

A MULTI-ELEMENT ELECTROCHEMICAL CAPACITOR AND A METHOD FOR MANUFACTURING THE SAME

FIELD OF THE INVENTION

The invention relates to electrical engineering, in particular, to the manufacture of electrochemical capacitors having a combined charge storage mechanism or other similar rechargeable electric energy storages.

BACKGROUND OF THE INVENTION

The closest related prior art of the claimed invention is disclosed in PCT publication No. WO 2009103661, published on August 27, 2009, application by BATSCAP, for the design of a multi-element capacitor and a method for making the same, which capacitor comprises at least two adjacent composite electrodes separated by a spacing d and at least one composite electrode common for the two electrodes and held apart therefrom by a porous separator, the composite electrodes being coiled into a spiral to produce a roll.

The prior art invention is deficient because its multi-element capacitor design uses individual components in the form of spaced electrodes and is, for this reason, difficult to manufacture from many elements, particularly in a continuous roll assembly process. It is also deficient because it uses a multilayer composite structure that is an electrode applied to the surface of a metal collector. This design causes inevitable problems in providing reliable low-resistance contact between the electrode and current collector. Furthermore, the discontinuous electrode material may be the likely cause of undesirable reaction between electrolyte and current collector material and reduce the operating voltage of the capacitor to the electrochemical decomposition potential of the current collector. No insulation being provided between the adjacent capacitor electrodes is yet another significant deficiency of the prior art design that reduces the voltage and, as a result, specific energy of the capacitor. When, therefore, the capacitor sections are connected in series the potential differentials of the electrode may reach magnitudes equal to twice the operating voltage of the capacitor elements. In turn, this may initiate electrochemical electrode reactions limiting the service life of the capacitor.

SUMMARY OF THE INVENTION

It is an object of the claimed invention to develop a sectionalized multi-element

electrochemical roll-type capacitor free from the deficiencies of the closest related prior art and having specific performance characteristics acceptable in electrical engineering that make it a reasonable engineering and economic choice in use.

The technical result of this invention relates to improved specific characteristics of an electrochemical energy storage, stability of its specific characteristics, and longer service life.

This technical result is achieved in a multi-element electrochemical capacitor comprising at least one layer of insulating film and alternating opposite-polarity electrode sheets placed thereon in succession and interspaced by a porous ion-permeable separator, all coiled into a roll and impregnated with electrolyte, each electrode sheet being a substrate made of nonwoven polymer material of a high pore ratio, with at least one electrode secured to one side or both sides thereof, or embedded within the same, the electrodes of the opposite-polarity electrode sheets consisting of nano-structured carbon materials of different types, one of said materials having the largest possible specific surface area and a relatively low conductance, and the other material having a relatively large specific surface area and a relatively high conductance, the electrodes further comprising nano-sized particles of a metal or compounds thereof, or redox polymers.

The substrate is made of a material chemically and electrochemically inactive in electrolyte and is electron-impermeable and ion-impermeable. The electrodes are made of compositions of nano-carbon materials such as activated carbon, activated carbon black, carbon impregnated with metals, nano-carbon material based on carbides of metals such as boron, titanium, and silicon mixed with carbon nano-tubes a few layers thick mixed with natural flake graphite or acetylene carbon black. The nano-structured carbon material comprises of carbon nano-tubes a few layers thick. The electrode sheet placed in contact with the electrical insulation film has its electrochemically active layer facing up to the electrical insulation film, and the next electrode sheet is placed at a shift to half the width of its electrochemically active layer, the electrochemically active layers of the electrode sheets facing one another and being spaced from one another by a porous ion-permeable separator. The electrodes are secured to the substrate in succession.

The technical result is also achieved in a method for making a multi-element electrochemical capacitor, which method comprises preparing electrode mixtures comprising nano-structured carbon materials of different types, one of which has the largest possible specific surface area and a relatively low conductance, and the other has a relatively large specific surface area and a relatively high conductance; adding nano-sized particles of a metal or compounds thereof, or redox polymers to said electrode mixtures; making opposite-polarity electrode sheets by securing an electrode mixture to a substrate made of a nonwoven polymer material of a high

pore ratio of each electrode sheet on one side or both sides thereof, or embedded within the same; covering at least one layer of the electrical insulation film successively with opposite-polarity electrode sheets interspaced by a porous ion-permeable separator; coiling the layers thus placed into a roll; and impregnating the roll with electrolyte.

Carbon nano-tubes a few layers thick obtained by pyrolysis of a mixture of a gaseous hydrocarbon and hydrogen and having a size of 5 to 50nm, a specific surface area of 500 to 1,000 m²/g, and specific conductance of 10 to 100 Sm/cm are used as one nano-structured carbon material, and activated carbons and nano-porous carbon materials obtained from carbide materials are used as the other nano-structured carbon material. Pyrolysis of the mixture of the gaseous hydrocarbon and hydrogen is carried out at a temperature maintained within the range of 650 °C to 900 °C and pressure within the range of 0.1 to 1.0 MPa, on a catalyst such as compounds based on cobalt and molybdenum, and natural gas, or propane, or butane, or ethylene is used as the gaseous hydrocarbon. Carbon nano-tubes are produced by pyrolysis of a mixture of an aromatic hydrocarbon and alcohol. Pyrolysis of the mixture of the aromatic hydrocarbon and alcohol is conducted at a temperature maintained within the range of 650 °C to 900 °C and at a pressure within the range of 0.1 to 1.0 MPa, on a catalyst such as compounds based on iron, nickel, and magnesium oxide; benzene and toluene are used as the aromatic hydrocarbon; and ethanol is used as the alcohol. After the carbon nano-tubes are produced they are subjected to treatment with oxidizing agents, ultrasound, and water in supercritical conditions to increase the specific surface area thereof. Activated carbons are produced by forming a synthetic monomer in fluid followed by carbonization and high-temperature vapor-gas activation at a temperature of 600 °C to 1,100 °C. Nano-porous carbon materials are produced from carbides of boron, titanium, and silicon, followed by high-temperature thermochemical treatment with chlorine at a temperature between 600 °C and 1,200 °C. To prepare an electrode mixture, the thin carbon nano-tubes and activated carbon are mixed at ratios of 1:3 to 3:1 and ground in ball mills to a grain size of 10 to 100 nm, sifted on typical 100 nm mesh sieves, and treated with ultrasound to make the electrode mixture as homogeneous as possible by centrifuging in a centrifuge. The positive electrode is produced from nano-sized particles of metals such as manganese, mercury, silver, and nickel, and metal compounds such as manganese dioxide, manganese hydroxide, mercury oxide, silver oxide, lead oxide, lead sulfate, nickel hydroxide, and lithium-cobalt oxide. The negative electrode is produced from nano-sized particles of metals such as zinc, lead, cadmium, iron, and lithium, and metal compounds such as zinc hydroxide, zinc chloride, lead sulfate, cadmium hydroxide, and iron hydroxide.

An electrode sheet is produced by applying the electrode mixture to a porous polymer

sheet in the form of an electrode suspension comprising the electrode mixture dispersed by ultrasound in an organic solvent. Isopropanol or ethanol is used as the organic solvent for preparing the electrode suspension. The electrode mixture is applied to the porous polymer sheet in the form of powder by electrostatic forces. Following application of the electrode mixture, the electrode sheet is placed on a contact electrode such as graphite foil, whereupon it is heated to a temperature between 120 °C and 150 °C and subjected to a pressure of 0.5 to 1.0 MPa. A porous separator one to four layers thick may be obtained from a track membrane made of polymer film 3 to 5 µm thick, at a pore ratio of 20% to 40%, and pore size of 0.05 to 0.1 µm, or a sheet of nonwoven polymer material, such as propylene 10 µm thick at a density of 15 to 40 mg/cm², or an ion-permeable polymer membrane made of polybenzimidazole 10 to 15 µm thick impregnated with electrolyte and containing 3 to 10 mass parts of electrolyte. An electrode roll is produced from lengths of electrode sheet at the opposite ends of the electrical insulation film brought into contact with a contact electrode, one end of the contact electrode is connected to the central electrode, and a two-layered electrode sheet is wrapped around the central electrode such that the second length of the electrode sheet in contact with the second electrode sheet forms the outer surface of the roll; and the outer surface of the roll is connected to a peripheral electrode. The central and peripheral electrodes are made from metal tubing of, for example, aluminum or alloys thereof, and caps of an electrical insulation material, for example, plastics, are inserted between the central and peripheral collectors at both ends of the electrode roll, the caps of electrical insulation material being inserted after the roll has been impregnated with electrolyte. The electrolyte used for impregnating the electrode roll is an organic electrolyte that is an organic salt solution containing cations based on ammonium or imidazole and anions including tetrafluoroborate, hexafluorophosphate, or triflatimide, or bis-triflatimide, or tris(pentafluoroethyl)trifluorophosphate in acetonitrile, or propylene carbonate, or formamide, or a mixed electrolyte that is a solution of zinc chloride in acetonitrile, or an inorganic electrolyte that is an aqueous solution of potassium alkali. The electrode roll is impregnated with electrolyte in a vacuum chamber, for example, at a residual pressure of 10 Pa. According to the claimed method, several parallel electrode sheets are coiled into a roll and placed in a parallelepiped- or cylinder-shaped casing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view of the multi-element electrochemical capacitor;

FIG. 2 is a diagrammatic view of the structure of the multi-element electrochemical capacitor, showing diagrammatically the stacking of electrical insulation film and electrode sheets, with a porous separator placed between them;

FIG. 3 is a diagrammatic view of the structure of a multi-element electrochemical capacitor, showing the locations of electrodes of an electrode sheet coiled into a roll;

FIG. 4 is a view of an electrode made of a composite nano-structured carbon material consisting of activated FAS carbon and carbon nano-tubes;

FIG. 5 illustrates an example of a cyclic volt-amperogram of a three-element capacitor manufactured by the claimed method and comprising two electrode sheets, each of them having two electrodes of a composite carbon material secured thereto and spaced by a porous separator made of PVDF track membranes impregnated with ionic fluid of 1-butyl-3-methyl-imidazole tetrafluoroborate;

FIG. 6 illustrates an exemplary charge-discharge cycle of a 60-element capacitor having 1 M of KOH electrolyte (charge current 0.4 A); and

FIG. 7 illustrates an example of calculation of charge-discharge energy of a 15-element capacitor containing EMIM BF₄ organic electrolyte.

DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION

The multi-element electrochemical capacitor (FIG. 1 to FIG. 3) comprises at least one layer of electrical insulation film 40; an electrode sheet 10, which is a substrate 11 having electrodes 1 secured thereon in succession, and an electrode sheet 20, which is a substrate 11 having electrodes 2 secured thereon in succession, said electrode sheets being interspaced or spaced apart by a porous separator 30. The layers of the electrical insulation films, electrode sheets 10 and 20, and porous separator 30 are coiled into a roll and impregnated with an ion-permeable electrolyte.

Electrodes 1 and 2 are made of a composition of nano-carbon materials such as activated carbon, activated carbon black, carbon impregnated with metals, nano-carbon material on the basis of carbides of metals (CDC), for example, Ti, B, or Si, mixed with carbon nano-tubes, for example, carbon nano-tubes a few layers thick, mixed with natural flake graphite, or heat-expanded graphite, or acetylene carbon black. The type, ratio, and distribution of the composition components over the electrode area depend on the polarity of the working part of the electrode, electrolyte type, and voltage applied. For example, when ethyl-methyl imidazole tetrafluoroborate (EMIM BF₄) is used, it is preferred to use activated carbon, or CDC on the

basis of boron carbide having a specific sorption surface area measured by the BAT method within the range of 1,500 to 1,800 cm²/g, preferably having a bimodal pore distribution according to size, with the micro-pore size ranging from 0.6 to 0.8 nm, submicro-pore size within 1.1 to 1.5 nm, and specific pore volume of 0.7 to 0.9 cm³/g, at a volume ratio of 1:2 to 2:1. Even though activated carbon and CDC having the above parameters do not display a high specific conductance, they provide a high charge surface density. In order to increase local conductance, carbon nano-tubes, preferably having thin walls and diameter within the range of 7 to 12 nm and specific sorption surface area measured by the BAT method within 700 to 900 cm²/g, are added to said composition. The ratio of nano-carbon materials to carbon nano-tubes added is preferably within the range of 1:3 to 3:1.

The integral volume conductance of the composition is raised and a low electrode resistance is achieved by adding 10% to 20% by mass of a highly conductive carbon material, such as natural flake graphite, or heat-expanded graphite, or acetylene carbon black.

Porous separator 30 may be provided by, for example, a track membrane of polymer film, such as PVDF, 3 to 5 μm thick, at a pore ratio of 20% to 40% and pore size of 0.05 to 0.1 μm, or a sheet of nonwoven polymer material (polypropylene) 10 μm thick, at a density of 15 to 40 mg/cm², or an ion-permeable polymer membrane obtained, for example, from PBI (polybenzimidazole) polymer 10 to 15 μm thick, impregnated with electrolyte and containing 3 to 10 mass parts of electrolyte.

Substrates 11 of electrode sheets 10 and 20 of the claimed electrochemical capacitor are made of a material inactive chemically and electrochemically in the working electrolyte, for example, polypropylene (PP) produced, for example, by extrusion, or PVDF obtained, for example, by extrusion, or electrospinning, polytetrafluoroethylene (PTFE) produced, for example, by extrusion, or carbon fabric. The thickness and specific pore ratio of the substrate are selected out of considerations of assembly convenience and desired specific parameters, for example, a thickness of 10 to 100 μm and density within the range of 15 to 45 mg/cm².

Where the electrode pairs are connected in series, lengths of electrode sheets 10 and 20 are placed at a shift equal to half the width of the electrode with their electrochemically active layers facing one another to produce alternating pairs of opposite-polarity electrodes. The composition of the opposite parts of electrodes of both sheets is selected out of consideration for the intended polarity of the charge generated on the inside surface of the electrochemically active material of the respective electrode part, or is identical depending on the type of the materials used and required parameters of the multi-element electrochemical capacitor. The halves of the

outlying electrodes of the electrode sheet serve as current collectors common for all elementary capacitors produced by alternating electrodes and connected in series. For reliable electrical contact to be maintained with outer switching lines and for the inner space of the multi-element capacitor to be sealed off, the outlying electrodes are brought into contact with contact electrodes 12 made of an electrically conducting carbon material, for example, graphite foil.

The electrochemically active surface material of the positively charged working part of electrodes 1 and 2 of the claimed electrochemical capacitor is produced by adding nano-sized particles of metals, for example, manganese or nickel, metal compounds, for example, manganese dioxide or nickel hydroxide, or redox polymers chemically and/or electrochemically to the composite electrode mixture comprising, for example, thin-walled carbon nano-tubes and activated carbon black.

The electrochemically active surface material of the negatively charged working part of electrodes 1 and 2 of the claimed electrochemical capacitor is produced by adding nano-sized particles of metals, for example, zinc or iron, metal compounds, for example, zinc hydroxide or iron hydroxide, or redox polymers chemically and/or electrochemically to the composite electrode mixture comprising, for example, thin-walled carbon nano-tubes and activated carbon black.

The aforesaid chemical and/or electrochemical treatment of the electrochemically active material in particular embodiments of the claimed electrochemical capacitor may be carried out in aqueous solutions of sulfuric or phosphoric acid at concentrations of 1% to 30% by mass, in aqueous and non-aqueous solutions of potassium sodium or ammonium salts of organic and inorganic acids, such as sulfates, chlorides, fluorides, phosphates, diphosphates, acetates, tartrates, and formates of alkaline metals or ammonium, or composite compounds, or in aqueous or water-organic solutions of alkalis at concentrations of 1% to 70% by mass.

Additives of metals or compounds thereof, or redox polymers alter the structure and composition of the surface layer of the positively charged and negatively charged working parts of electrodes 1 and 2 and can improve the operating characteristics of the electrodes and capacitor as a whole, such as energy output growth as a result of reversible redox reactions, higher operating voltage, and improved mechanical properties of the coating.

Electrodes 1 and 2 were obtained by applying a dispersion of said electrode mixture prepared in an organic electrolyte (ionic liquid) chemically and/or electrochemically to the polymer framework of the electrode sheet at a ratio of the masses of electrode material to electrolyte ranging from 1:1 to 1:2 by ultrasonic dispersion with or without solvents added, followed by treatment of the dispersion prepared as above in vacuum.

Organic electrolyte is added by applying an aerosol dispersion of organic electrolyte with or without solvent to the electrode sheet prior to coiling, or by impregnating the composite electrode material and porous separator during the coiling process, or by pre-impregnating the composite electrode material in supercritical CO₂ conditions, or by placing the multi-element capacitor coiled into a roll in an electrolyte bath, or by impregnating the composite carbon material and porous separator coiled into the multi-element capacitor roll in supercritical CO₂ conditions.

The thickness of substrate 11 in the specific embodiments of the claimed electrochemical capacitor may be varied within 5 to 150 μm , preferably between 10 and 50 μm , and the thickness of the electrochemically active layers of electrodes 1 and 2 within 100 to 500 μm , preferably between 300 and 400 μm .

Electrode sheets 10 and 20 provided as above and interspaced by porous separator 30 are placed on electrical insulation film 40 and subjected to heat treatment under pressure (lamination) so as to seal off electrode sheet areas separating the electrodes, whereupon the electrode sheets are coiled, together with the porous separator and electrical insulation film, into roll 50 comprising one layer of electrical insulation film supporting lengths of the electrode sheet placed thereon opposite one another at a shift equal to half the width of electrodes 1 and 2 and interspaced or spaced apart by the porous separator.

To produce an electrode roll, the outlying electrodes of the electrode sheet projecting beyond the last opposite electrode at the opposite ends of the electrical insulation film are connected to the conducting current collectors; one of the outlying electrodes is connected to a central current collector 13; and the two-layered electrode sheet is coiled around the central current collector so as to form a peripheral current collector 12 on the outer surface of the roll, said peripheral current collector 12 being connected to the second electrode. The central and peripheral current collectors are made from metal tubing of, for example, aluminum and alloys thereof, and caps 60 of electrical insulation material, for example, plastics, are inserted between the central and peripheral current collectors at the two ends of the electrode roll. Typically, the caps of electrical insulation material are inserted after the electrode roll has been impregnated with electrolyte. The point of contact between a cap and the end edges of the coiled electrode roll are sealed by a known method, for example, by a composition based on epoxy resin.

The electrolyte used to impregnate the electrode roll is an organic electrolyte that is a solution of an organic salt, for example, on the basis of ammonium tetra-alkyl or dialkyl-imidazole tetrafluoroborate, in an organic solvent, for example, acetonitrile, or a mixed

electrolyte comprising a solution of an inorganic salt, for example, zinc chloride, in an organic solvent, for example, acetonitrile, or an inorganic electrolyte, for example, aqueous solutions of potassium alkali. The electrode roll is impregnated with electrolyte in a vacuum chamber, for example, at a residual pressure of 10 Pa.

The electrochemical capacitor may comprise one electrode sheet or several parallel electrode sheets coiled into a roll and impregnated with electrolyte. One electrode sheet or several parallel electrode sheets impregnated with electrolyte may be placed in a parallelepiped-shaped casing.

An electrochemical capacitor assembled as described above is ready for immediate use. To improve the energy characteristics of the electrochemical capacitor, it is operated at elevated temperatures within the range of 30 °C to 65 °C, preferably at 60 °C. The electrochemical capacitor is charged with relatively high currents in galvanostatic mode conditions. Individual electrochemical capacitors are connected into a battery in a parallel-series circuit that delivers optimal energy and power output of the electric charge stored by the capacitor.

Furthermore, in contrast to the closest prior art, the electrochemical capacitor improves specific characteristics (specific energy output, energy density, current density, specific power, specific charge, and voltage) in comparison with conventional electrochemical capacitors having carbon electrodes and using a two-layered charge storage mechanism, or chemical current sources using reversible redox chemical reactions, at approximately equal material costs. This helps achieve the claimed objective of developing an electrochemical capacitor having practicable specific characteristics that make it a suitable technical and economic choice for use.

The multi-layered electrochemical capacitor produced by the claimed method is operated at temperatures within the range of 30 °C to 60 °C, the electrochemical capacitor is charged in galvanostatic conditions, and its parameters (discharge current and voltage) are controlled when it is discharged.

The feasibility of the claimed multi-element electrochemical capacitor is illustrated by the following examples:

Example 1

Assembly of a three-element capacitor. Electrodes measuring $80 \times 45 \text{ mm}^2$ were made of a mixture of activated FAS carbon and carbon nano-tubes by benzene pyrolysis on a catalyst containing ferrocene, with ASCG silica gel added thereto, at a ratio of 1:1:1, of a total weight of 0.14 g. Following ball mill grinding for 20 minutes and preliminary treatment of the carbon material solution in ethanol for 10 minutes by a 10 W ultrasonic source, they were applied to

GF-D graphite foil by aerosol dispersion. The adjacent electrodes were spaced 5 mm apart. The electrodes were spaced by a separator consisting of four layers of track membrane having a pore ratio of 11.7% and a thickness of 23 μm . The electrodes and membrane were impregnated with EMIM BF₄ (Merck) ionic fluid. FIG. 5 shows a cyclic volt-amperogram at a charge-discharge rate of 50 mV/sec. The specific parameters calculated on the basis of CVA data were as follows: charge voltage $dU = 9 \text{ V}$, $C = 0.4 \text{ F}$; $E_{\text{charge}} = 47.7 \text{ W.hr/kg}$, and $E_{\text{discharge}} = 32.2 \text{ W.hr/kg}$ of the weight of the active electrode material, and efficiency was equal to 67.6%.

Example 2

Assembly of a 60-element capacitor. Electrodes measuring $200 \times 85 \text{ mm}^2$ were made of activated carbon (coco base) and carbon nano-tubes obtained by toluene pyrolysis on a catalyst containing ferrocene and carbon black added thereto at a ratio of 2:2:1. Following ball mill grinding for 20 minutes and preliminary treatment of the carbon material solution in ethanol for 10 minutes by a 10 W ultrasonic source, they were applied to GF-D graphite foil by aerosol dispersion in a layer 140 μm thick. The electrode material weighed 46.8 g. The adjacent electrodes were spaced 5 mm apart. The electrodes were spaced apart by a porous separator consisting of four layers of track membrane having a pore ratio of 11.7% and a thickness of 23 μm . The electrodes and membrane were impregnated with electrolyte, 1 M of KOH solution. When the specific parameters were calculated on the basis of data for voltage and current versus time, the energy stored was 2.7 W.hr/kg of active electrode mass.

Example 3

Assembly of a 15-element capacitor. Electrodes measuring $40 \times 85 \text{ mm}^2$ were made of activated carbon black PFT-O and carbon nano-tubes obtained by methane pyrolysis on a catalyst containing cobalt and molybdenum at a ratio of 5:1 and 20% of GSM-2 graphite added thereto. Following ball mill grinding for 20 minutes and preliminary treatment of the carbon material solution in ethanol for 10 minutes by a 10 W ultrasonic source, they were applied to a nonwoven polypropylene sheet by aerosol dispersion in a layer 90 μm thick. The electrode material applied to lengths of GF-D graphite foil weighed 1.1 g. The adjacent electrodes were 5 mm apart. The electrodes were spaced apart by a porous separator consisting of two layers of track membrane having a pore ratio of 11.7% and a thickness of 23 μm . The electrodes and membrane were impregnated with electrolyte, EMIM BF₄ (Merck) ionic fluid. When the specific parameters were calculated on the basis of the data for voltage and current versus time, the

discharge energy stored was 41 W.hr/kg of active electrode mass for the electrode charge voltage of 45 V and 107 W.hr/kg of active electrode mass for the electrode charge voltage of 60 V. The specific power on discharge was 13.5 kW/kg of active electrode mass for the electrode charge voltage of 45 V and 14.3 kW/kg of active electrode mass for the electrode charge voltage of 65 V.

CLAIMS

1. A multi-element electrochemical capacitor comprising at least one layer of electrical insulation film and alternating opposite-polarity electrode sheets placed thereon in succession and spaced apart by a porous ion-permeable separator, the electrode sheets and porous separator being coiled into a roll, each of the electrode sheets being a substrate of nonwoven polymer material having a high pore ratio and provided with at least one electrode secured to one side or both sides thereof, or embedded within the same, the electrodes of the opposite-polarity electrode sheets being made of nano-structured carbon materials of different types, one of the nano-structured carbon materials having the largest possible specific surface area and a relatively low conductance, and the second nano-structured material having a relatively large specific surface area and a relatively high conductance, the electrodes further containing nano-sized particles of a metal or compounds thereof, or redox polymers.
2. The capacitor as claimed in claim 1, wherein the substrate is made of an electron-impermeable and ion-impermeable material that is chemically and electrochemically inactive in electrolyte.
3. The capacitor as claimed in claim 1, wherein the electrodes are made in the form of compositions of nano-carbon materials such as activated carbon, activated carbon black, carbon impregnated with metals, nano-carbon material on the basis of carbides of metals such as boron, titanium, and silicon mixed with carbon nano-tubes a few layers thick, in a mixture with natural flake graphite, or heat-expanded graphite, or acetylene carbon black.
4. The capacitor as claimed in claim 1, wherein the nano-structured carbon material comprises of carbon nano-tubes a few layers thick.
5. The capacitor as claimed in claim 1, wherein the electrode sheet in contact with the electrical insulation film is placed with its electrochemically active layer facing up to the electrical insulation film, and the next electrode sheet is shifted to half the width of its electrochemically active layer, the electrochemically active layers of the electrode sheets facing each other and being interspaced by a porous ion-permeable separator.

6. The capacitor as claimed in claim 1, wherein the electrodes are secured on the substrate in succession.

7. A method for making a multi-element electrochemical capacitor, comprising preparing electrode mixtures containing nano-structured carbon materials of different types, one of the nano-structured carbon materials having the largest possible specific surface area and a relatively low conductance, and the other nano-structured carbon material having a relatively large specific surface area and a relatively high conductance, with nano-sized particles of a metal or compounds thereof, or redox polymers added thereto; making opposite-polarity electrode sheets by applying an electrode mixture to a substrate of a nonwoven polymer material of each electrode sheet on one side or both sides thereof, or embedded within the same, said nonwoven polymer material having a high pore ratio; placing successively on at least one layer of the electrical insulation film opposite-polarity electrode sheets spaced apart by a porous ion-permeable separator; coiling the layers placed as above into a roll; and impregnating the roll with electrolyte.

8. The method as claimed in claim 7, wherein carbon nano-tubes a few layers thick are used as one nano-structured carbon material, said carbon nano-tubes being produced by pyrolysis of a mixture of a gaseous hydrocarbon and hydrogen and having a size of 5 to 50 nm, specific surface area of 500 to 1,000 m²/g, and specific conductance of 10 to 100 Sm/cm, and activated carbons and nano-porous carbon materials obtained from carbide materials are used as the other nano-structured carbon material.

9. The method as claimed in claim 8, wherein pyrolysis of a gaseous hydrocarbon and hydrogen is conducted at a temperature maintained within the range of 650 °C to 900 °C and pressure within 0.1 to 1.0 MPa, and compounds based on cobalt and molybdenum are used as a catalyst, and natural gas, or propane, or butane, or ethylene is used as the gaseous hydrocarbon.

10. The method as claimed in claim 8, wherein the carbon nano-tubes a few layers thick are produced by pyrolysis of a mixture of an aromatic hydrocarbon and alcohol.

11. The method as claimed in claim 10, wherein pyrolysis of a mixture of an aromatic hydrocarbon and alcohol is carried out at a temperature maintained within the range of 650 °C to 900 °C and pressure within the range of 0.1 to 1.0 MPa, and compounds based on iron, nickel,

and magnesium oxide are used as a catalyst, benzene and toluene are used as the aromatic hydrocarbon, and ethanol is used as alcohol.

12. The method as claimed in claim 8 or 10, wherein the carbon nano-tubes a few layers thick are subjected, following production thereof, to further treatment with oxidizing agents, ultrasound, and water in supercritical conditions.

13. The method as claimed in claim 8, wherein activated carbons are produced by wet formation of a synthetic monomer, followed by carbonization and high-temperature vapor-gas activation at a temperature ranging from 600 °C to 1,100 °C.

14. The method as claimed in claim 8, wherein nano-porous carbon materials are obtained from boron, titanium, and silicon carbides and subjected to further high-temperature thermochemical treatment with chlorine at a temperature of 600 °C to 1,200 °C.

15. The method as claimed in claim 7, wherein an electrode mixture is prepared by mixing carbon nano-tubes a few layers thick and activated carbon at a ratio of 1:3 to 3:1 in ball mills producing grains measuring about 10 to 100 nm that are sifted on screens with a typical mesh size of 100 nm and treated with ultrasound to give maximum homogeneity to the electrode mixture.

16. The method as claimed in claim 7, wherein the positive electrode is produced from nano-sized particles of metals such as manganese, mercury, silver, and nickel, and metal compounds such as manganese dioxide, manganese hydroxide, mercury oxide, silver oxide, lead oxide, lead sulfate, nickel hydroxide, and lithium-cobalt oxide, and the negative electrode is produced from nano-sized particles of metals such as zinc, lead, cadmium, iron, and lithium, and metal compounds such as zinc hydroxide, zinc chloride, lead sulfate, cadmium hydroxide, and iron hydroxide.

17. The method as claimed in claim 7, wherein an electrode sheet is produced by applying the electrode mixture in the form of a electrode suspension to a substrate, said electrode suspension being an electrode mixture dispersed by ultrasound in an organic solvent.

18. The method as claimed in claim 17, wherein isopropanol or ethanol is used as an organic

solvent for preparing an electrode suspension.

19. The method as claimed in claim 7, wherein the electrode mixture is secured in powder form to the substrate under the effect of electrostatic forces.

20. The method as claimed in claim 7, wherein the resultant electrode sheet is placed, after the electrode mixture has been applied thereto, on a contact electrode such as graphite foil and then heated to a temperature between 120 °C and 150 °C and subjected to a pressure of 0.5 to 1.0 MPa.

21. The method as claimed in claim 7, wherein the porous separator made up of one to four layers is a track membrane produced from polymer film 3 to 5 µm thick, at a pore ratio of 20% to 40%, and pore size of 0.05 to 0.1 µm, or a sheet of nonwoven polymer material such as polypropylene 10 µm thick at a density of 15 to 40 mg/cm², or ion-permeable polymer membrane produced from polybenzimidazole 10 to 15 µm thick impregnated with electrolyte and containing 3 to 10 mass parts of electrolyte.

22. The method as claimed in claim 7, wherein the electrode roll is provided by bringing lengths of the electrode sheet at the opposite ends of the electrical insulation film into contact with the contact electrode; one end of the contact electrode is connected to the central electrode; the two-layered electrode sheet is coiled around the central electrode such that the second length of the electrode sheet in contact with the second electrode sheet forms the outer surface of the roll; and the outer surface of the roll is connected to the peripheral electrode.

23. The method as claimed in claim 22, wherein the central and peripheral electrodes are made from metal tubing of, for example, aluminum or alloys thereof, and caps of an electrical insulation material, for example, plastics, are inserted between the central and peripheral collectors at both ends of the electrode roll, the caps of an electrical insulation material being inserted after the roll has been impregnated with electrolyte.

24. The method as claimed in claim 7, wherein the electrolyte used for impregnating the roll is an organic electrolyte that is a solution of an organic salt containing cations on the basis of ammonium or imidazole, anions including tetrafluoroborate, hexafluorophosphate or triflatimide,

or bistriflatimide, or tris(pentafluoroethyl)trifluorophosphate, in acetonitrile, or propylene carbonate, or formamide, or a mixed electrolyte such as a solution of zinc chloride in acetonitrile, or an inorganic electrolyte such as an aqueous solution of potassium alkali.

25. The method as claimed in claim 7 or 24, wherein the roll is impregnated in electrolyte in a vacuum chamber at a residual pressure of 10 Pa.

26. The method as claimed in claim 7, wherein several parallel electrode sheets are coiled into a roll and placed in a casing in the form of a parallelepiped or cylinder.