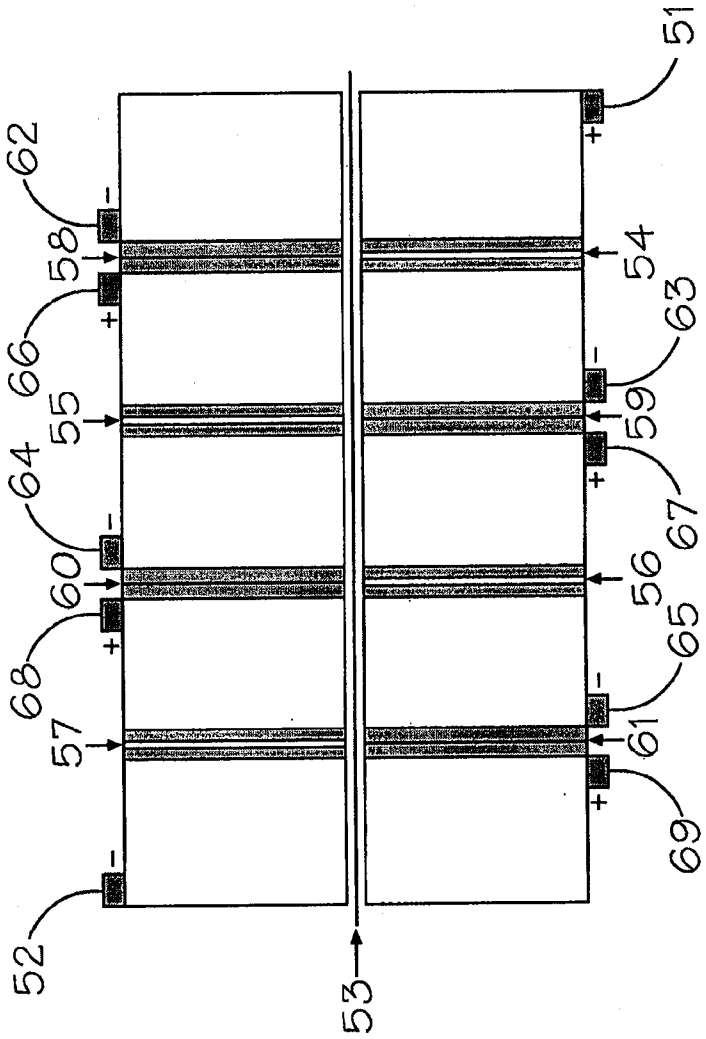


Figure 4

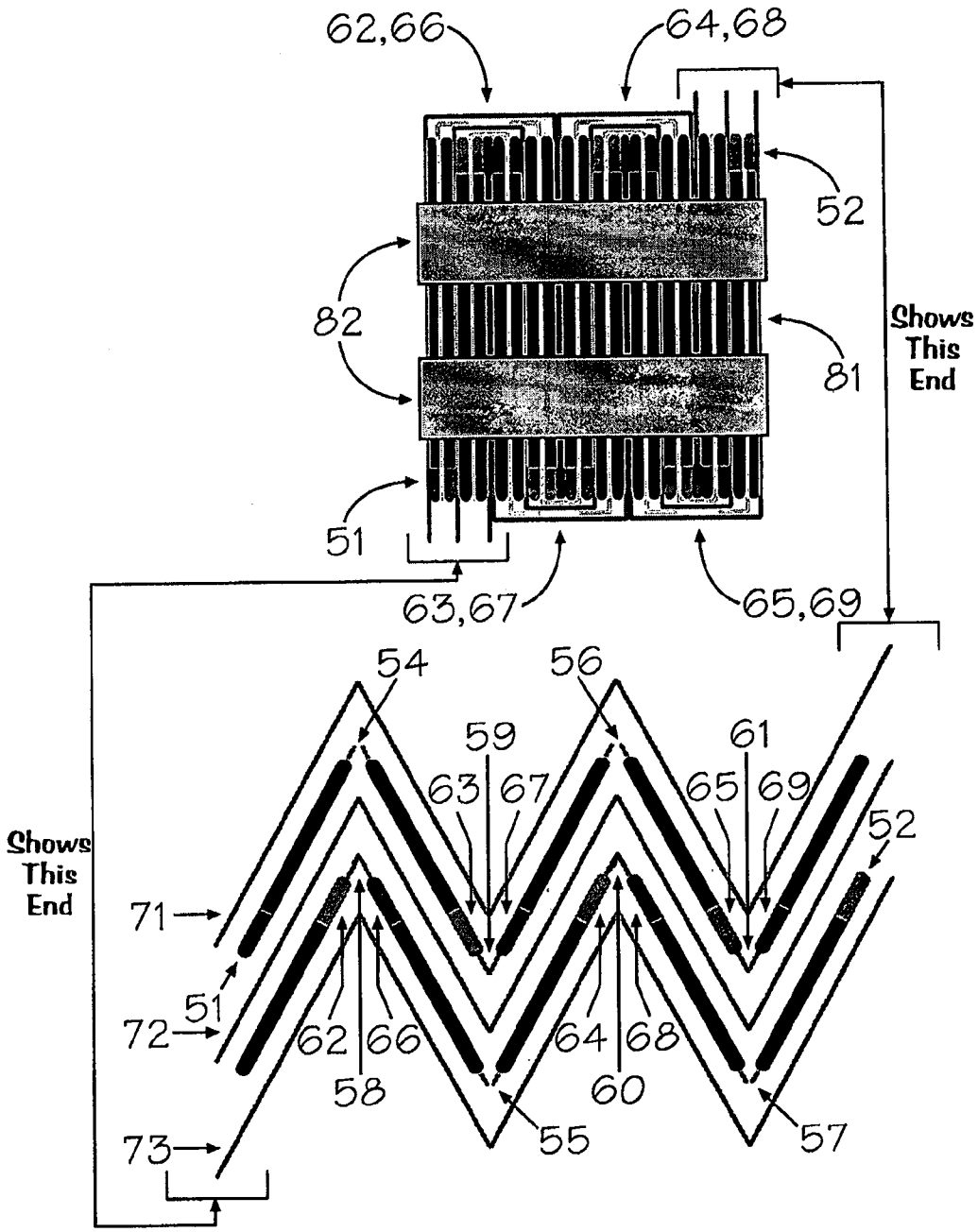

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Figure 5

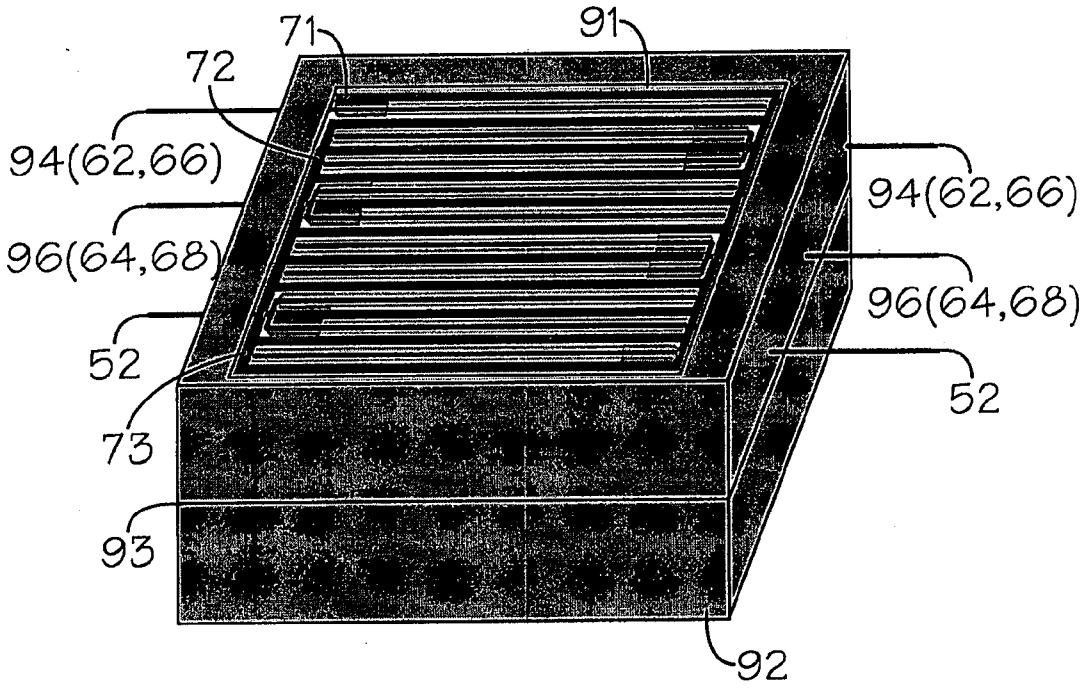


Figure 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2008/077460

A. CLASSIFICATION OF SUBJECT MATTER

H01G 9/155(2006.01)i, H01G 9/04(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: H01G 9/155

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
KOREAN UTILITY MODELS AND APPLICATIONS FOR UTILITY MODELS SINCE 1975
JAPANESE UTILITY MODELS AND APPLICATIONS FOR UTILITY MODELS SINCE 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKIPASS; double layer capacitor, electrolyte, poly bag

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6099600 A (YAN, J.F. et al.) 08 August 2000. see abstract; column 19 line 4-column 23 line 40; figures 4-10; claim 1	1-16
A	US 6379402 B1 (SUHARA, M. et al.) 30 April 2002. see abstract; column 2 line 49-column 6 line 34; claim 1	1-16
A	US 2003/0192170 A1 (JAN, Y.S. et al.) 16 October 2003. see abstract; paragraphs [0017]-[0030]; figures 1-3; claim 1	1-16
A	US 6762926 B1 (SHIUE, L.R. et al.) 13 July 2004. see abstract; column 4 line 45-column 8 line 8; figures 1-4; claim 1	1-16
A	US 2006/0274475 A1 (CHIBA, K.) 07 December 2006. see abstract; paragraphs [0029]-[0060]; figure 1; claim 11	1-16

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 FEBRUARY 2009 (27.02.2009)	**27 FEBRUARY 2009 (27.02.2009)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2008/077460

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