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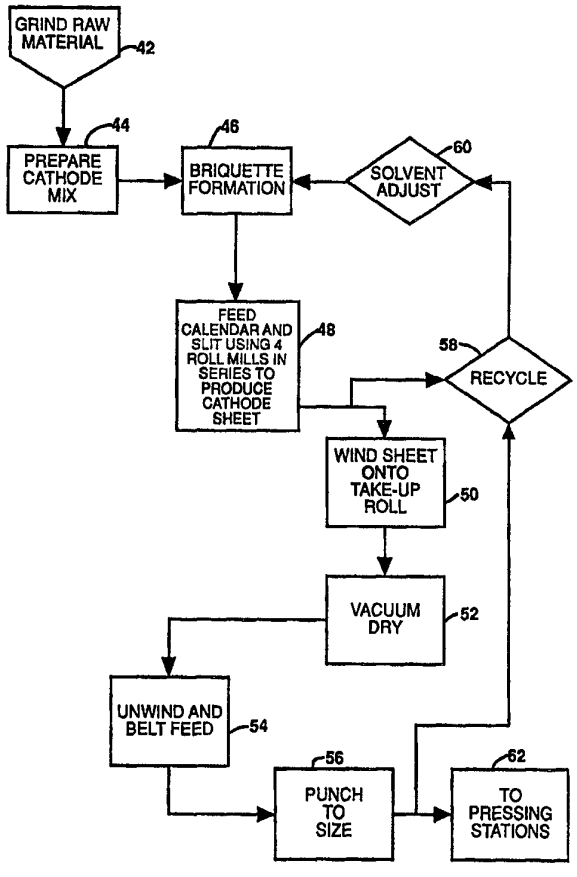
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(57) Abstract

A new process for manufacturing a cathode component from a free-standing sheet of cathode material, is described. The process comprises a first step of adjusting the particle size of the cathode active material (42) to a useful size followed by mixing with a binder and conductive additives suspended in a solvent to form a paste (44). The paste is then fed into a series of roll mills (48) to form the sheet material or the paste can first be pelletized before the rolling step (46). The cathode sheet material is dried (52) and punched (56) into cathode plates having a myriad of geometric shapes suitable for cathode preparation by compressing a current collector between two plates of the cathode material (62).



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PROCESS FOR MAKING CATHODE COMPONENTS FOR USE IN ELECTROCHEMICAL CELLS

BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to the art of electrochemical cells and more particularly to a method for manufacturing a cathode component for use in an electrochemical cell from a free-standing sheet of cathode active material.

2. Prior Art

It is known to form cathodes of metal oxides and mixed metal oxides, such as silver vanadium oxide cathode material, by a pressing process that requires powder mix charges to be manually spread into press fixture cavities. The prior art process is illustrated in the block diagram flow chart in Fig. 1 and begins with introducing the cathode material as a dry granular admixture comprising conductive diluents and a suitable binder material into press platens or fixtures 12. The loaded fixtures are then placed in a hydraulic press which compresses the cathode admixture into cathodes plates for use in an electrochemical cell, as is known to those of ordinary skill in the art.

More particularly, receptacle cups for the cathode admixture are first weighed on a tare

scale 14 and then filled with the dry cathode material 16. Two charges of the cathode material 18 are weighed in this manner and a first weighed charge is loaded into a bottom press fixture 20. This requires an operator to chop and spread the cathode material to form an even consistency throughout the fixture 22. A suitable current collector is placed on top of the dry powder cathode admixture centered in the fixture 24.

A top fixture is then positioned on the bottom fixture, ready to receive a second weighed charge of the cathode material 28. Again, the second charge must be chopped and spread evenly in the top fixture 30 to ensure uniform distribution therein. A plug is positioned on top of the second cathode charge to close the fixture assembly 32 and the assembly is placed into the hydraulic press 34. The compressed dry charges of cathode material, having the intermediate current collector sandwiched therebetween 36, form a cathode component suitable for use in an electrochemical cell.

After pressing is completed, the fixture assembly is removed from the hydraulic press 38 and separated from the cathode component. The newly pressed cathode component is then placed in a collection tray 40 ready for assembly into a

high energy density electrochemical cell, as is well known to those of ordinary skill in the art.

There are several problems associated with this prior art manufacturing process including dust generated as a result of handling the dry cathode mix. This cathode dust being airborne represents material loss which may need to be replenished. Additionally, the step of chopping and spreading the dry cathode material admixture loaded into the fixture cavities adds significantly to the process time required to make a cathode component. If this step is not carried out properly, the resulting cathode plate will have a non-uniform density or unit weight, which can detract from the performance of the electrochemical cell.

U.S. Patent No. 4,956,247 to Miyazaki et al. describes a process for making a positive electrode for use in a secondary electrochemical cell comprising a mixture of a metal oxide or a mixed metal oxide material having an average particles size of up to 3μm, a conductive agent such as acetylene black, and a binder such as a powder fluoro-resin. These ingredients are kneaded into an admixture with an organic solvent to form a paste that is subsequently formed into a cathode sheet by moving the paste through a roll mill followed by drying. A coupon is cut

out of the resulting sheet and bonded to a stainless steel plate by means of a conductive adhesive containing carbon to thereby form the positive electrode.

This prior art process requires the use of the conductive adhesive to bond the cathode sheet material to the current collector. The adhesive may detract from the cell performance and the adhesive represents an additional manufacturing step that is not needed in the process of the present invention.

In the present invention, a cathode current collection is laminated between at least one shaped cathode plate pressed on each side of the current collector. This is accomplished without the use of conductive adhesives so that in the present invention the cathode plates are in direct contract with the current collector. The compression of the cathode onto the current collector provides the needed electrical contact rather than the use of an adhesive.

OBJECTS

It is, therefore, an object of the present invention to provide an improved cathode component for use in an electrochemical cell and made from free-standing sheet of cathode active material.

It is another object to provide an improved process for manufacturing a cathode component from a free-standing sheet of cathode active material having a uniform unit weight throughout.

Still another object is to provide a cathode component made from an improved free-standing sheet of cathode active material that can be cut or punched into various geometric shapes and laminated on a cathode current collector for use in an electrochemical cell.

Finally, another object is to provide a cathode component made from a free-standing sheet of cathode active material that has a uniform cross-sectional thickness throughout and which thickness can be made relatively thin.

SUMMARY OF INVENTION

The present invention relates to a new and improved method of preparing a laminated cathode component made from a cathode sheet material and useful in high energy density electrochemical cells. The present method comprises taking granular cathode active starting material and comminuting the cathode material to reduce the particle size. The ground cathode material is mixed with conductive diluents and a suitable binder material and suspended in a solvent to form a depolarizer admixture in the form of a

paste. The depolarizer admixture is then fed into rollers to form briquettes, and the briquettes are gravity fed to roll mills to produce the cathode material in a sheet form. Alternatively, the depolarizer admixture can be fed directly into the roll mills. The cathode sheet material is then cut into cathode plates having a variety of geometric shapes that allow for the assembly of variously shaped cathode components by laminating a cathode current collector between at least one cathode blank pressed on either side of the current collector. This is done without the use of conductive adhesives, and the resulting cathode components are useful in electrochemical cells having a variety of geometric forms.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects will become increasingly more apparent to those of ordinary skill in the art by reference to the following detailed descriptions taken in conjunction with the accompanying drawing, in which:

Fig. 1 is a block diagram and flow chart illustrating the steps involved in making a cathode plate according to the prior art method.

Fig. 2 is a block diagram and flow chart illustrating the steps involved in making a free-

standing sheet of cathode material according to the present invention.

Fig. 3 is a block diagram and flow chart illustrating the steps involved in manufacturing a cathode component for use in an electrochemical cell from a free-standing sheet of cathode material made according to the method of the present invention.

Fig. 4 is a graph showing the discharge curves of an electrochemical cell containing a cathode component comprising a laminate of silver vanadium oxide plates made according to the prior art dry powder pressing process.

Fig. 5 is a graph showing the discharge curves of an electrochemical cell containing a cathode component laminate comprising silver vanadium oxide plates cut from sheet material made in accordance with the method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The method of the present invention comprises taking an already prepared cathode active starting material comprising a metal oxide or a mixed metal oxide, such as silver vanadium oxide, preferably present in a granular form and manufacturing a free-standing cathode sheet for use in an electrochemical cell. Carbonaceous

cathode materials are also useful as starting materials for forming cathode components by the process of the present invention. The cathode starting material can be made by the chemical addition, reaction, or otherwise intimate contact of various metal oxides, mixed metal oxides and/or metal elements during thermal treatment, sol-gel formation, chemical vapor deposition or hydrothermal syntheses in mixed states, as is well known to those of ordinary skill in the art. Examples of cathode materials that may be formed into a cathode sheet according to the present invention include silver vanadium oxide (SVO), copper silver vanadium oxide (CSVO), carbon, manganese dioxide, fluorinated carbon, titanium disulfide, cobalt oxide and nickel oxide, copper vanadium oxide, and other cathode materials typically used in lithium anode cells.

As illustrated in the block diagram flow chart in Fig. 2, the method of the present invention starts by taking granular cathode active material and adjusting the particle size to a useful range. This is done by comminuting the cathode material in an attrition or grinding step 42 to reduce the particle size. A ball mill or vertical ball mill is preferred and typical grinding time ranges from between about 10 to 15 minutes. The finely divided cathode material is

preferably mixed with carbon black and/or graphite as conductive diluents and a powder fluoro-resin such as polytetrafluoroethylene powder as a binder material to form a depolarizer cathode admixture in the step designated 44. Preferably, the admixture comprises about 3 weight percent of the conductive diluents and about 3 weight percent of the binder material. This is typically done in a solvent of either water or an inert organic medium such as mineral spirits. The mixing process provides for the fibrillation of the fluoro-resin to ensure material integrity. In some cases, no electronic conductor material is required and the percent cathode active material is preferably held between about 80 percent to about 99 percent. After mixing sufficiently to ensure homogeneity in the admixture, the cathode admixture is removed from the mixer as a paste.

Following the mixing step, the admixture paste can be fed into a series of roll mills that compact the cathode material into a thin sheet having a tape form, or the cathode admixture first can be run through a briquette mill in the step designated 46. In the latter case, the cathode admixture is formed into small pellets which are then fed into the roll mills.

Typically, the compacting step 48 is performed by roll mills comprising two to four calendar mills that serve to press the admixture between rotating rollers to provide a free-standing sheet of the cathode material as a continuous tape. The cathode tape preferably has a thickness in the range of from between about 0.004 inches to about 0.020 inches. The outer edges of the tape leaving the rollers is trimmed and wound up on a take-up reel as indicated at 50 to form a roll of the cathode material that is subsequently subjected to a drying step under vacuum conditions. The drying step serves to remove any residual solvent and/or water from the cathode material. Alternatively, the process can include dropwise addition of liquid electrolyte into the cathode mixture prior to rolling to enhance the performance and rate capacity of an assembled electrochemical cell incorporating the cathode material.

The cathode material can be stored for later use, or unwound and fed on a conveyor belt as shown at 54 to a punching machine. The punching operation 56 forms the continuous tape of cathode material into any dimension needed for preparation of a cathode component for use in a high energy density electrochemical cell, as is well known by those of ordinary skill of the art.

As shown in Fig. 2, the method of the present invention contains several feedback loops that serve to recycle the cathode active material should the quality control not be up to an acceptable level. This contributes to the process yield as very little cathode material is actually lost to waste. After the cathode admixture is pressed during step 48 by the series of calendar mills, if the resulting tape is too thin or otherwise of insufficient quality, the tape is sent to a recycler, indicated as step 58 that reintroduces the cathode material into the feed line entering the calendar mills. If needed, the solvent concentration is adjusted during step 60 as needed to provide a more uniform consistency to the cathode admixture paste for rolling into the cathode tape. This first recycle step 58 is also useful for reintroducing trimmings and similar leftover cathode material back into the feed line entering the calendar mills.

A second recycle loop removes the cathode material from the process after the punching operation and feeds back into the calendar mills, through the recycler indicated in step 58 and the briquette mill in step 46, if that latter step is included in the process, as previously discussed. Again, the solvent concentration is adjusted

during step 60 to produce a paste that is suitable for rolling into a tape of uniform cross-sectional thickness.

Upon completion of the drying step 52, the tape of cathode material can be stored for later use, or immediately sent to a punching operation 56. The punching operation serves to cut the sheet material into cathode plates having a variety of shapes including strips, half-round shapes, rectangular shapes, oblong pieces, or others, that are moved during step 62 to a pressing station for fabrication of a cathode component for use in a high energy density electrochemical cell, as will presently be discussed in detail.

As illustrated in the block diagram flow chart shown in Fig. 3, the punching operation provides for turning the continuous tape of cathode material into cathode plates having any geometric dimension needed for preparation of a cathode component. Thus, during the cathode pressing process, a roll of dry cathode material is obtained during step 64 for operation thereon. The punching machine, which is of a commercially available type, is set up during step 66 to produce the desired geometric form and the tape of cathode material is run through the punching

machine to form cathode plates or blanks during step 68.

A hydraulic press having platens or fixtures is provided at 70. Receptacle cups for the punched cathode plates are weighted on a tare scale during step 72 and as quality control check, selected ones of the cathode plates are weighted to insure cross-sectioned uniformity. To build a cathode component, a first plate is placed in a bottom fixture during step 74 and a cathode current collector, such as an expanded metal screen, is placed on top of the plate during step 76. A top press fixture is then positioned on the bottom fixture and over the current collector screen as indicated at 78. This fixture receives a second shaped cathode plate during step 80 followed by a top plug during step 82 which closes the fixture assembly. The fixture assembly is then inserted into the hydraulic press as indicated at 84 which compresses the two cathode plates together 86 with the cathode current collector sandwiched therebetween to form the cathode component as a laminate.

Following the pressing step, the fixture assembly is removed from the press during step 88 and the cathode component is separated from the press fixture and placed into a collection tray

during step 90. The cathode component can then be stored for later use, or the cathode can be incorporated into a high energy density electrochemical cell, as is well known to those of ordinary skill in the art.

In that respect, a cathode component prepared by the method of the present invention can be used, as for example, in a nonaqueous electrochemical cell as described in U.S. Patent No. 4,830,940 to Keister et al., which patent is assigned to the assignee of the present invention and which patent is incorporated herein by reference. The electrochemical cell can also contain an anode of a metal selected from Group IA of the Periodic Table of Elements, including lithium, sodium, potassium, etc., preferably lithium, and their alloys and intermetallic compounds, for example Li-Si, Li-Al, Li-B and Li-Si-B alloys and intermetallic compounds. The form of the anode may vary, but typically the anode is in the form of a thin sheet or foil of the anode metal, and a current collector having an extended tab or lead affixed to the anode sheet or foil.

The high energy density electrochemical cell also contains a nonaqueous electrolyte which preferably comprises a combination of a lithium salt and an organic solvent, and a separator

material that electrically insulates the anode from the cathode with sufficient porosity to allow for electrolyte flow therethrough. Suitable materials for such a separator include glass non-woven, polytetrafluoroethylene or polypropylene membranes that isolate the active components from each other without impeding the free flow of ions therethrough.

Figs. 4 and 5 illustrate discharge curves from electrochemical cells constructed in a manner similar to that described in the previously mentioned Keister et al. patent and having eight cathode plates, each sealed in a polypropylene separator, and a single lithium anode strip sealed in a polypropylene separator and snaked between the cathode plates. The cathode plates were connected in parallel to a terminal pin, and the anode was connected to the cell case. The cells where vacuum filled with electrolyte consisting of 1M lithium hexafluoroarsenate in a 50/50 dimethoxyethane (DME) and propylene carbonate (PC). The cells were cathode limited and had a stoichiometric capacity of 1.8 ampere hours.

The cell in Fig. 4 had cathode component made according to the prior art dry powder pressing process and the cell in Fig. 5 was made according to the present rolled cathode paste

process, respectively. In particular, the high energy density cell of Fig. 4 contained a cathode component laminate comprising silver vanadium oxide (SVO) made by manually spreading a dry powder mix charge of SVO material into a press fixture cavity, and applying pressure to the powder to form a cathode plate, as previously discussed with respect to the prior art process. The high energy density cell of Fig. 5 contained silver vanadium oxide cathode material made from a paste or dough-like admixture comprising ground cathode active material, conductive diluents and binder material that is formed into a tape of cathode material according to the improved method of the present invention. The cathode tape is then cut into plates having the appropriate shapes and pressed against a current collector for forming a laminated cathode component, as previously described in detail.

The discharge curves were recorded by applying four ten-second, 1.5 ampere pulses every 15 seconds repeated every 30 minutes to the respective cells wherein in Fig. 4, curve 100 was recorded at open circuit with no load, curve 102 was constructed from the minima of the first pulse of each train and curve 104 was constructed from the minima of the fourth pulse of each train. In comparison, Fig. 5 shows a high energy

density cell having a silver vanadium oxide cathode made according to the method of the present invention wherein curve 110 was recorded at open circuit with no load, curve 112 was constructed from the minima of the first pulse of each pulse train and curve 114 was constructed from the fourth pulse minima of each pulse train. The latter cell of the present invention shows no loss in cell performance. When viewed in conjunction with the previously discussed improvements in handling during the manufacture, the cathode sheet process of the present invention represents a significant improvement over the prior art process.

It is intended that the foregoing description only be illustrative of the present invention and that the invention is limited only by the hereinafter appended claims:

What is claimed is:

1. A method for preparing a cathode for use in an electrochemical cell having an anode of a Group IA metal which is electrochemically oxidizable to form metal ions in the cell upon discharge to generate electron flow in an external electrical circuit connected to the cell, the electron flow being generated by intercalation of the metal ions into a cathode active material comprising the cathode and the cell characterized by an ionic conductive electrolytic solution associated with the anode and the cathode, which comprises:

a) providing the cathode active material comprising a metallic material;

b) mixing the cathode active material with a solvent material to form a paste comprising the cathode active material;

c) subjecting the paste to a first pressing step thereby forming the paste into a cathode sheet intercalatable by the metal ions formed by the anode;

d) removing any residual solvent material from the cathode active material;

e) subjecting the cathode sheet to a forming means that serves to provide at

least one cathode plate that can have a variety of geometric shapes; and

f) laminating at least one cathode plate on at least one side of a current collector means by subjecting the cathode plate to a second pressing step to form a laminated cathode component as the cathode for use in the electrochemical cell without the cathode active material losing its ability to intercalate metal ions formed by the anode.

2. The method of claim 1 wherein the cathode sheet comprises from about 80 weight percent to about 99 weight percent of the cathode active material.

3. The method of claim 1 wherein the paste comprising the cathode material further comprises the addition of binder and conductor materials.

4. The method of claim 1 wherein the paste is comprised of about 3 weight percent carbon, 3 weight percent of a powder fluoro-resin and 94 weight percent cathode active material.

5. The method of claim 1 wherein the solvent material is selected from the group consisting of water and an inert organic material.

6. The method of claim 1 wherein the cathode active material is subjected to a grinding step that reduces its particle size from a granular cathode active material to a finely divided particle size prior to mixing with the solvent material forming the paste.

7. The method of claim 1 wherein forming the paste into the cathode sheet comprises feeding the paste through a roll mill means as the first pressing step.

8. The method of claim 7 further including the step of first feeding the paste into a compaction means that serves to provide the cathode active material in a pellet form prior to introduction to the roll mill means as the first pressing step.

9. The method of claim 1 wherein the metallic material comprising the cathode active material is selected from the group consisting of a metal oxide, a mixed metal oxide and a metal element.

10. The method of claim 1 wherein the cathode active material is selected from the group consisting of silver vanadium oxide, copper silver vanadium oxide, manganese dioxide, titanium disulfide, cobalt oxide, nickel oxide and copper vanadium oxide.

11. The method of claim 1 wherein the step of forming the paste into the cathode sheet further comprises the dropwise addition of a liquid electrolyte.

12. The method of claim 1 wherein the cathode sheet has a thickness in the range of from between about 0.004 inches to about 0.020 inches.

13. A cathode component for use in an electrochemical cell comprising as active material at least one cathode plate prepared from a cathode active material mixed with a solvent material to form a paste comprising the cathode active material, wherein the paste is pressable into a cathode sheet material that is then subjectable to a forming means that serves to provide cathode plates having various geometric shapes and wherein at least one cathode plate is pressable on either side of a current collector

means to form a laminated cathode component as the cathode for use in the electrochemical cell.

14. The cathode component of claim 13 wherein the cathode sheet comprises from about 80 weight percent to about 99 weight percent of the cathode active material.

15. The cathode component of claim 13 further comprising binder and conductor materials.

16. The cathode component of claim 13 wherein the cathode sheet comprises about 3 weight percent carbon, 3 weight percent of a powder fluoro-resin and 94 weight percent cathode active material.

17. The cathode of claim 13 wherein the cathode active material is selected from the group comprising a metal oxide, a mixed metal oxide, a metal element and a carbonaceous compound.

18. The cathode component of claim 13 wherein the cathode active material is selected from the group consisting of silver vanadium oxide, copper silver vanadium oxide, carbon, manganese dioxide, fluorinated carbon, titanium disulfide, cobalt

oxide and nickel oxide, and copper vanadium oxide.

19. The cathode component of claim 13 wherein the cathode sheet material has a thickness in the range of from between about 0.004 inches to about 0.020 inches.

20. A nonaqueous electrochemical cell having a cathode component comprising as active material at least one cathode plate prepared from a cathode active material mixed with a solvent material to provide a paste comprising the cathode active material wherein the paste is pressable into a cathode sheet and the resulting cathode sheet is subjectable to a forming means that serves to form cathode plates having various geometric shapes with at least one cathode plate being pressable on either side of a current collector means to form a laminated cathode component as the cathode for use in the electrochemical cell; wherein the electrochemical cell further comprises an alkali metal anode; a nonaqueous electrolyte; and a separator material electrically insulating the anode from the cathode and of sufficient porosity to allow for electrolyte flow.

21. The electrochemical cell of claim 20 wherein the cathode sheet comprises about 3 weight percent carbon, 3 weight percent of a powder fluoro-resin, and 94 weight percent cathode active material.

22. The electrochemical cell of claim 20 wherein the cathode active material is selected from the group comprising a metal oxide, a mixed metal oxide, a metal element and a carbonaceous compound.

23. The electrochemical cell of claim 20 wherein the cathode active material is selected from the group consisting of silver vanadium oxide, copper silver vanadium oxide, carbon, manganese dioxide, fluorinated carbon, titanium disulfide, cobalt oxide and nickel oxide, and copper vanadium oxide.

24. The electrochemical cell of claim 20 wherein the cathode sheet further comprises binder and conductor materials.

25. The electrochemical cell of claim 20 wherein the cathode sheet has a thickness in the range of from between about 0.004 inches to about 0.020 inches.

26. The electrochemical cell of claim 20 wherein the cathode sheet comprises from between about 80 weight percent to about 99 weight percent of the cathode active material.

27. The electrochemical cell of claim 20 wherein the anode comprises lithium.

28. The method of claim 1 wherein the step of removing the residual solvent material from the cathode active material comprises drying the cathode sheet.

AMENDED CLAIMS

[received by the International Bureau on 7 March 1995 (07.03.95); original calims 1, 2, 4, 9, 10, 13, 14, 16, 17,18, 20-23, 26 amended; remaining claims unchanged (8 pages]

1. A method for preparing a cathode for use in an electrochemical cell having an anode which is electrochemically oxidized to form metal ions in the cell upon discharge to generate electron flow in an external electrical circuit connected to the cell, wherein the electron flow is generated by intercalation of the metal ions into a cathode active material comprising the cathode and the cell is characterized by an ionically conductive electrolytic solution associated with the anode and the cathode, which comprises:

a) providing the cathode active material comprising a metal containing material, wherein the metal containing material is characterized by interstitial space to provide for the intercalation of the metal ions in the interstices;

b) mixing the cathode active material with a solvent material to form a paste comprising the cathode active material;

c) subjecting the paste to a first pressing step thereby forming the paste into a cathode sheet which is intercalatable by the metal ions formed by the anode;

d) removing any residual solvent material from the cathode sheet, wherein the step of removing the solvent material from the cathode sheet does not appreciably contribute to the interstices;

e) subjecting the cathode sheet to a forming means that serves to provide at

least one cathode plate having a desired geometric shape; and

f) laminating at least one of the thusly formed cathode plates on at least one side of a current collector means by subjecting the cathode plate to a second pressing step to form a laminated cathode component as the cathode for use in the electrochemical cell, wherein during the laminating step the cathode active material does not lose its interstitial characteristic and therefore its ability to intercalate metal ions formed by the anode.

2. The method of claim 1 wherein the metallic material comprising the cathode sheet comprises from between about 80 weight percent to about 99 weight percent of the cathode active material.

3. The method of claim 1 wherein the paste comprising the cathode material further comprises the addition of binder and conductor materials.

4. The method of claim 1 wherein the paste is comprised of about 3 weight percent carbon, 3 weight percent of a fluoro-resin powder and about 94 weight percent cathode active material comprising the metallic material.

5. The method of claim 1 wherein the solvent material is selected from the group consisting of water and an inert organic material.

6. The method of claim 1 wherein the cathode active material is subjected to a grinding step that reduces its particle size from a granular cathode active material to a finely divided particle size prior to mixing with the solvent material forming the paste.

7. The method of claim 1 wherein forming the paste into the cathode sheet comprises feeding the paste through a roll mill means as the first pressing step.

8. The method of claim 7 further including the step of first feeding the paste into a compaction means that serves to provide the cathode active material in a pellet form prior to introduction to the roll mill means as the first pressing step.

9. The method of claim 1 including selecting the metallic material comprising the cathode active material from the group consisting of a metal oxide, a mixed metal oxide, a metal sulfide, and a metal element.

10. The method of claim 1 including selecting the cathode active material from the group consisting of silver vanadium oxide, copper silver vanadium oxide, manganese dioxide, titanium disulfide, cobalt oxide, nickel oxide and copper vanadium oxide.

11. The method of claim 1 wherein the step of forming the paste into the cathode sheet further comprises the dropwise addition of a liquid electrolyte.

12. The method of claim 1 wherein the cathode sheet has a thickness in the range of from between about 0.004 inches to about 0.020 inches.

13. A cathode component for use in an electrochemical cell, wherein the cathode component comprises at least one cathode plate prepared from a cathode active material comprising a metallic material mixed with a solvent material to provide a paste comprising the cathode active material, and wherein the metallic material is characterized by interstitial space to provide for the intercalation of metal ions from an anode in the interstices, wherein the paste is pressable into a cathode sheet that is then subjectable to a forming means to provide cathode plates having a desired shape and wherein with any residual solvent material removed from the cathode plates without appreciably contributing to the interstices, at least one cathode plate is pressable on either side of a current collector

means to form a laminated cathode component as the cathode for use in the electrochemical cell.

14. The cathode component of claim 13 wherein the metallic material comprising the cathode sheet comprises from between about 80 weight percent to about 99 weight percent of the cathode active material.

15. The cathode component of claim 13 further comprising binder and conductor materials.

16. The cathode component of claim 13 wherein the cathode sheet comprises about 3 weight percent carbon, 3 weight percent of a fluoro-resin powder and about 94 weight percent cathode active material comprising the metallic material.

17. The cathode of claim 13 wherein the cathode active material is selected from the group consisting of a metal oxide, a metal sulfide, a mixed metal oxide and a metal element.

18. The cathode component of claim 13 wherein the cathode active material is selected from the group consisting of silver vanadium oxide, copper silver vanadium oxide, manganese dioxide, titanium disulfide, cobalt

oxide and nickel oxide, and copper vanadium oxide.

19. The cathode component of claim 13 wherein the cathode sheet material has a thickness in the range of from between about 0.004 inches to about 0.020 inches.

20. A nonaqueous electrochemical cell having a cathode component, wherein the cathode component comprises at least one cathode plate prepared from a cathode active material comprising a metallic material mixed with a solvent material to provide a paste comprising the cathode active material and wherein the metallic material is characterized by interstitial space to provide for the intercalation of metal ions from an anode in the interstices, wherein the paste is pressable into a cathode sheet and the resulting cathode sheet is subjectable to a forming means to provide cathode plates having a desired shape and wherein with any residual solvent material removed without appreciably contributing to the interstices, at least one cathode plate is pressable on either side of a current collector means to form a laminated cathode component as the cathode for use in the electrochemical cell; wherein the electrochemical cell further comprises the anode; a nonaqueous electrolyte; and a separator material electrically insulating the anode from the cathode and of porosity to allow for electrolyte flow.

21. The electrochemical cell of claim 20 wherein the cathode sheet comprises about 3 weight percent carbon, 3 weight percent of a fluoro-resin powder and about 94 weight percent cathode active material comprising the metallic material.

22. The electrochemical cell of claim 20 wherein the cathode active material is selected from the group consisting of a metal oxide, a metal sulfide, a mixed metal oxide and a metal element.

23. The electrochemical cell of claim 20 wherein the cathode active material is selected from the group consisting of silver vanadium oxide, copper silver vanadium oxide, manganese dioxide, titanium disulfide, cobalt oxide and nickel oxide, and copper vanadium oxide.

24. The electrochemical cell of claim 20 wherein the cathode sheet further comprises binder and conductor materials.

25. The electrochemical cell of claim 20 wherein the cathode sheet has a thickness in the range of from between about 0.004 inches to about 0.020 inches.

26. The electrochemical cell of claim 20 wherein the metallic material comprising the cathode sheet comprises from between about 80 weight percent to about 99 weight percent of the cathode active material.

27. The electrochemical cell of claim 20 wherein the anode comprises lithium.

28. The method of claim 1 wherein the step of removing the residual solvent material from the cathode active material comprises drying the cathode sheet.

STATEMENT UNDER ARTICLE 19

Claims 1, 13 and 20 have been amended to set forth Applicant's invention comprising the cathode active material as comprising a metal containing material inherently characterized by interstitial space to provide for the intercalation of metal ions therein. The cathode active material is mixed with a solvent material to provide a paste that is pressed into a cathode sheet intercalatable by metal ions formed by oxidation of the anode. Either before or after removing any remaining solvent material, the cathode sheet is formed into a desired shape cathode plate. The step of removing the solvent material from the cathode sheet does not appreciably contribute to the interstices and the inherently rigid nature of the metallic material comprising the cathode active material enables the shaped cathode plate to be pressed onto a current collector to form a cathode component without destroying the interstices.

By comparison, the three patent references which the search report indicated were of particular relevance (U.S.A. 4,556,618 - Shia; U.S.A. 4,161,063 - Goebel et al.; and U.S.A. 4,179,799 - Fritts), all lack the use of a metal containing material comprising the cathode active material to provide sufficient interstices for the intercalation of metal ions from the anode therein. Additionally, the inherently rigid characteristics of the metal containing material of the present invention provides that the solvent material is removable from the cathode plate formed from the cathode paste and subsequently, the solvent-free cathode plate is pressable onto a current collector to form a cathode component without destroying the interstices.

In Shia, the solvent material must be maintained in the cathode plate until after pressing to serve as a propant that prevents collapse of the interstices in the carbonaceous cathode active material during the pressing

step. In Goebel et al. the carbonaceous cathode material must be chopped into relatively small pieces or portions that are then pressed onto a current collector. In either case, some structure for maintaining the interstices or permeability in the carbonaceous cathode active material is required. This is not necessary in the present invention due to the inherently rigid nature of the metal containing material.

In view of the amendments and these comments, it is believed that all of the claims are now directed to allowable subject matter.

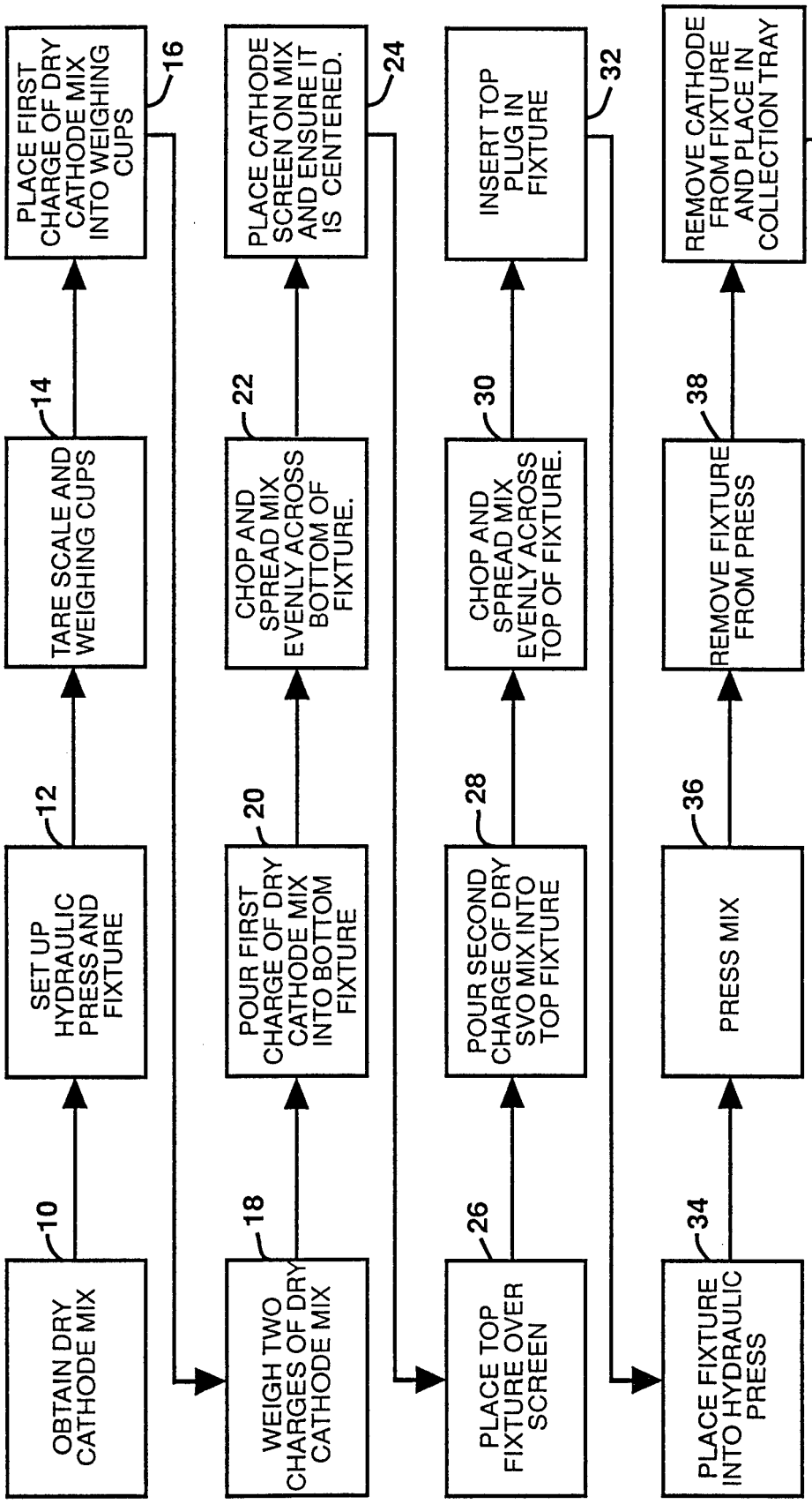


FIG. 1
(PRIOR ART)

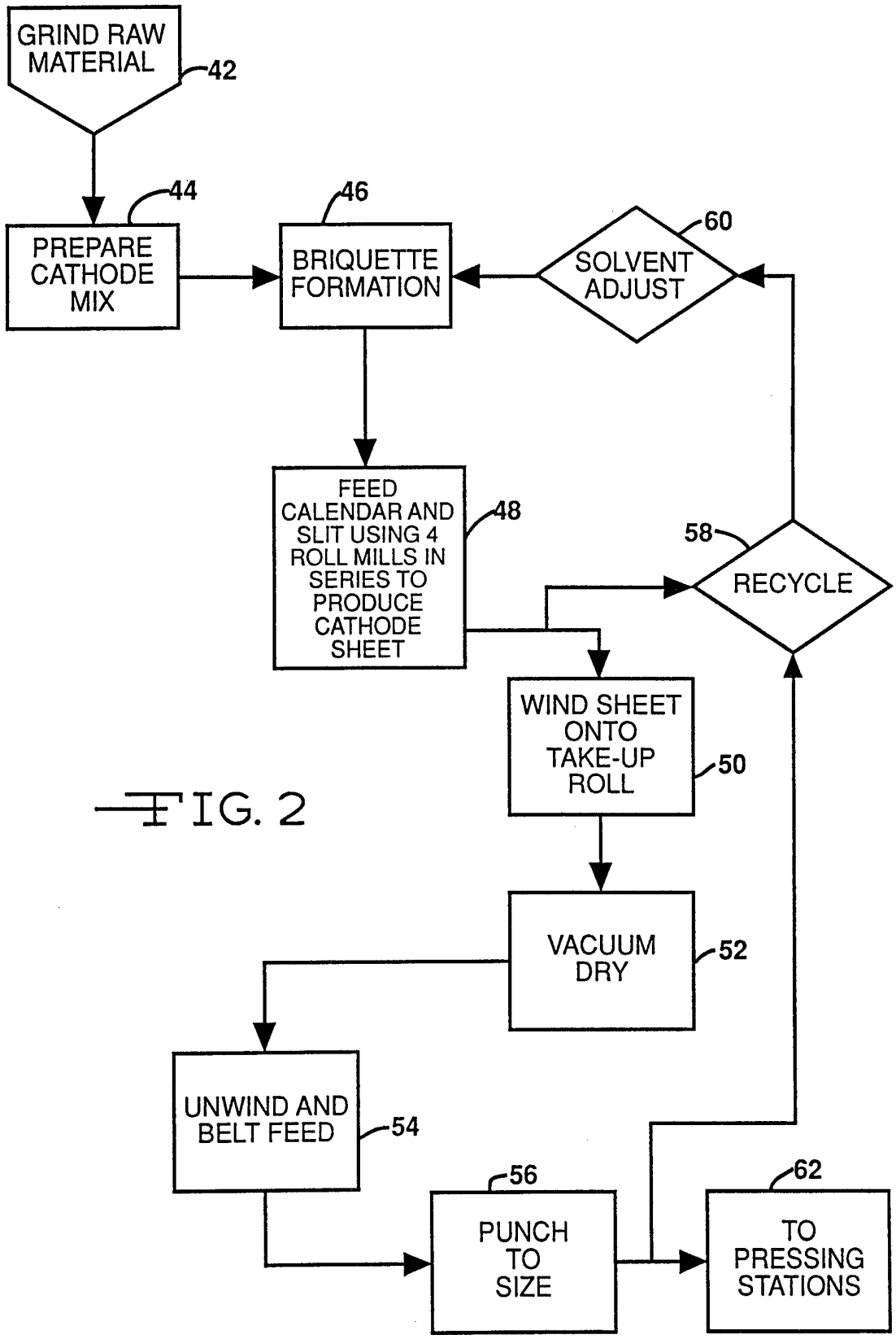

GRIND RAW MATERIAL
42
PREPARE CATHODE MIX
44
BRIQUETTE FORMATION
46
SOLVENT ADJUST
60
FEED CALENDAR AND SLIT USING 4 ROLL MILLS IN SERIES TO PRODUCE CATHODE SHEET
48
RECYCLE
58
WIND SHEET ONTO TAKE-UP ROLL
50
VACUUM DRY
52
UNWIND AND BELT FEED
54
PUNCH TO SIZE
56
TO PRESSING STATIONS
62

FIG. 2

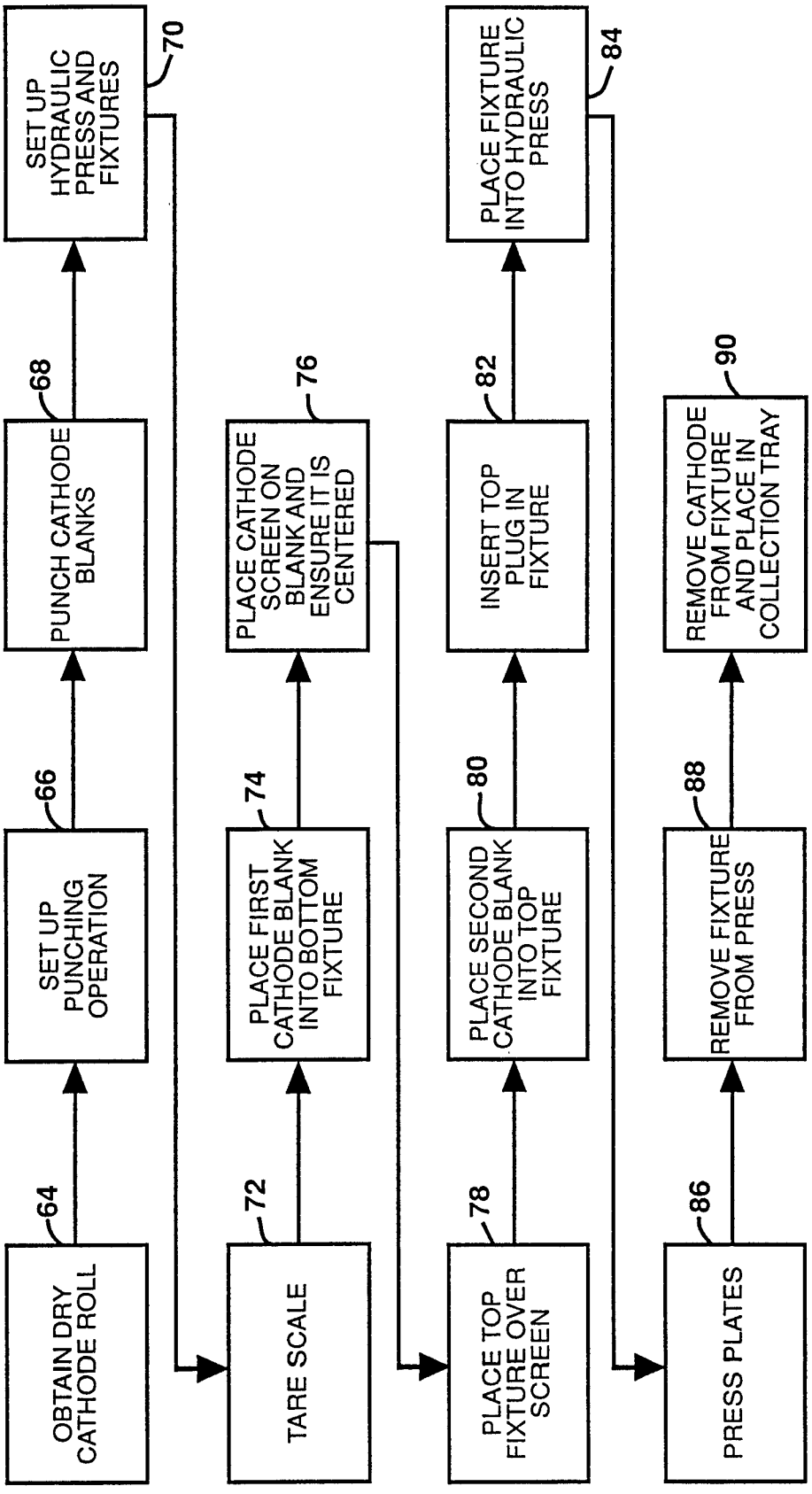

OBTAIN DRY CATHODE ROLL
64
SET UP PUNCHING OPERATION
66
PUNCH CATHODE BLANKS
68
SET UP HYDRAULIC PRESS AND FIXTURES
70
TARE SCALE
72
PLACE FIRST CATHODE BLANK INTO BOTTOM FIXTURE
74
PLACE CATHODE SCREEN ON BLANK AND ENSURE IT IS CENTERED
76
PLACE TOP FIXTURE OVER SCREEN
78
PLACE SECOND CATHODE BLANK INTO TOP FIXTURE
80
INSERT TOP PLUG IN FIXTURE
82
PLACE FIXTURE INTO HYDRAULIC PRESS
84
PRESS PLATES
86
REMOVE FIXTURE FROM PRESS
88
REMOVE CATHODE FROM FIXTURE AND PLACE IN COLLECTION TRAY
90

FIG. 3

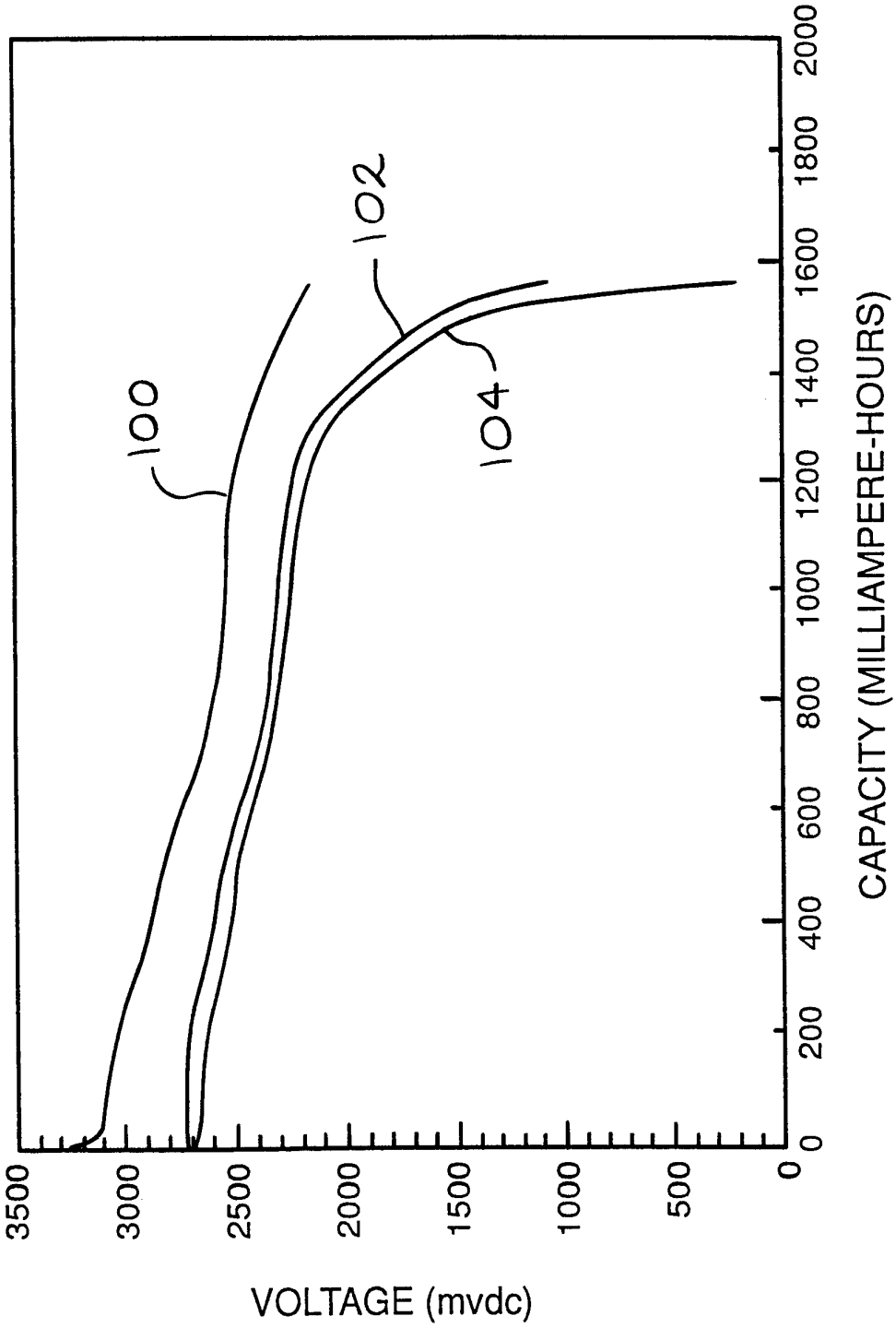

100
102
104
3500
3000
2500
2000
1500
1000
500
0
VOLTAGE (mvdc)
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200
400
600
800
1000
1200
1400
1600
1800
2000
CAPACITY (MILLIAMPERE-HOURS)

FIG. 4

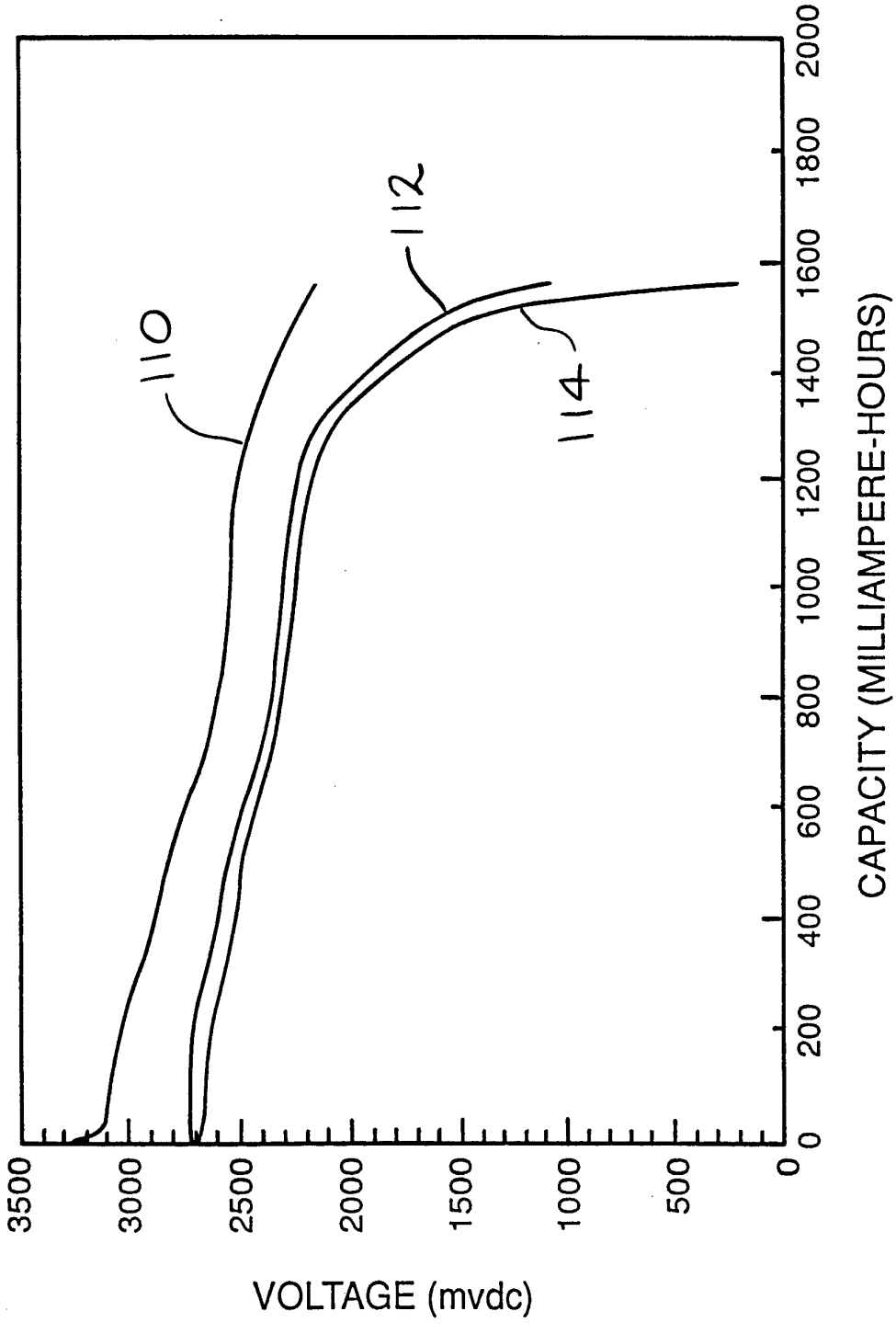

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112
114
3500
3000
2500
2000
1500
1000
500
0
VOLTAGE (mvdc)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
CAPACITY (MILLIAMPERE-HOURS)

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/11633

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :Please See Extra Sheet.
US CL :Please See Extra Sheet.
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)

U.S. : 264/104, 105, 112, 115, 117, 272.15, 272.21, 294; 156/242; 429/209, 218, 219, 223

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS:cathode# or anode# or electrode#; paste#; form# or forming or formed; pressed or presses or pressing or press; mold# or molding or molded; soldeerbirg or soederbirg;

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y --- X	US, A, 4,556,618 (SHIA) 03 DECEMBER 1985 FIG. 1 AND EXAMPLE 1	1-12, 28 ------- 13-27
Y ---- X	US, A, 4,161,063 (GOEBEL ET AL.) 17 JULY 1979 COL. 3, LINES 14-33; FIG. 3; AND COL. LINES 9-11.	1-12, 19, 25, 28 ---------- 13-18, 20-24, 26-27
X ---- Y	US, A, 4,179,799 (FRITTS) 25 DECEMBER 1979 ABSTRACT; COL. 2, LINES 20-36.	13-18, 20-24, 26-27 -------- 19, 25, 28

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
"E"	earlier document published on or after the international filing date	"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
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 12 DECEMBER 1994	Date of mailing of the international search report 11 JAN 1995
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer KATHRYN GORGOS Telephone No. (703) 308-3328

Form PCT/ISA/210 (second sheet)(July 1992)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/11633

A. CLASSIFICATION OF SUBJECT MATTER:
IPC (6):

C04B 35/00; C09C 1/56; B29B 7/00; B29C 67/00; D04H 1/20, 3/16; H01M 4/02, 4/48, 4/52, 4/58,

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

264/104, 105, 112, 115, 117, 272.15, 272.21, 294; 156/242; 429/209, 218, 219, 223